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User Guide - Life Cycle Cost Model
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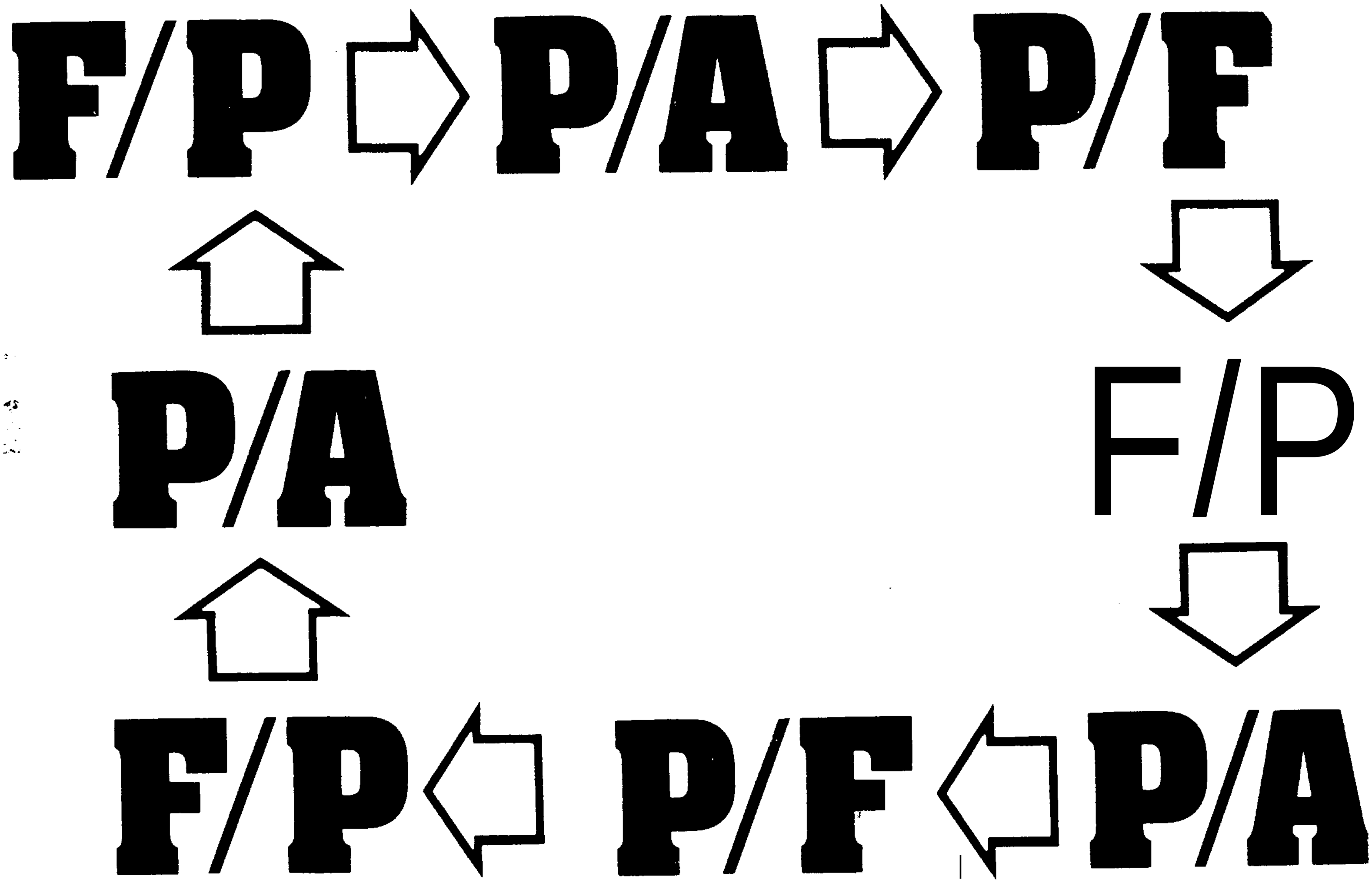
User Guide:
Life Cycle Cost Model



Evaluation and
Analysis Division
Socio-Economic Branch

SUMMARY

Durinq the oast few vears, budqetarv constraints imposed bv the various levels of government have limited or restricted investment opportunities for departments and aqencies while the number of capital proiects to be analyzed has continued to arow. At the same time, central aqencies such as Treasury Board have required better justification for capital proiects. Accordinqlv, oraanizations like Parks Canada who wish to maintain or diversify their operations have had to justify their expansion projects in terms of minimizing project costs while providina an acceptable response to demand.

Life cvcle costinq is an analytical tool that permits better management of financial resources. It may be defined as the systematic analytical process of evaluating various alternative courses of action in a project, with the objective of choosinq the best wav to emplov scarce resources. The objective of this report is to facilitate and promote the "use of life cycle costinq. For this purpose, the technique was computerized. This report is intended as a user's auide to this technique.

Concepts and Methodoloqv

One of the fundamental principles of life cycle costina is the value of money over time. Since a dollar in hand can be invested and accumulate interest, it is qenerally recognized that a dollar todav is worth more than a dollar in the future. Since expenditures related to a particular project are spread over a number of vears, the analvst must find a wav to compare them on an equivalent basis. In other words, the flow of costs and expenditures for each alternative beinq considered must be equated to a common reference point.

Three equivalence factors are used to convert any amount or series of recurrina amounts into a sinqle amount, takinq interest into account. Thev are the Future Value of a Present Amount (F/P), the Present Value of a Future Amount (P/F) and the Present Value of an Annuity (P/A). The mathematical equations for these factors are qiven in Chapter 1.

The interest rate in the conversions usinq factors P/F, F/P and P/A is called the discount rate. This rate, in the case of public proiects, takes into account the return on government obligations as well as the return on capital in the private sector. Since 1976, Treasury Board's Technical Advisory Group and Parks Canada's liaison officer have recommended a real discount rate of 10 percent.

The most important aspects of life cycle costinq are the identification of need/demand and the selection of the various options to

be analvzed. First, the demand for the service in question and the level of service to be achieved are clearlv assessed. Then, the alternatives that meet this level of service and that appear to be the most attractive are identified.

The costs associated with the various options are separated into recurrina and nonrecurring costs. Recurrina costs refer, for example, to expenditures that are repeated every year, every two years or everv three years. Most operatina and maintenance costs are recurrinq in nature. Nonrecurring costs, on the other hand, are associated with a particular vear and are not of a repetitive nature. They include the purchase and installation of equiPment and durable aoods, the construction and repair of buildinas as well as major maintenance costs. Some Parks Canada projects also produce operatinq revenue from rentals and campgrounds. This revenue must be included in the analvsis as it reduces the actual cost of the Project. Operatina revenue is aenerally considered to be recurrina in nature.

In comparina ootions, the analyst will often find that thev have different economic lives. In order to make a valid comparison, the various options must provide the same service. Thus , the notions of economic life, analvsis period, residual value and reolacement cost are introduced to facilitate comparison between the various options.

Computerized Approach

The life cycle cost model was proarammed for an IBM-PC computer. Written in WYLBUR and BASIC, this proaram is desiqned to be "user friendlv", meanina that it can be used without prior knowledae of proarammina. With this program, discounting calculations can be performed without knowinq all the subtleties or havina to manuallv perform the many calculations required by the model.

Since the information associated with an option can 'be extensive, it is essential to have a simple and effective met'hod of creatina, editinq and savinq data files. The proaram developed can be used with all t'ne usual database management operations. In addition to the life cycle cost analysis per se, the proaram has the followina commands: 1) create a new data file; 2) edit an old data file; 3) view a data file; 4) list existina data files; and 5) erase a data file. These commands are listed on the proaram's main menu.

Database management operations are very easy to perform. For example, to create a data file, the user chooses option 1 on the menu and then enters the name of the new file. He presses the "RETURN" kev and must then complete five different screens which show the names and numbers of the various input data items as well as boxes reserved for values. Information is entered on the screen by using the cursor positioning keys and the "TAB" key. The program is set up so that the user can fill in only specific boxes clearly identified on the screen. The user instructs the computer by pressing the "F" keys. The F1 key is used to change screens while the F5, F7 and F10 keys are used respectively to return to the main menu, save a data file and expand a screen.

The information contained in a data file is divided into five groups. Each group is associated with a separate screen. The first group includes identifying information of a general nature such as the park's name, the project's name and number and the option number analyzed. It also contains technical data used as parameters in the analysis, such as the discount rate, the first year analyzed and the number of years analyzed. The second, third and fourth groups deal respectively with buildings and durable goods, recurring costs and other nonrecurring costs. Finally, the fifth group contains data on revenue. The data format does not vary significantly between the second, third, fourth and fifth groups. First, a description of the expenditure is shown, followed bv the expenditure years, the economic life of the asset, the inflation rates and finally, the amount of the expenditure.

An error message appears at the bottom of the screen if the user enters data that is not compatible or if he forgets to specify the value of an item. The error messaae appears after the F1, F7 or F10 kev has been pressed. It is then impossible to continue without correcting the false entry.

To discount the costs of an alternative, the user selects option 6 or. the main menu and indicates the name of the data file to be addressed. When discounting is completed, the results appear on the screen. The format of the results is very similar to the format of the data files except that a summarv of results is shown immediately following general information. Other differences are the addition of the discounted cost of each expenditure or revenue at the extreme riaht of each line, the indication of the total discounted cost for each group at the bottom of the data for each group, and the indication of the total discounted cost for the entire project. The user has the option to print the results, in which case they appear in the form of two tables. The first table shows detailed results whereas the second table shows a summary of results.

Once all options have been analysed, option 7 can be used to produce a table summarizing the results of up to 6 options at a time. This summary table will only show a summary of the results.

Sample Application

In order to help the user understand the concepts of life cycle costing and the operation of the computer program, we have simulated a session using the Gros Morne National Park Plateau Access System as an example. A report submitted to Parks Canada in August 1985 contained a life cycle cost analysis of several access system options. The data used in our analysis is based in large part on the data contained in that report.

The approach used in the Plateau Access example is consistent with the approach in the "User Guide: Socio-Economic Analysis and Impact Assessment in Capital Projects" published by the Socio-Economic Branch. First, the problem was defined, the solution discussed and the demand, in terms of visitors, was quantified. According to the park's management plan, the plateau is one of two distinct natural areas in the park. The steep slopes and harsh conditions prevailing on the plateau raise insurmountable access barriers for most visitors. The access system would permit quick and safe access to that environment. It has been estimated that 35,000 visitors would use this service annually.

Next, certain parameters of analysis were defined. A real discount rate of 10 percent was used as well as a period of analysis of 30 years. This was followed by a description of the six access systems analyzed and careful development of cost and revenue profiles. Once these steps were completed, six computer data files were created and the life cycle cost analysis was performed. A comparison of results showed that the "gondola four pulse; fixed grip; 4-seat cabin/pulse" access system were the least expensive. This was confirmed by conducting a sensitivity analysis on the discount rate and the economic life.

In addition to minimum cost, there are usually other considerations in selecting the optimum alternative. Indeed, minimum cost was not the sole selection criterion used in the August 1985 report which recommended a more expensive system, the funicular. Nevertheless, life cycle cost analysis is an important decision-making tool in determining the most attractive alternative.

The life cycle cost analysis presented in this report is intended as an example and should be considered as such. Many elements were simplified or eliminated to make it easier to understand the analysis.

Conclusion

The purpose of this report is to present a computerized life cycle cost model. This model is used to analyze various project options in order to determine the least costly option from a life cycle perspective. A computerized approach should facilitate the use of life cycle cost analysis and at the same time improve management of Parks Canada resources.

The principal concepts used will be discussed in the first chapter. The second chapter will describe the computer program in detail and the third and final chapter will provide a simulation of life cycle costing.

Finally, it should be noted that the computer program should be used in the planning stage of a project, more specifically at the option development stage, and that all options should respond to the same need/demand or provide the same level of service.

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INTRODUCTION

Life cycle costing, also known as "technique of discounting", is not a new analytical tool. It is used to various degrees by governments, businesses and individuals to evaluate the investment alternatives available to them. However, the evaluation is often incomplete because few costs are considered and those that are, are not estimated in terms of the project's useful life.

From another point of view, budgetary constraints imposed by the various levels of government have limited, if not restricted, investment opportunities for departments and agencies while the number of capital projects to be considered 'nas continued to grow. At the same time, central agencies such as Treasury Board have required better justification for capital projects. Under its new submission system for funding of capital projects[1], Treasury Board requires that a life cycle cost analysis be performed during the preliminary planning stage if the project has several viable alternatives. Certain Parks Canada projects have already been returned by Treasury Board for not complying with this policy.

Accordingly, plans by Parks Canada to maintain or diversify its network of parks and sites will have to be justified in terms of minimizing project costs while providing an acceptable response to demand. It is imperative that its investment decisions be based using consistent techniques and criteria. Efforts have already been made in this direction. In 1984, the Socio-Economic Branch Proposed a procedure for classifying capital projects on the basis of their importance. Life cycle costing is another analytical tool that may be defined as the systematic analytical process of evaluating various alternative courses of action with the objective of choosing t'he least costly way to employ scarce resources. The principal application of life cycle costing is therefore in decision-making where resources are limited.

Life cycle cost analysis has been used on several occasions within Parks Canada. Section II, Part 2 of the "User Guide: Socio-economic Analysis and Impact Assessment in Capital Projects", published in April 1984, provides an example. Moreover, Directive 2.2.2 entitled "Socio-Economic Analysis and Impact Assessment in project Planning", published in August 1983, refers to this technique. It mentions that if the project proposal is not part of an approved management or area plan, the project sponsor should provide a life cycle costing of project planning options among other things.

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1 See <u>Treasury Board</u>, (1984).

The objective of this report is to facilitate and promote the use of life cycle costing. In order to achieve this, the technique was computerized. The user no longer needs to be familiar with all the subtleties of the approach or to perform the many calculations involved. The computer program has been designed to be "user friendly", meaning that it requires no prior knowledge of programming. It thus makes it much easier to estimate the total discounted cost of each project option. This working tool is intended primarily for economists and professionals involved in project evaluation. This report is intended as a user's guide to this technique.

The report is divided into three parts. The first part describes the various concepts and equations used and discusses certain methodological aspects associated with the approach. The second part deals with the use of the computer program. It explains the special features of the program, the database, the limitations set for input data and the result tables. The last part provides a practical example. Finally, the report as a whole should provide the reader with a practical knowledge of life cycle costing.

CHAPTER I

CONCEPTS AND METHODOLOGY

By way of introduction to this chapter, it seems appropriate to call attention to the definition of life cycle costing. Life cycle costing mav be defined as the systematic analytical process of evaluating various alternative courses of action in a project, with the objective of choosing the best way to employ scarce resources. The application of discounting techniques-to investment decisions is based on the principle that the optimal choice of investment should aim to minimize the total discounted cost. Thus , in a capital project with multiple options, life cycle costing will determine the option with the lowest discounted cost. However, minimum cost is seldom the sole criterion in the selection process. Life cycle costinq is simply part of a more general approach whereby the selected option satisfies the greatest number of decisional criteria.

The main body of this chapter describes in detail how these techniques work and examines such important concepts as discount rate and costs. Other significant criteria in project analysis are also discussed.

1.1 Time Value of Money

One of the fundamental principles of life cycle costing is the time value of money. It should be recognized that a dollar today is worth more than a dollar in the future, primarily due to interest. Since a dollar in hand can be invested and accumulate interest each year, one's preference should be to receive the dollar now rather than in the future. For example, an investment of $10,000 at a compound interest rate of 10%, i.e. where t'he annual interest payment is added to the principal invested, would be worth about $16,000 in five years. This means that the present value associated with the future $16,000 is $10,000.

The various costs associated with a project are generally spread over different years. For example, acquisition costs may occur in year 1, repair costs in year 5 and operating costs in years 2 through 10. A common reference point must then be considered in order to compare all costs on an equivalent basis. In other words, the flow of costs or expenditures for each alternative being considered must be equated to a single point in time. This point is generally the present time when decisions that have a significant impact on the future are made. Thus , all future costs must be discounted to the present value.

1.2 Discounting Techniques

Discounting techniques are used to convert any amount or series of recurring amounts into a single sum using a defined compound interest rate. Three equivalence factors are essential to life cycle costing: 1) the Future Value of a Present Amount (F/P); 2) the Present Value of a Future Amount (P/F); and 3) the Present Value of an Annuity (P/A). An annuity is a series of equal amounts paid or received every year over a period of time "n".

These factors, whose values depend on the interest rate "i" and time period "n", are expressed as follows: F/P(i,n), P/F(i,n) and P/A(i,n). Factor F/P is used to calculate the value of a present amount invested at an interest rate "i", for "n" number of years. It can also take inflation into account; this application "is of great interest to us. Section 1.10 will deal specifically with inflation. The mathematical equation for this factor is:

$$F/P(i,n) = (1+i)^n \qquad (1)$$

Factor P/F is the inverse of the above factor. It is of primary importance as it converts future amounts (disbursements) into an equivalent value at the point of decision. Its mathematical equation is:

$$P/F(i,n) = 1/(1+i)^n \qquad (2)$$

Finally, factor P/A converts a series of identical annual amounts into an equivalent single amount at the beginning of the period. It is used to discount the operating costs of projects. This factor is one of the most commonly used in this type of analysis.

$$P/A(i,n) = ((1+i)^n-1)/(i*(1+i)^n) \qquad (3)$$

Formula (3) is equivalent to the following formula:

$$P/A(i,n) = P/F(i,n=1)+P/F(i,n=2)+...+P/F(i,n=r) \qquad (4)$$

Factor P/A is therefore the cumulative value of the present values of future amounts (P/F) shown in equation (2).

Certain decisions affect the results of these three factors in their application, especially those regarding the timing of expenditures and the start of the analysis period, i.e. at the beginning or end of the year. For example, if the analysis begins in January 1985 and the expenditure occurs at the end of the year, an expenditure made in 1986 will be discounted over a period of two years. On the other hand, if the analysis begins in January 1985, and the expenditure occurs at the beginning of the year, the expenditure will be discounted over a period of one year. The method suggested in this report uses the latter approach. Accordingly, using 1985 as the baseline year, an expenditure made in 1985 will not be discounted whereas an expenditure made in 1986 will be discounted over a one-year period.

1.3 Discount Rate

The interest rate used in conversions involving factors P/F, F/P and P/A is called the discount rate. Discounting is based on the assumption that the discount rate remains constant over the analysis period. We are forced to assume a constant rate since it is practically impossible to predict changes in interest rates over the long term.

However, that is not the most important issue. The most important issue is to determine the discount rate to be used in “public” projects funded by the government. “Public” projects are those where part or all of the capital is provided by the government and whose product will either be available free of charge to private agencies or sold below the cost of providing the public service in question. Parks Canada projects obviously fall under the latter category.

The discount rate used to evaluate public projects is often referred to as the social rate of discount. The choice of a particular social rate of discount in the use of government funds can have a significant impact on the determination of government intervention. Indeed, a small variation in the interest rate can make the difference as to whether or not a project is approved and can affect the choice of option. Thus , option A may be preferable to option B at a rate of 10% while option B may be preferable to option A at a rate of 7%.

Economists have suggested two approaches for determining ‘he discount rate applicable to public projects:

1. The social rate of time preference: this rate is approximately the same as the return on private savings or more precisely the return to individuals on government bonds (r).

2. The opportunity cost of private capital: this rate corresponds to the return to corporations before tax, i.e. the return on capital in the production of goods (p).

Determinina the discount rate to be used does not mean simply choosinq between (r) and (p) but weiqhtinq the various opportunity costs. Accordinq to H.C. Harberqer, the opportunity cost of additional government borrowing is the sum of the opportunity cost of foreaone return on private capital and the opportunity cost of foreqone individual consumption. In other words, the opportunity cost of government funds is the weighted sum of the various alternative returns that would have been produced by various sources of government funds. The researcher S.A. Marqlin also recognizes the importance of includinq various sources of government funds in estimating the social value of a project.

For many years now, Canadian economists seem to have rallied behind Harberqer's method as applied to the Canadian economv by G.P. Jenkins. Jenkins pioneered the empirical calculation of the Canadian social rate of discount. In 1977, he estimated the social rate of discount as follows:

TABLE 1

Estimation of the Social Rate of Discount by G.P. Jenkins

Sector (Source of Funds)	Opportunity Cost of Funds in %	Proportion of Government Borrowinq	Real Opportunity cost of Government Funds in %
Industrial Activities	12.53	0.59	7.39
Residential Construction	7.50	0.16	1.20
Domestic Consumption	4.14	0.05	0.21
Non-Residential Consumption	6.11	0.20	1.22
		1.00	10.02

Source : Jenkins (1977), p. 137.

Treasury Board relied on Jenkins' work when it recommended a real rate of 10 percent in 1976. In 1983, Jenkins confirmed the social rate of discount of 10 percent following new empirical studies. In July 1985, Treasury Board's Technical Advisory Group and Parks Canada continued to recommend the use of a real social rate of discount of 10 percent.

1.4 Identification of Need/Demand and Alternatives

Certainly, the most important aspects of life cycle costing are the clear identification of need/demand or of the level of service to be achieved, and the clear identification of the various options. Before identifying the various options, the analyst determines the level of service to be achieved. In the case of a visitor reception centre, this means determining the number of visitors the building will serve. In the case of a fleet of vehicles, it may be a matter of acquiring a sufficient number of trucks of a certain size and in good working condition. Once these needs have been identified and before developing viable options in detail to meet these needs, the analyst identifies available resources, such as raw materials, products, the time-frame, knowledge and budgeted funds, which he may combine to meet the need/demand.

Once available resources have been identified, they can be considered in a wide range of combinations to provide a satisfactory response. The identification process usually begins with an in-depth examination of all possible combinations.; through the process of elimination, the analyst retains the ones that are technically feasible and, finally, the ones that are economically attractive. This is followed bv a description of the various alternatives retained, indicating their differences.

'Within the framework of project planning, life cycle cost analysis should be undertaken once the need/demand or level of service to be achieved has been estimated. The analyst then determines the least costly option relative to the required level of service. Since the ultimate objective of the analysis is to achieve optimal use of financial resources, it is essential that all options refer to t'he same level of service. In the opposite case, it would be preferable to use an approach which permits consideration of the benefits, or level of service, associated with each option. This way, the options would be rated in terms of their ability to provide a specific level of service. Benefit-cost analysis is one approach which can be used in these circumstances.

1.5 costs

As mentioned earlier, life cycle costing is used to determine the lowest present value of costs associated with a project. But which costs should be considered? The notion of cost is used in a variety of situations; some analysts use a narrow definition of cost while others use a broad definition. Thus , it is necessary to indicate clearly which types of costs will be considered and how they will be classified.

Many of the costs associated with a project can be expressed in dollars. These costs are referred to as "economic costs". On the other hand, there are non-economic costs of a more indirect nature which are difficult to convert into dollars, e.g. psychological, political and social costs. The analysis suggested applies only to economic costs. Where non-quantifiable costs are significant or represent the greater part of the costs of a project, another approach should be considered.

Some of the costs associated with a project may be viewed initially by the analyst as irrelevant. Actually, all costs are relevant to some decision or other and should be considered in the initial stages of life cycle costing. If, some costs later appear to be irrelevant to the problem at hand, the analyst should carefully review these costs before discarding them. Moreover, in order to determine which costs should be considered, the analyst should clearly identify the options and retain all costs affected by each option. Failure to specify the components of each alternative will result in the inability to correctly identify the various costs.

costs, or rather expenditures, that have already been incurred are the consequences of past decisions and should not be included in the analysis. In other words, the analyst should retain only those costs that are affected by the option itself. It would be illogical to consider expenditures already made, such as archeological or design work, which cannot be affected by the decision to be made. We should bear in mind that the purpose of life cycle costing is the efficient allocation of presently available funds. However, the mention of past costs or expenditures, as supplemental information, may be of interest to budget reviewers. The important issue however, lies in the future cost of a given alternative.

The distribution of costs varies from agency to agency dependinu on the type of project examined. Since the projects analyzed by Parks Canada are mostly capital projects, they should include the cost of acquisition, installation and construction as well as the operatina and maintenance costs of equipment or buildings. Costs are classified as recurring costs or nonrecurring costs. Recurring costs refer to those costs which occur on a regular basis, like every year, every two years, every three years, etc. They include operating and maintenance costs such as salaries and wages, general personnel costs, office supplies, energy, insurance and other general and administrative costs.

Nonrecurring costs, on the other hand, are associated with a particular year and are not of a repetitive nature. They include the acquisition and installation of equipment and durable goods, the construction or repair of buildings, and major maintenance work. Some examples of costs related to durable goods are the purchase price, transportation costs, the cost of land and salaries/wages for installing equipment. Construction costs include salaries and wages, materials, design, engineering and project supervision costs, etc. Finally, major maintenance costs include major maintenance work to buildings and durable goods, such as roof repair, road repaving, replacing a burner in a furnace, etc. These costs include the cost of materials and replacement parts, transportation, salaries and wages to Perform maintenance work, etc. The cost breakdown is shown in Table 2.

With the cost breakdown structure established, it is now necessary to generate the cost data. The estimation of future costs is probably one of the most difficult tasks in life cycle costing. What will the inflation rate of non-residential construction be in 10 or 20 years? In order to minimize inaccuracy in this aspect of estimation, costs are expressed in dollars of the first year analyzed and the inflation rate is determined later. The cost of facilities, their operation and maintenance in current dollars is supplied by the project enaineer experienced in estimating costs. Essential data on inflation may be obtained from various sources. The analyst must therefore use a combination of historical data, data from manufacturers and engineers, analogies through experience with similar projects, and forecasting.

The equations relative to the three types of assets are as follows:

<u>Buildings and Other Durable Goods</u>:

$$VALDk = COSTk*F/P(n,e)*P/F(n, i) \quad (5)$$

$$VALR_k = COST_k*F/P(n1,e)*P/F(n1,i) *P/A(r1_k,t)/P/A(e1_k,t) \quad (6)$$

$$VALT_k = VALD_k-VALR_k \quad (7)$$

TABLE 2

Distribution of Costs

Recurring Costs	1. Operating and Maintenance Costs: salaries and wages general personnel costs office supplies, furniture, transportation energy insurance other administrative costs other
Nonrecurring Costs	1. Costs of Acquisition and Installation of Equipment and Durable Goods: purchase price transportation land salaries/wages for installing equipment other 2. Construction Costs: salaries and wages materials transportation design, engineering and project supervision 3. Major Maintenance Costs: materials and replacement parts transportation salaries/wages for maintenance work

where

$VALD_k$: Discounted value of acquisition of asset k in first year dollars.

$COST_k$: Value of acquisition of asset k for the first year analysed.

$VALR_k$: Residual value of asset k at the end of the period analysed, discounted to first year dollars.

$VALT_k$: Discounted value in first year dollars, of the use of asset k during the total period of analysis.

rl_k : Residual life of asset k at the end of the period analyzed.

el_k : Economic life of asset k

k : Asset

n : Number of years between the first year analyzed and the year of expenditure.

nl : Number of years between the first and last years analyzed.

i : Nominal discount rate

e : Annual inflation rate

t : Net discount rate.

The discounting calculations can be made simpler than shown in equations (5) to (7). Indeed, when the inflation rate is nil, the coefficient F/P(n,e) is equal to one. Moreover, if the asset is purchased during the first year analysed, the discounted value of the asset ($VALD_k$) is obtained directly from $COST_k$. Similarly, if the economic life of the asset is shorter than the analysis period, the residual value is nil and the discounted value of the use (VALTk) is equal to the discounted value of the acquisition ($VALD_k$). The notions of residual value and useful life are discussed in sections 1.8 and 1.6.

The net discount rate takes the annual inflation rate into account; it is estimated with the following equation:

$$t = (i-e)/(1+e)$$

where

i : nominal discount rate

e : annual inflation rate

When the inflation rate e is nil, the net discount rate t is equal to the nominal discount rate i.

Recurring Costs (Maintenance, Operation, Etc.) :

A : Cycle 1 (the expenditure is made every year) :

$VALT_k = (COST_k + COST_k * P/A(n2, t1)) * F/P(n, e1) * P/F(n, i)$ (9)

$t1 = (i - e2)/(1 + e2)$ (10)

where

$VALT_k$: Discounted value, in first year dollars, of the recurring cost of asset k, for n years, at a net discount rate t1.

e1 : Annual inflation rate between the first year analyzed and the first year of expenditure.

e2 : Annual inflation rate between the first and last years of expenditure.

n2 : Number of years between the first and last years of expenditure.

For example, if a recurring cost k is incurred only in years 7 through 11, and the inflation and discount rates are 4% and 14% respectively, the following equation would apply:

$VALT_k = (COST_k + COST_k * P/A(4; 9, 6\%)) * F/P(6; 4\%) * P/F(6; 14\%)$

This equation discounts to year 7 the costs of years 8 to 11 and then adds them to the cost of year 7 using the expression $COST_k + COST_k * P/A(4; 9, 6\%)$. Once the recurring costs have been discounted to year 7, inflation is taken into account between years 1 and 7 and discounting to year 1 is achieved with the expressions F/P(6;4%) and P/F(6;14%) respectively.

If the first year of expenditure coincides with the first year analyzed, the expressions F/P(n,e) and P/F(n,i) are equal to one and may be omitted from equation (9).

B: If the cycle is greater than 1 (the expenditure is made every two years, three years, four years, etc.) :

$$VALT_k = \left(\sum_{i=1}^{f} COST_k * F/P(n3,e2) * P/F(n3,e2) \right) * F/P(n,e1) * P/F(n,i) \quad (11)$$

where

e1 : Annual inflation rate between the first year analyzed and the first year of expenditure.

e2 : Annual inflation rate between the first and last years of expenditure.

n : Number of years between the first year analyzed and the first year of expenditure.

n3 : Number of years between the first year of expenditure and expenditure year i.

f : Number of times the expenditure is made.

Equation (11) discounts recurring expenditures f to the first Year of expenditure by summation (Σ) as indicated in the parentheses and then discounts the result to the first year analyzed using the expression F/P(n,e1)*P/F(n,i).

<u>Other Nonrecurring Costs (Major Maintenance, Etc.)</u> :

$$VALT_k = COST_k * F/P(n,e) * P/F(n,i) \quad (12)$$

This equation is very simple as a single expenditure was made in a particular year without consideration of economic life. The analysis consists simply of discounting (P/F) and taking inflation into account (F/p). Here again, the terms F/P and P/F are equal to one and the discounted value is equal to the cost of acquisition when the expenditure is made in the first year analyzed.

1.6 Revenues

The capital projects analyzed by Parks Canada may involve operating revenue from rentals, use of campgrounds, etc. This revenue must be included in life cycle cost analysis as it reduces the actual cost of the project. As in the case of costs, Past revenue must not be considered in the calculations. Only revenue actually associated with project options is included in the analysis.

We can generally expect operating revenue to be of a recurring nature during the period analyzed. The equation used to discount revenue is therefore similar to the one for recurring costs:

$$REVD_k = (REV_k + REV_k * P/A(n2, t1)) * F/P(n, e1) * P/F(n, 1) \quad (13)$$

$$t1 = (i - e2)/(1 + e2) \quad (14)$$

where

$REVD_k$: Discounted value of recurring revenue k, in first year dollars, for n years, at a net discount rate t1.

REV_k : Revenue associated with asset k during the first year analyzed.

e1 : Annual inflation rate between the first year analyzed and the first year of revenue.

e2 : Annual inflation rate between the first and last years of revenue.

n : Number of years between the first year analyzed and the first year of revenue.

n2 : Number of years between the first and last years of revenue.

The use of two inflation rates in equation (13) enables the analyst to consider price increases as well as revenue increases resulting from higher utilization of facilities. Thus, an inflation rate e2 of 6% may include an actual inflation rate of 3% and an increased visitation rate of 3%.

Although equation (13) appears quite complex at first glance, it is simple to use. The part $(REV_k+REV_k*P/A(n2,t1))$ discounts all revenues to the first year of revenue while the term $(F/P(n,e1)*P/F(n,i)$ discounts all revenues to the first year analyzed. In the case of revenue of a recurring nature produced in years 1 to 5 of the analysis period, equation (13) becomes:

$$REVD_k = REV_k + REV_k * P/A(4, t1)$$

If the revenue is not of a recurring nature and is produced only in the first vear analyzed, equation (13) becomes:

$REVD_k = REV_k$

If revenue is produced only in year 3, equation (13) becomes:

$REVD_k = REV_k*F/P(2,el)*P/F(2,i)$

Revenue data is easily generated. Revenue is derived essentially from future visitation and fees. Projected visitation figures are available in most cases. Where projects cannot be compared to existing Parks Canada facilities, future service fees must be estimated. On the other hand, since the various project options aim to meet the same need/demand or level of service, the revenues of all the options should be near identical.

1.7 Economic Life

In performing life cycle cost analysis, one mav assume a time period of a shorter duration than the total physical life cycle of an asset. This period, usually referred to as the "economic life", is the time which is considered directly relevant to the objectives of the analysis in question. For instance, a period of 40 years may constitute the physical life cycle of a particular asset but 30 years may be preferable for operatina and decision-makinq purposes.

According to U.S. Department of the Navy, engineers in a document entitled "Economic Analysis Handbook", the economic life of a facility is the period of time it provides benefits to the oraanization. The specific factors limiting the duration of economic life are:

1. The mission life, or period over which a need for the facility is anticipated;

2. The physical life, or period over which the facility may be expected to last physically:

3. The technological life, or period before obsolescence would dictate replacement of the facility.

The economic life is the shortest of these three periods.

According to t'he Department of Public Works, the economic life is the period of time durina which an asset can be operated at a profit. It is the period of time during which the asset can generate a return on the investment. This period is usually shorter than the physical life of the facility.

In the analyses performed by Parks Canada, there is obviously no assessment of return on investment. The economic life of a facility/equipment is the period during which Parks Canada makes effective use of the facility/equipment, taking into account operational and maintenance policies. The economic life corresponds as closely as possible with the following:

- the actual period during which the facility/equipment fulfills its intended purpose, i.e. period during which the facility/equipment responds adequately to the demand, will offer the service for which it has been conceived and will be effectively used.

- the period corresponding with the moment of first use to when replacement cost must be considered. That is the period of its physical life or the period where new technology makes the replacement of the facility/equipment necessary.

The economic life begins only after the facility/equipment has been built or installed and has begun to fulfill its intended purpose. Where the construction of a building takes three years to complete, the economic life begins only in year 4.

The Engineering and Architecture Branch produced a document (EA-HQ-79-48) in 1979 which lists the physical life of many types of facilities managed by Parks Canada. This type of information is useful in determining the economic life. From another point of view, the engineer who manages the project is often able to determine the economic life of the various facilities and equipment involved in an option.

1.8 Analysis Period

The comparative estimation of discounted costs is only valid if each option analyzed serves an identical purpose in terms of service provided. It is therefore necessary to use an identical analysis period for each case or option. It is possible to consider different economic lives in different options by taking into account replacement of assets and residual value.

The analysis period is the period of service used as a reference period during which shorter-life components are replaced and at the end of which residual values are taken into account. The period analyzed is usually the longest possible and is at least equal to the useful life of the principal facility under study. The analyst should use the longest period where the options to be compared involve principal facilities of different economic lives. For example, where two options have economic lives of 20 and 30 years respectively, he should use the 30 year period for purposes of analysis. So that both options meet the same need/demand, option 1 will be replaced in year 21 and its residual value will be estimated at vear 30.

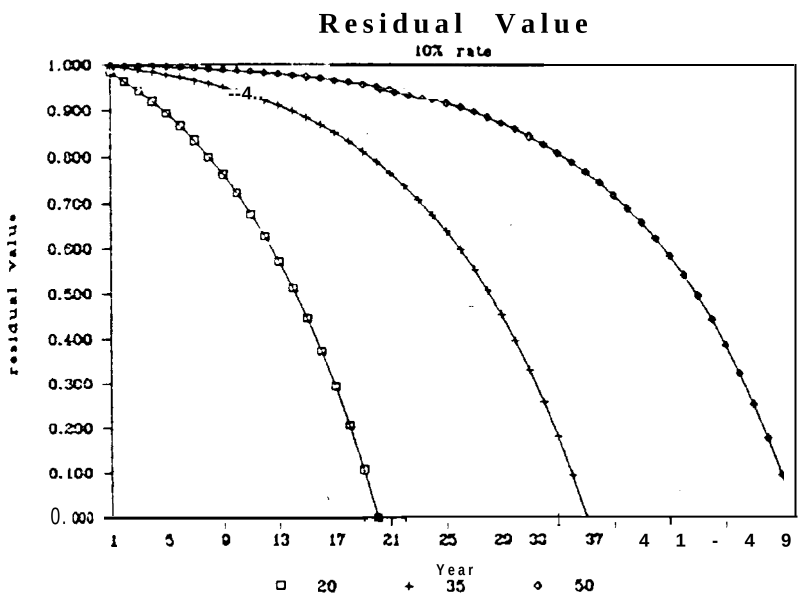
1.9 Residual Value

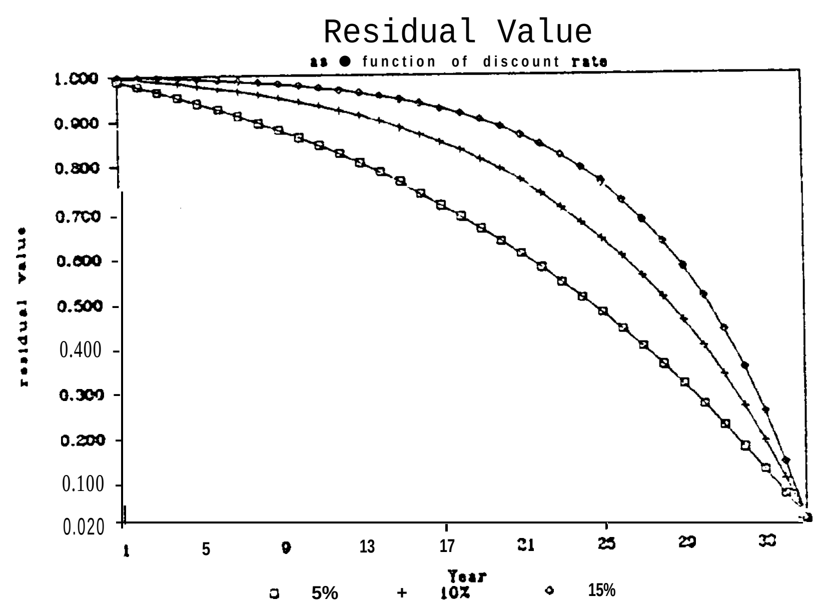
The residual value of a facility is the real value the facility will probably have at the end of the period analyzed. By considering residual values, the analyst is able to compare options with different economic lives usina a common period of analysis. Residual value is treated as revenue at the end of the period analyzed. Once the residual value is established, it is discounted to the beginning of the period analyzed and deducted from the initial cost.

Residual value may have the following components: salvage value of parts still usable at the end of the equipment or facility's useful life; removal and dismantling costs relative to components that are still of some use; and reuse value of the equipment or facility whose economic life is not over. The reuse value should correspond to the projected cost of service that the equipment or facility could still provide after the analysis period, i.e. the use value. The estimation of residual value, as used in the model implemented by the Socio-Economic Branch, is based on the concept of use value; this concept is defined as the cost of an alternative if the present facility or equipment were no longer available.

The formula for calculating residual value at the end of the period analyzed is shown in equation (6) under section 1.5. The ratio P/A(residual life, t)/P/A(economic life, t) is the most important element of the formula. It estimates residual value in non-discounted first year dollars. In order to do this, it considers the value of the asset as an annual amount and discounts this annuity for the asset's residual life and economic life. It then calculates a ratio between these two periods. Thus, the residual value corresponds to the service that the asset will still be able to provide compared to the service that it can provide throughout its economic life.

Two residual value graphs are shown on the following page, based on calculations using equation (6). An examination of these graphs provides a better understanding of this equation. The Y axis corresponds to the value of tune asset, from O to 1 (or 100%) while the X axis indicates the years. The curves in these graphs indicate that the value of an asset diminishes with time and that the loss in


Residual Value
10% rate
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
residual value
1
5
9
13
17
21
25
29
33
37
Year
20
35
50


Residual Value
as a function of discount rate
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.020
residual value
1
5
9
13
17
21
25
29
33
Year
5%
10%
15%

value increases from year to year. The first graph shows that the longer the economic life of an asset, the more convex the residual value curve. This means that for longer economic lives, the loss in value is relatively smaller in the early years and relatively greater in the later years. The second graph shows, on the other hand, that the curve grows more convex with t-he rise in the discount rate, for a specific economic life. In other words, at a higher discount rate, the loss in value is relatively smaller in the early years and relatively greater in the later years.

1.10 Inflation

The model permits the comparison of expenditures made at different points in time, taking inflation into account. Inflation is the phenomenon of rising costs of products and services accompanied by a decrease in the purchasing power of the dollar. It is usually measured by industry and consumer price indexes, the latter being the most widely used. Inflation during the seventies and early eighties seriously reduced the purchasing power of the dollar. The inflation rate, however, 'nas remained below five percent since September 1984.

When the cost of an asset is expressed in current dollars, inflation is included. When the impact of inflation is excluded, the cost is expressed in constant dollars. Constant dollars are obtained by subtracting the inflation rate from current dollars. Life cycle costing brings back all costs to first vear constant dollars.

Inflation may be treated two different ways in life cycle cost analysis. The first way expresses costs in first year dollars taking future inflation rates into account. The discount rate must then include the inflation rate. Under the second approach, the entire analysis is performed in first year dollars without taking inflation into account. The discount rate in this case is expressed in constant dollars. It is implicitly assumed that all the assets included in the capital project will have the same inflation rate. It is useful to introduce inflation rates in life cycle cost analysis in two cases: when inflation rates vary substantially between the assets involved in the capital project and when the distribution of costs over time is very different from one option to another.

Equation (l), shown in section 1.2, is used to estimate the impact of inflation. Projected inflation rates are available from many sources such as aaencies specializing in economic forecasts (Conference Board, Bank of Canada, Economic Council of Canada, Informetrica, etc.), from the analysis of Past inflation rates,

TABLE 3

Annual Average Inflation Rate of Selected Goods Purchased by Parks Canada
1975 to 1984

Goods	Years										Index March 1985 (1971=100)
	75	76	77	78	79	80	81	82	83	84	
Fuel	0.135	0.161	0.155	0.140	0.125	0.202	0.434	0.222	0.103	0.065	834.6
Gas	0.210	0.289	0.132	0.188	0.055	0.118	0.274	0.242	0.101	0.015	497.9
Electricity	0.115	0.160	0.170	0.081	0.087	0.093	0.088	0.115	0.086	0.067	326.2
Communications	0.017	0.081	0.087	0.059	0.050	0.027	0.074	0.196	0.064	0.023	209.4
Transport	0.117	0.107	0.070	0.058	0.097	0.123	0.184	0.138	0.050	0.042	307.0
Durable Goods	0.077	0.054	0.051	0.058	0.096	0.109	0.094	0.054	0.039	0.033	216.0
Services	0.107	0.122	0.090	0.068	0.070	0.082	0.115	0.129	0.065	0.038	287.8
Furniture	0.125	0.063	0.055	0.025	0.083	0.073	0.072	0.077	0.036	0.052	234.2
Non-residential construction	0.015	0.102	0.084	0.075	0.111	0.090	0.097	0.088	0.068	0.030	307.3[2]
Wages [1]	0.142	0.121	0.096	0.062	0.087	0.101	0.119	0.100	0.074	0.053	329.3
C.P.I.	0.109	0.076	0.080	0.088	0.092	0.102	0.125	0.100	0.065	0.044	297.9

Source: Statistics Canada, Catalogue 62-001 and other sources.

1. Wages for the entire economy excluding those for education, health services and government.
2. Annual mean of 1984.

etc. Table 3 shows the inflation rates of selected goods purchased by Parks Canada. They can provide an interesting basis on which to forecast inflation rates.

Based on this table, it appears that inflation rates have varied substantially between 1975 and 1985 as well as between assets. However, the table does not show inflation rates by province which could differ substantially from those shown in the table.

It is interesting to observe that the inflation rate and the interest rate have opposite effects on the value of the dollar. For example, an investment of $100. in 1975 at 8 percent interest would have been worth $216 in 1985. However, if the consumer price index rises bv 75 percent in the same period, due to inflation, the $216 in 1985 dollars can only buy consumer goods and services valued at $124 in 1975 dollars. The effect of inflation therefore tends to reduce the effect of interest. The actual return on investment in this example is therefore only 2 percent per year.

1.11 Replacement Cost

The replacement cost of a facility/equipment includes all costs involved in removing any component whose economic life has ended during the period of analysis as well as all costs involved in replacing it by another which will continue to provide the same service.

The replacement cost includes the costs of removal, transportation, engineering design and administration, the cost of purchasing and installing a new asset, but less the salvage value. It is often considered acceptable and practical to assume that the cost of replacing a facility/equipment is equal to its initial cost plus inflation.

Like residual value, the concept of replacement cost is used in the comparison of options with different economic lives. If a facility has a shorter economic life than the period analyzed, the replacement cost should be included in the analysis.

1.12 Sensitivity Analysis

The preciseness of the discounting technique described is often in striking contrast with the uncertainty and lack of reliability of the input data usually available. Results of analysis are only as valid as the least valid input data.

The purpose of sensitivity analysis is to verify precisely the extent to which the results of analysis can be affected by variations in certain input parameters. If a variation in basic data does not alter results to the point of weighing in favour of another alternative, much uncertainty has thus been removed. The simplest way of performing sensitivity analysis is to redo the discounting calculations and assign the most extreme values to the parameter tested.

Consider a project with two options: the first involves an initial investment of $10,000 and annual operating costs of $4,000; the second requires an initial investment of $20,000 and annual operating costs of $3,000. Both options have an economic life of 30 years. Their discounted cost varies according to the discount rate as follows:

	8%	10%	12%
Option A	$55,000	$47,800	$42,200
Option B	$53,800	$47,300	$44, 200

At a discount rate of 10%, option B is more attractive. However, analysis of sensitivity to the discount rate shows that, at a rate of 12%, option A is the least expensive.

It is also possible to generalize the sensitivitv analysis when the values of the input data are difficult to forecast. The analyst systematically makes a series of calculations to determine the extent to which results are affected by variations in key parameters. The parameters most often varied simultaneously are the discount rate, the inflation rate, the initial cost and the economic life.

Treasury Board recommends the use of discount rates of 5% and 15% for sensitivity analysis. The 5% rate corresponds to the real minimum interest rate on federal government obligations and the 15% rate corresponds to the maximum return on investment in the Canadian economy. In practice, the values of factor P/F for discount rates of 5%, 10% and 15% are 0.25, 0.39 and 0.61 respectively: the variation between the rates of 5% and 10%, and 10% and 15% is greater than 55%. The wide range of this variation implies t-hat the results of sensitivity analysis can easily vary by 40%. For this reason, there is strong opposition to the rates of 5% and 15%. It would be preferable to perform the sensitivity analysis with rates of 8-12%.

CHAPTER II

COMPUTERIZED APPROACH

A computer program was developed to facilitate the use of the proposed approach. All the calculations performed by this program can be done with t'he aid of a pocket calculator with the appropriate memory for certain financial operations. The main advantage of this program is that it offers speed of execution, reliability of results and the ability to analyze various input parameters quickly.

This chapter deals specifically with the use of the computer program; it also describes the key features of the program, t'ne database and the results.

2.1 Program Features

The program developed to perform life cycle cost analysis has been named "Coucyc". It is used with an IBM-PC computer. "Written in WYLBUR and BASIC, the program is designed to be "user friendly". It can be used without prior knowledge of computers. With the aid of the program, the user enters the cost data on each capital project and performs the discounting calculations. The procedure for loading the program into the computer is outlined in Appendix 1.

The various operations performed by the program are listed on the main menu. The menu, as it appears on the screen, is shown below:

```
                         MENU
      Options:  1:  create a new data file
                2:  edit an old data file
                3:  examine a data file
                4:  number existing data files
                5:  erase a data file
                6:  run program
                9:  exit
                7:  print summary table 3
               Data file name: A: TEST1

               Press RETURN to continue
```

In this case, the user has chosen to examine the contents of a data file named TEST1, located on the diskette in drive A (option 3).

As the amount of data relative to each option in a capital project can be fairly extensive, it is necessary to have the capability of savina the data in a file. Options 1 to 5 on the menu refer solely to database management operations such as creating, editing, erasing a data file, viewing a data file and listing existing data files. Options 6 and 7 permits the user to analyse the results. Option 6 allows the user to proceed with discounting the costs in a data file whereas option 7 is used to produce a summary table of results. Option 9 is used to end the session.

To create a data file, the user first selects option 1 on the menu and indicates the name of the new file. He presses the "RETURN" key and must then complete five different screens which show the names and numbers of the various input data items in the data file as well as boxes reserved for values. Information is entered by pressing various cursor positioning keys " ", " ", " ", " " or the "TAB" key which moves the cursor from one box to another. In this respect, the program has been designed so that the user can only fill in certain boxes clearly identified on the screen. Once the screen has been completed, the user proceeds to the next screen by pressinq the F1 key.

Screens 2 to 5 have space for a maximum of 10 different assets but can be expanded by pressinq F10. After entering the data on the 10th asset, a user with 17 recurrinq costs will press F10 and the program will provide the space required for the additional assets. Once the data has been entered in the "expanded" screen, the user can recall the data on assets 1 to 10 by pressing F4.

After screen 5 has been completed, t'he file can be saved by pressina the F7 key. The program then requests the user to indicate the name of the data file to be saved and to Press F7 aqain. If the name chosen already exists, the program will indicate so and ask whether it should be changed. If the user answers "no", he must type in a new data file name.

The user may stop the procedure for creatinq a data file at any time by simply pressing the F5 key. The program then asks whether the user really wants to terminate the current session. If the user answers "no", the F5 command is iqnored. Otherwise, the proqram returns to the main menu and the work in progress is erased. This command operates the same way for options 2 and 3.

Similarly, the user may at any time save a file he has developed; he need not proceed to the fifth screen. In the case of an alternative with non-recurring and recurring costs only, the user presses the F7 key on screen 3.

The F1, F4, F5, F7 and F10 keys are therefore very important as they are used to convey most instructions relative to the proqram. Following is a brief review of their functions:

F1: go to the next screen
F4: go back in a screen
F5: to return immediately to the main menu
F7: to save a file
F10: to expand a screen

Later, it will be seen that the F8 key is used to print results.

The commands and procedures for editing an existing data file or for viewing a data file are practically identical to those of option 1. One difference is that the program shows the word "plus" under the data in an "expanded" screen. With respect to option 2, it should be noted that the user need not go through the entire data file to edit it. For example, if he changes the value of item (2) in the data file, he can save the file as soon as he has made the change. To erase information on a particular expenditure while editing a data file, the user presses the "DEL" key. To erase all data on an expenditure, the user simply erases the description of the expenditure, i.e. the first input data. The program will then automatically remove the other data in the data file. If the user wants to erase only one piece of information regarding the expenditure, for example the inflation rate, he simply moves the cursor to this information and presses the "DEL" key. The cursor positioning keys and "TAB" and "DEL" keys are used to change information in a data file. The user can erase the information to be changed and type in the new information or simply type in the new information above the old one. Option 3, on the other hand, does not permit the changing of information in a data file nor the saving of a data file.

When requesting to view a data file, if the user types in the name of a nonexistent file, the message "data file not found" will appear at the bottom of the screen after pressing the "RETURN" key. The same message appears for options 2, 3, 5 and 6 when the user requests the name of a nonexistent file. The user must then correct the name of the data file in order to proceed with the session.

When the user requests the list of existing data files, the program checks which data files it created. If a file named "BASIC1.BAS" was created by another program and is stored on the diskette in diskette drive A, the program will not list this file. If the computer has two diskette drives, both will be searched. The file names are accompanied by the letter A or B identifying the diskette drive. To return to the menu once the files have been listed, the user presses the "RETURN" key.

To erase a data file, the user selects option 5 and indicates the location and name of the file, for example A:TEST1. The program then indicates at the bottom of the screen that the file has been erased and the menu reappears on the screen. It is possible to erase any file located in diskette drives A, B or C.

Once the data relative to a project option have been entered in a data file, the user can proceed with life cycle costing by selecting option 6. Once the command is entered, the message "please wait program processing data" appears on the screen. A moment later, the results are displayed. Detail results are not, however, stored in a file. The user may record the results manually, have them printed or he may simply rerun the program later. Printing the results does not take much more time than viewing the results themselves. Section 2.4 deals specifically with the format of the results.

Finally option 7 is used to print a table comparing the results of different project options. A maximum of 6 options can be shown at one time. Each option must, however, be compatible. That is the same discount rate is used, the first year of analysis is the same and the period of analysis is identical. In addition, each option will have had to been run through the model and saved in a file.

To select the options to be analysed, the user indicates a number from 1 to 6 in front of the files already created. The program will tell you which files are available to print out. The numbers from 1 to 6 assigned by the user serves to order the files in the table comparing the results. Once the numbers have been indicated and the F8 key pressed, the comparative table will be printed.

2.2 Database

The information contained in a data file may be divided into five groups. The first group includes information of a general nature used to identify the project, such as the name of the park or site, the name and number of the project and the option number analyzed. It also includes analytical information used as parameters on the various screens, such as the discount rate, the first year analyzed and the number of years analyzed which obviously do not vary from one project option to another. The second, third and fourth groups contain information relative to buildings and other durable goods, recurring costs and other nonrecurring costs respectively. Finally, the fifth group contains information on revenue. Table 4 shows the information contained in a data file as well as their order of entry on the screens.

The general format of the data does not vary significantly between

TABLE 4
Information Contained In A Data File

Information	Order in Entering Information	screen
General Information		
Date	1°	1
Park/Site Name	2°	1
Project Name	3"	1
Project Number	4°	1
Option # Analysed	5°	1
Discount Rate	6°	1
First Year Analysed	7°	1
Number of Years Analysed	8°	1
Buildings and Other Durable Goods		
Types of Expenditures	9"	2
Year Expenditures Made	100	2
Economic Life of Good	11°	2
Inflation Rate	12°	2
Expenditures in Dollars for First Year	13"	2
Recurring Costs (Operation and Maintenance)		
Expenditure Types	14°	3
First Year of Expenditure	15°	3
Cost Year of Expenditure	16°	3
Cycle	17°	3
Inflation Rate #1	18°	3
Inflation Rate #2	19°	3
Expenditures in Dollars for First Year	200	3
Other Non-Recurring Costs Major Maintenance, etc.		
Expenditure Types	21°	4
Year of Expenditure	22°	4
Inflation Rate	230	4
Expenditures in Dollars for First Year	24"	4
Revenue		
Types of Revenues	25°	5
First Year on Revenue	26°	5
Last Year of Revenue	27°	5
Inflation Rate #1	28"	5
Inflation Rate #2	29°	5
Revenues in Dollars for First Year	30°	5

the second, third, fourth and fifth groups. First shown is the description of the expenditures or revenues. This information serves mainly to identify the costs or revenues in question. The next information shown will vary slightly from one type of asset to another. For buildings and other durable goods, the user indicates the year the expenditures were made and the economic lives of the assets. In the case of other nonrecurring costs, he simply types in the year of the expenditure. For revenue, the user specifies the first and last years of revenue. Finally, for recurring costs, he types in the first and last years of expenditure as well as the cycle of the expenditure (every year, every two years, every three years, etc.). It should be noted that, in the case of recurring costs, the last year of expenditure must be later than the first. Finally, the user types in the rate of inflation and the expenditure or revenue amounts. These amounts must always be expressed in dollars of the first year analyzed.

The inflation rate is expressed in annual terms. For buildings and other durable goods and other nonrecurring costs, the rate corresponds to the annual inflation rate between the first year analyzed and the year of expenditure. In the other cases, two inflation rates may be entered (see equations (9), (11) and (13)). The first, expressed as INF1, corresponds to the annual inflation rate between the first year analyzed and the first year of expenditure. The second inflation rate, INF2, is the rate between the first and last years of expenditure. The use of two inflation rates allows more flexibility in the analysis. For example, the user may specify electricity costs of $100 at an inflation rate of 10% for the first 10 years analyzed and 5% for the last 10 years of a 20-year project. To do this, he identifies two expenditures with specific inflation rates: INF1 and INF2 will be 0% and 10% for the first expenditure, and 10% and 5% for the second.

2.3 Error Messages

Error messages appear at the bottom of the screen when the user introduces incompatible data or forgets to specify the value of data in options 1 and 2. They also appear at the bottom of screens 1 to 5 if the user presses the F1 or F10 key which permits the entry of additional data. At the same time, the screen with t'he error reappears with the cursor positioned next to the data to be corrected. The user cannot continue the session without making the necessary correction. Once he has entered compatible data, he may go to the next screen or save the data file. Table 5 shows the limitations set for input data.

According to this table, the user must type in a value for each item

TABLE 5

LIMITATIONS SET FOR INPUT DATA

INPUT DATA ITEMS (1) to (29)	LIMITATIONS
(1) DATE	MUST HAVE A VALUE
(2) NAME OF PARK/SITE	MUST HAVE A VALUE
(3) PROJECT NAME	MUST HAVE A VALUE
(4) PROJECT NUMBER	MUST HAVE A VALUE
(5) OPTION TO BE ANALYZED	0.1 TO 99.9
(6) DISCOUNT RATE	0.1 TO 99.9
(7) FIRST YEAR ANALYZED	1985 TO YEAR 2000
(8) NUMBER OF YEARS TO BE ANALYZED	1 TO 80
(9) (14) (21) (25) EXPENDITURE TYPE	MUST HAVE A VALUE
(10) (15) (22) (26) YEARS	LARGER OR EQUAL TO FIRST YEAR AND SMALLER OR EQUAL TO LAST YEAR
(16) YEAR	MUST BE GREATER THAN # (15)
(27) YEAR	MUST BE EQUAL TO OR GREATER THAN # (25)
(11) ECONOMIC LIFE	1 TO 99
(12) (18) (19) (23) (28) (29) INFLATION RATE	0.1 TO 99.9
(13) (20) (24) (30) COSTS & REVENUE IN DOLLARS	GREATER THAN O
NUMBER OF COST ITEMS	MAXIMUM OF 100
NUMBER OF REVENUE SOURCES	MAXIMUM OF 25

(numbers in ( ) correspond with data entry forms) on screen 1. If he decides to indicate an expenditure number on screens 2, 3 or 4, he must type in a value for each item on that line. The limitation "0.1 to 99.9" set for item (6) means that the discount rate must be greater than O and smaller than or equal to 99.9. Finally, the limitation "larger or equal to first year and smaller or equal to last year" set for items (10), (1S), (22) and (26) imply that the years when the expenditures are made must not be later than the last year analyzed. For instance, in a project beginning in 1985 with a 30-year analysis period, expenditures must not be made past the year 2014.

Following are examples of error messages for a project beginning in 1985:

> the maximum number of costs items is 100;
> Item 5 does not have a value;
> Item 12 must be greater than or equal to O;
> Item 13 must be greater than O; and
> the year must be greater than or equal to 1985.

If the user changes the first year to be analyzed or reduces the number of years to be analyzed under the editinq option, he cannot save the data file until he 'nas reviewed the five screens. If he tries to save a data file by pressing the F7 key, a message will appear indicating that he has edited item (7) or (8) and therefore cannot use the F7 key. The F7 key appears only on the fifth screen. This procedure forces the user to check the information in the data file for compliance with the limitations listed in Table 5.

2.4 Format of Results

The results of life cycle costing are shown on the screen after the analysis is completed. The format is very similar to the format used in the five data file screens, except t'nat a summary of results appears immediately following the general information screens. The summary s'news the total discounted costs for each asset group as well as the total net discounted costs for the option. Detailed results follow. All the information contained in screens 2 through 5 of the data file is repeated on the screens. The discounted cost of each expenditure or revenue is shown at the extreme right of each line and the total discounted cost for each asset group (buildings and other durable goods, recurring costs and other nonrecurring costs) is shown under t'he results for each group. Total discounted costs are shown at the end of the cost section. This is followed by revenue results. Total net discounted costs are shown at the end. This amount corresponds to t'ne total discounted costs minus discounted revenues.

The F4, F5, F8 and F10 keys may be used to control the viewing of results on tune screen. F10 and F4 are used respectively to go forward or backward in the screen whereas F5 is used to return to the main menu. The results can be printed by pressing the F8 key. This key may be pressed anytime during the viewing of results. The screen turns blank for a moment and then returns to normal viewing.

The length of the printout will vary depending on the number of cost items involved. Results are printed in the form of two tables which are almost identical to the format viewed on the screen. The first table s'hews the date, name of file, and heading of the program, the general information on the project and then the detailed results of screens 2 through 5. The second table is a much shorter summary of the analysis results. It shows the date, name of file, and heading of t'he program and the general information on the project followed by the discounted costs of the three main types of expenditures, the total discounted costs of the project, the total discounted revenues and the total net discounted costs. Appendix 4 contains a sample printout of results.

Detail results are not saved in a data file when the F5 key is pressed. To c'heck or review results at a later date, the user must run the program again by selecting option 6 on the main menu.

It should be noted that the table comparing the results will not appear on the screen but will appear on t'he printout. The format of the table is similiar in appearance to a table showing only the results of one option. The only difference is that up to 6 options may be shown at one time.

CHAPTER III

SAMPLE APPLICATION

To help the user understand the concepts of life cycle costing and the operation of the computer program, we have simulated a session based on the Gros Morne National Park Plateau Access System study. This study, prepared by the firm Marshall Macklin Monaghan Limited and submitted to Parks Canada in August 1985, evaluates several plateau access systems. Chapter 6 of the document contains a life cycle cost analysis of various access systems. Initially, we used the cost data presented in that chapter. This data was subsequently refined by Robert Nash, the engineer in charge of the project at Parks Canada.

3.1 Procedure

There are many ways of performing a life cycle cost analysis effectively. It would be useful at this point to describe the procedure sugaested in the "User Guide: Socio-Economic Analysis and Impact Assessment in Capital Projects" published by the Socio-Economic Branch. Accordinq to this guide, the following steps should be considered in preparing a life cycle cost analysis:

(1) prepare a problem statement including:

- a brief description of the project
- identification of the alternatives to be included in the analysis
- the rationale for t'ne selection of the alternatives
- objectives of the analysis;

(2) choose and provide the basic rationale for the parameters used in the analysis

- baseline year
- life cycle
- discount rate
- cost factors;

(3) describe the alternatives analyzed

- physical components and" building elements included in the analysis
- the rationale for the inclusion/exclusion of cost factors
- sources and assumptions about the cost information used;

(4) prepare an analysis of each alternative

drawing up a profile of the associated costs
calculating their total net present value
testing each for sensitivity (to the discount rate and life cycle used);

(s) prepare a summary report recommending a preferred option and identifying other consequences or issues which should be considered.

It would be useful to follow this procedure which permits a precise evaluation of pre-analytical elements, namely steps 1, 2 and 3, as well as a systematic approach to life cycle costing. The example provided in this chapter follows this procedure.

3.2 Parameters and Assumptions Used in the Analysis

3.2.1 Problem Statement and Proposal

According to the Gros Morne National Park management plan, the park has two very distinct natural areas. The first, located at sea level, is a narrow strip of land. The second, at an elevation of approximately 800 metres, is a vast tundra-type plateau covered by an area of low forest, some vegetation of sub-arctic type, many ponds and streams, and hilly ground.

Steep slopes and the harsh conditions prevailing on the plateau represent access barriers that only the most seasoned hikers can overcome. In fact, most of the visitors to the park lack the experience and skill to make this type of excursion safely. They also lack the time. These people can only see and experience the plateau if assistance and controls are available to make the experience interesting and safe. This can be achieved with a plateau access system.

The system will permit quick and safe access to the plateau and its environment. From that height, visitors will also get a view of the area at sea level.

This project is included in the federal-provincial agreement (amended in May 1983) on the creation of Gros Morne National park as well as in the park's management plan.

3.2.2 Identification of Need/Demand

Once the need for a plateau access system has been established, it is necessary to estimate the number of visitors who would use this new service. This information is essential to the physical design of equipment and facilities. In this regard, the Halifax office of the Socio-Economic Branch has forecasted the demand on the basis of available local, regional and national statistics.

Based on the assumption that the system would operate daily from 9 a.m. to 6 p.m., from mid-June to Labour Day, it has been estimated that the system would average 426 visitors per day in 1995. Annual visitation would then be in the range of 34,080 to 36, 210 people. Peak hour visitation would be 85 visitors on an average day and 113 visitors on a peak day.

The Socio-Economic Branch then forecasted the demand for the next 10 years by developing "strong", "average" and "low" demand scenarios. The authors of the life cycle cost analysis retained the scenario for a "strong" demand, assuming that the demand would remain strong over the entire use period, at approximately 34,000 visitors per year.

3.2.3 Discount Rate, Analysis Period and Baseline Year

The discount rate used in this session is a real rate of 10%, as recommended by Treasury Board. The sensitivity analysis performed later will use rates of 5%, 7%, 13% and 15% to evaluate the impact of the discount rate on the selection of an option.

The period to be analyzed is 30 years, which corresponds to the longest economic life of the access systems examined, namely the funicular. The life cycle cost analysis will therefore evaluate the replacement costs for the other systems as well as their residual values at the end of 30 years. Table 6 shows the economic life of each system.

According to the "PIP" documents, the access system will be built mainly in 1990-91 and according to Robert Nash, the terminals can easily be built and the equipment installed wit'nin a period of six months. Thus , the baseline year for the project would be 1990-91. Operating and maintenance costs and revenues would then be calculated starting in 1991-92. The costs presented in the MMM report, however, are all expressed in 1985 dollars. To simplify matters, the first year to be analyzed, i.e. the year to which all costs will be discounted, will be 1985 and construction and installation work will be done in year 7, 1991. The operating and maintenance costs and the revenues will be calculated from year 7 through year 36, i.e. a period of 30 years.

3.2.4 Access Systems Analysed

Six access systems were analyzed:

1. gondola, four pulse, fixed grip, 4-seat
2. gondola, two pulse, fixed grip, 6-seat
3. gondola, detachable grip, 4-seat
4. funicular
5. aerial tramway, two pulse, fixed grip
6. aerial tramway, two cabins, twin fixed cables.

Table 6 shows the physical and operational characteristics of these systems.

The implementation of these systems requires the construction of base and summit terminals for equipment and visitors. The ropeway terminals are comprised of a roofed structure to protect passengers against the elements during loading and unloading of passengers as well as an area to house terminal equipment. This terminal would be boarded up in the off-season. The electric drive motor and gearbox assembly are located below the terminal platform. Attached to the ropeway terminals are the visitors' terminals which house a waiting area, ticketing, interpretative displays, information racks and washroom facilities. A power substation and a water supply and sewage system will also be installed.

The various access systems are described in detail in chapter 4 of the Marshall Macklin Monaghan report. The choice and technical design of these systems have taken into account the anticipated demand as well as the bio-physical characteristics of the land, climate, etc.

3.2.5 Cost Profiles

Table 7 shows capital cost estimates for the various access systems in 1985 dollars. It appears that gondolas are by far the least expensive, costing between" $2,995,000 and $3,600,000, followed by the funicular and aerial tramways. The greatest variations between systems are observed in the cost of equipment supply. The cost of equipment supply ranges between $875,000 and $1, 200,000 for gondolas and between $2,800,000 and $4,000,000 for aerial tramways.

Cost data on equipment supply was obtained from various sources. The cost of terminals, engineering design and civil works was estimated by t'ne project engineers. The cost of the power station was provided by Newfoundland and Labrador Hydro. The economic lives of the systems shown in Table 6 apply only to the purchase of t'he

TABLE 6

Description of Access **System Possibilities**

	Access Systems Examined					
	GONDOLA			FUNICULAR	AERIAL TRAMWAY	
Description	Four Pulse Fixed Grip, Three 4-Seat Cabins/ Pulse	Two pulse Fixed Grip, Four 6-seat Cabins/ Pulse	Deatchable Grip, 4-Seat Cabins		Two Pulse Fixed Grip, 'IWin Cable, Two Cabins/ Pulse	Two Cabins, on Twin Fixed Cables
Cabin-type -number	4 Seats 12	6 Seats 8	4 Seats 20	25 Seats 2	10 Seats 4	25 Seats 2
Speed	3,0 m/see	3,5 m/see	3,5 m/see	6, 0m/sec	6,0 m/see	6,0 m/see
Departure Trip Length	0,5 min 11,0 min	1,0 min 10,0 min	 9,0 min	1,0 min 6,0 min	1,0 min 6,0 min	1,0 min 6,0 min
Hourly Capacity	120 pers.	135 pers.	200 pers.	215 pers.	170 pers.	215 pers.
Power k.w.	100	100	100	125	125	125
Number of Supports	35	18	18	rails	4	3
Economic Life	20 yrs.	25 yrs.	25 yrs.	**30** yrs.	20 yrs.	30 yrs.
<u>Site Description</u>						
Length		1 890 m				
Vertical Elevation		580 m				
Elevation at the Base		75 m				
Summit Elevation		655 m				

Source: Report by <u>Marshall Macklin Monaghan,</u> (1985).

TABLE 7

Access system
Capital Cost Estimates ($1985 ,000)

Expenditures	Access Systems Examined					
	GONDOLA			FUNICULAR	AERIAL TRAMWAY	
	Four Pulse Fixed Grip, Three 4-Seat Cabines/ Pulse	Two Pulse Fixed Grip, Four 6-seat Cabins/ Pulse	Deatchable Grip, 4-Seat Cabins		Two Pulse Fixed Grip, Twin Cable, Two Cabins/ Pulse	Two Cabins, on Twin Fixed Cables
Equipemnt supply	87.5	1 050	1 200	2 000	2 800	4 000
Equipment Installation	500	500	500		900	900
Terminal						
- Equipment	200	240	330			–
- Visitors	420	420	420	420	420	420
Civil Works	100	100	100	980	50	50
Electricity Station	150	150	150	150	150	150
Water & Sewage	20	20	20	20	20	20
Sub Total	2 265	2 480	2 720	3 570	4340	5 550
Engineering & Management - 15%	340	370	410	535	650	830
Sub Total	2 605	2 850	3 130	4 105	4 990	6 380
Contingencies - 15%	390	430	470	615	750	960
Total	2 995	3 280	3 600	4 720	5 740	7 340

source: Report by Marshall Macklin Monaghan, (1985).

equipment, their installation and civil works. We have assumed an economic life of 50 years fcr the terminals and an economic life of 30 years for the power station, water supply and sewage systems.

Tables 8 and 9 show the costs associated with the operation and maintenance of the various access systems. As can be seen from Table 8, the material costs are very low compared to the capital costs. In general, the material costs of operating the various systems do not vary significantly between the systems, are recurring in nature and have a cycle of 1 year, i.e. are constant throughout the operating life. They range between $1,000 and $1,400 per year.

The material costs of maintaining the various access systems are more irregular in nature. The figures in brackets indicate the frequency of expenditure. The pulley cable, for example, is replaced after 10 years of operation whereas cable inspection and painting is done every year. The cable is usually replaced at the end of the economic life, at the same time as the rest of the eauipment . The cost of cable replacement is then included in the cost of equipment. This expenditure, however, is not reauired in the case of the last two types of gondola and the last type of aerial tramway as the economic life of the cable in these systems is 50 years, i.e. much greater than the analysis period. This is taken into account in the analysis by separating the cost of the cable from that of the eauipment. On the whole, the material costs for maintaining t'ne systems, excluding the cable, range between $53,000 and $71,000 over the entire period analyzed.

Table 9 adds labour and power costs to the costs shown in Table 8. Labour estimates fcr operations are based on minimum level staffing and do net include interpretation and guide staff. They are based on 80 days of operation 12 hours per day, 7 days per week. Labcu r estimates for maintenance are based on the use of contract mechanics, assuming local availability.

Based on Table 9, it appears that labour costs are far greater than material costs. Under operating costs, labour costs account for more than 90 percent of all costs. Total operating costs are relatively similar between the systems; they amount to approximately $43,000 per year. Proper maintenance and replacement of equipment at the optimal time can ensure long-term stability in operating costs. Since it is impossible to estimate with accuracy future increases in operating costs, we have assumed stable costs for the first 10 years of operation followed by an increase of 20 percent for the remaining economic life of the access systems analyzed.

Maintenance costs, however, vary substantially from one access

TABLE 8

Access System
Operation and Maintenance Costs - Materials
($ 1985 ,000)

	Access Systems Examined					
	GONDOLA			FUNICULAR	AERIAL TRAMWAY	
Expenditures	Four Pulse Fixed Grip, Three 4-Seat Cabines/ Pulse	Two Pulse Fixed Grip, Four 6-seat Cabins/ Pulse	Deatchable Grip, 4-seat Cabins		Two Pulse Fixed Grip, Twin Cable, Two Cabins/ Pulse	Two Cabins, on Twin Fixed Cables
<u>Operations</u>						
Grease & Oil	300	300	400	300	300	300
Cable Hub	200	300	300	200	400	500
Miscellaneous Parts	300	200	400	300	300	300
Expendables	300	200	300	200	200	300
Annual Total	1 100	1 000	1 400	1 000	1 200	1400
<u>Maintenance</u>						
Pulley Cable	17 000 (lo)	7 000 (lo)	7 000 (lo)	1 000 (lo)	14 000 (lo)	3 000 (lo)
Major Repairs	15 000 (lo)	12 000 (13)	18 000 (13)	15 000 (15)	18 000 (lo)	15 000 (15)
Cable Inspection	500 (1)	500 (1)	500 (1)	(3:	1 000 (1)	1 000 (1),
Truck Maintenance	—	—	--	600 (1)	—	—
Paint	300 (1)	(2:	200 (1)	200 (1)	300 (1)	300 (1)
Total for 30 yrs	56 000	47 000	53 000	54 000	71 000	60 000
Cable Replacement	45 COO (25)	75 000 (50)	80 000 (50)	20 000 (30)	75 000 (20)	150 000 (50)

Source: Report by Marshall Macklin Monaghan, (1985); Robert Nash; S.E.B.

TABLE 9

Access System
Operation & Maintenance Costs
($ 1985 , 000)

Expenditures	GONDOLA: Four Pulse Fixed Grip, Three 4-Seat Cabines/ Pulse	GONDOLA: Two Pulse Fixed Grip, Four 6-seat Cabins/ Pulse	GONDOLA: Deatchable Grip, 4-seat Cabins	FUNICULAR	AERIAL TRAMWAY: Two Pulse Fixed Grip, Twin Cable, Two Cabins/ Pulse	AERIAL TRAMWAY: Two Cabins, on Twin Fixed Cables
Operations						
Labour - p/d	480	480	480	480	480	480
Power - kwh	60 000	70 000	80 000	80 000	70 000	80 000
cost						
- Labour	38 400	38 400	38 400	38 400	38 400	38 400
- Power	2 700	3 200	3 600	3 600	3 200	3 600
- Materials	1 100	1 000	1 400	1 000	1 200	1 400
Total Annual costs	42 200	42 600	43 400	43 000	42 800	43 400
Maintenance						
Labour						
- Pulley Cable	10 000 (lo)	6 000 (lo)	6 000 (lo)	3 000 (lo)	10 000 (lo)	3 000 (lo)
- Major Repair	20 000 (lo)	20 000 (13)	20 000 (13)	20 000 (15)	20 000 (lo)	20 000 (15)
- Annual Maintenance	15 000 (1)	5 400 (1)	8 600 (1)	3 800 (1)	5 400 (1)	3 800 (1)
Total	480 000	192 000	290 000	140 000	192 000	140 000
Materials	56 000	47 000	53 000	54 000	71 000	60 000
Total Cost For 30 yrs	536 000	239 000	343 000	194 000	263 000	200 000

Source: Report by Marshall Macklin Monaghan, (1985): Robert Nash; S.E.B.

system to another. The costs associated with gondolas are generally higher than those of the other systems. The highest maintenance costs ($535,000) are associated with the first type of gondola while the lowest costs ($194,000) are associated with the funicular. Again, labour costs are by far the greatest: they account for at least 70 percent of total maintenance costs.

The costs shown in Tables 8 and 9 have been underestimated due to the exclusion of a number of elements that should have been considered, such as:

building maintenance and repair
sewage disposal system maintenance
power supply operations and maintenance
weather station monitoring.

The exclusion of these costs from the life cycle cost analysis should not affect the choice of the least expensive system as all the systems would most likely involve these costs.

3.2.6 Revenue Profiles

Since all the options are designed to respond to the same need/demand, revenues will not vary from one access system to another. Based on a projected visitation of 35,000 people per year and an assumed price of $3.00 for a return ticket, the operation of the system should produce a revenue of $185,000 per year.

This is only a preliminary estimate of revenues as no fee has yet been set for this service which will be the first of its kind for Parks Canada. The gondolas, funicular and aerial tramways currently in use in national parks are all privately operated. Ticket prices are based on informal consultations rather than an established rate system.

3.3 Database and Life Cycle Costing

Once all data on costs and revenues have been collected and the parameters selected, life cycle costing can begin using the computer program. First, it is preferable to complete a data entry form. Each option or access system is associated with a form. Appendix 5 shows the data entry form for the first type of gondola. All capital costs are included under buildings and other durable goods whereas operating costs are included under recurring costs. On the other hand, certain maintenance costs are under recurring costs while others are under nonrecurring costs. Since the economic life of this access system is 20 years and the analysis period is 30 years, certain replacement costs relative to equipment are included in total costs. For the same reason, operating costs are not adjusted by 20 percent for years 21 through 30.

Once a form has been completed for each option, the data files can be created. To run the COUCYC program, the user follows the procedure outlined in Appendix 1. "When the main menu appears on the screen, he selects option 1 to create a new data file. Then, guided by the program, he types in the appropriate screens the information contained in the form for the first type of gondola. He then closes this file under the name of OPTION1 for example. He can then create data files for the other access systems taking care to assign different data file names.

Appendix 3 shows the screens with the data on the first type of gondola typed in. It can be seen that the format of the data on the screens is similar to that on the data entry forms. Indeed, the forms were designed so that the user can easily refer to the various screens.

The next step consists of discounting costs and revenues. In order to do this, the user selects option 6 on t'he main menu. This procedure is repeated for each access system. Appendix 4 shows the results as they appear on the screens as well as a printout of results for the first type of gondola. Again, the format of the results is very similar to the format of the data files. Option 7 may then be used to print a table comparing results of different options.

3.4 Analysis of Results

Results are regrouped and displayed in a summary table using option 7. The main results of analysis are shown in Table 10. They are the result of the various simulations referred to in section 3.3. As can be seen from the table, the least expensive systems are the gondolas . At a cost of approximately $1,400,000, they are $800,000 cheaper than the funicular and at least $1,400,000 cheaper than the aerial tramways. The most attractive option is the four-pulse gondola at a cost of $1,360,000.

In regard to cost distribution, it is interesting to note that buildings and other durable goods represent the highest costs. The cost of equipment supply accounts for the greater part of these costs. Recurring and other nonrecurring costs are smaller in magnitude and relatively similar between the systems; therefore, they have no significant impact on the choice of the least expensive option. Operating and maintenance costs are included in these costs.

TABLE 10

Access **System**
Total Net Costs ($ 1985 ,000)

	Access Systems Examined					
	GONDOLA			FUNICULAR	AERIAL TRAMWAY	
	Four Pulse Fixed Grip, Three 4-Seat Cabins/ Pulse	Two Pulse Fixed Grip, Four 6-seat Cabins/ Pulse	Deatchable Grip, 4-Seat Cabins		Two Pulse Fixed Grip, Twin Cable, Two Cabins/ pulse	Two Cabins, on Twin Fixed Cables
COSTS						
Buildings and Other Durable Goods	1 791 100	1 876 200	2 058 700	2 652 700	3 528 800	4 121 800
Recurring Costs	351 100	336 100	324 300	297 900	297 100	302 200
Other Recurring costs	13 500	9 200	10 100	6 500	13 500	6 500
TOTAL COSTS	2 155 800	2 221 500	2 393 100	2 957 100	3 839400	4 430 500
REVENUE	796 100	796 100	796 100	796 100	796 100	**796 100**
TOTAL NET COST	1 359 700	1 425 400	1597000	2161000	3 043 300	**3 63440'**

Park/Site: Gros Morne
Project Name: Système d'accès au plateau
Project Number: 7558-376-24855
Discount Rate: 10,0
First Year Analysed: 1985
Year Analysed: 36 ans

On the other hand, the revenues shown in Table 10 are a very important element in the analysis. At a discounted value of $796,000, they far exceed operating and maintenance costs.

3.5 Sensitivity Analysis

Sensitivity analysis was performed to test the effect of different discount rates, analysis periods and economic lives on cost distribution. Discount rates of 5%, 7%, 13% and 15% were tested as well as analysis periods of 20 and 40 years, and economic lives of less than 5 years and more than 5 years. In order to test sensitivity to various discount rates, the input data for item (6) is varied and the program rerun. To test sensitivity to various analysis periods, more extensive changes are made to the data file. First, the input data for item (8), number of years to be analyzed, is varied making sure that all the years are compatible with the new analysis period. In the case of a shorter analysis period, the replacement costs and maintenance costs which occurred between year 21 and year 30 are removed from the data file. The last year of recurring operating costs and the last year of revenue are also changed. In the case of a longer analysis period, i.e. 40 years, certain replacement costs associated with equipment have to be added in many cases. The same kinds of changes are required to test sensitivity to economic life.

The results of the sensitivity analysis are shown in Table 11. It can be seen that the most economical access system is the first type of gondola which has lower costs with almost all the discount rates used and with all the analysis periods and economic lives used. The cost of the second type of gondola is slightly lower at a discount rate of 5%. The general results of the sensitivity analysis confirm, however, that the type of gondola selected is the best access system. It should be noted, furthermore, that the ranking of the other options was not affected by the sensitivity analysis.

3.6 Other Considerations

Following the completion of life cycle cost analysis, the results were incorporated in a more comprehensive method of selection by the engineer, Robert Nash, and the consulting firm. Since minimum cost was not the sole criterion of selection, the funicular emerged as the preferred access system. This illustrates the fact that decisions are not always made solely on the basis of life cycle costing. However, the exercise is not futile as it indicates the additional disbursements required to meet the other decisional criteria.

TABLE 11

Access **System**
Sensitvity Analysis ($ 1985 ,000)

	Access Systems Examined					
	GONDOLA			FUNICULAR	AERIAL TRAMWAY	
	Four Pulse Fixed Grip, Three 4-Seat Cabins/ Pulse	Two Pulse Fixed Grip, Four 6-seat Cabins/ Pulse	Deatchable Grip, 4-Seat Cabins		Two Pulse Fixed Grip, Twin Cable, Two Cabins/ Pulse	Two Cabins, on Twin Fixed Cables
<u>Discount Rate</u>						
5%	1 619 000	1 589 300	1 807 600	2 480 000	4 105 700	4419 OC
7%	1 527 100	1 551 400	1 750 400	2 382 000	3 632 400	4117 600
10%	1 359 700	1 425 400	1 597 000	2 161 000	3 043 300	3 634 40
13%	1 192 500	1 273 300	1 420 800	1 917 400	2 572 700	3 172 300
15%	1 089 100	1 172 200	1 305 500	1 759 700	2 310 600	2 889 5C
<u># Years Analysed</u>						
20 ans	1 244 600	1 291 300	1 447 000	1 948 600	2 761 400	3 279 2C
30 ans	1 359 700	1 425 400	1 597 000	2 161 000	3 043 300	3 634 4C
40 ans	1 408 400	1 473 500	1 651 100	2 236 000	3 158 000	3 765 400
<u>Economic Life</u>						
-5 ans	1 4% 500	1 513 800	1 749 900	2 249 900	3 420 500	3 861 7C
normale	1 359 700	1 425 400	1 597 000	2 161 000	3 043 300	3 634 40
+5 ens	1 268 300	1 378 000	1 601 100	2 104 400	2 851 000	3 629 1C

The life cycle cost analysis of the Gros Morne National Park Plateau Access System made in this chapter is intended as an example and should be considered as such. Many elements were simplified or eliminated to make it easier to understand the analysis. For instance, the year of construction was assumed to be the same as the first year of operation, certain nonrecurring costs were excluded, inflation rates were not considered, etc. However, identification of the need/demand and selection of the alternatives to be examined was a relatively easy task in this example. Parks Canada capital projects are not usually that simple to analyze. It is often difficult to determine the level of service to be achieved or the types of services to be provided. Definition and development of objectives often pose serious problems for the project analysts.

Finally, the reliability of the results of this analysis and of all the analyses performed with the model depends essentially on the quality of the basic data. The analyst should devote as much time as possible to collecting reliable data in order to achieve acceptable results.

CONCLUSION

The purpose of this report was to present a computerized life cycle cost model. This type of analysis is used to assess various project options with the objective of choosing the best way to employ financial resources. The computerized approach should facilitate the use of the model as well as ensure better management of Parks Canada financial resources.

The first chapter addressed the main concepts used in this type of analysis, namely discount rate, costs, economic life, residual value, etc.

The second chapter described the computer program in detail. It is apparent that the main advantage of the model developed in this report is simplicity of use and speed of execution. Indeed, it can identify the least expensive option in a fraction of the time needed to perform a manual evaluation. Also, the computer program was designed so that it can be used without prior knowledge of programming.

As in other software available from the Socio-Economic Branch, the most important element of life cycle cost analysis is the database. There are strict standards and procedures for the creation of a database and the sequence of data input. In this regard, the example given in the last chapter makes it easier to understand the operation of the database management system. Even more important is the quality of the information in the database. The reliability of results depends on the quality of the information in the database.

Finally, chapters III and IV showed how life cycle costing is accomplished with the program. The analysis sought to determine which plateau access system would be the least costly for Gros Morne National Park. It found that the first type of gondola is the preferred access system and this finding remained unchanged when the discount rate, analysis period and economic life were varied.

In conclusion, certain key points should be borne in mind. First, the computer model should be used during the project planning stage, more specifically during the development of options. At that point, all the options should offer the same response to the need/demand or the level of service to be achieved. Second, the final choice of option is not always based solely on the results of life cycle costing. This type of analysis should therefore be considered as only one of many decisional criteria.

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APPENDIX 1

LIFE CYCLE COST MODEL

LOADING PROCEDURE

The life cycle cost model was designed for use with the IBM-PC and compatible computers. It requires a minimum memory of 190K, a printer, a diskette drive, a copy of WYLBUR support software and the diskette containing the life cycle cost model. This software is available from COMTEK. It may be written to the diskette containing the life cycle cost model or to a second diskette. The following loading procedure applies when two diskettes are used:

(1) Insert the diskette containing the life cycle cost model in diskette drive A.

(2) Switc'h on the computer, screen and printer.

(3) When A appears on the screen, remove the.diskette containing the life cycle cost model from diskette drive A.

(4) Insert the diskette containing the WYLBUR support software in diskette drive A.

(5) Type in WYLBUR and press the "RETURN" key.

(6) When the word "COMMAND" appears on t'ne screen, remove the diskette containing the WYLBUR support software from diskette drive A.

(7) Insert the diskette containing the life cycle costing program in diskette drive A.

(8) Type in EXEC FRO PREVAP and press the "RETURN" key.

After a few moments, the menu presented in section 2.1.1 of this report appears on the screen and the session can begin.

There are many ways to simplify the loading procedure. One way is to write the WYLBUR support software to the diskette containing the life cycle cost model; this would reduce the procedure to steps (1) and (2).

APPENDIX 2

DATA ENTRY FORMS

DATA ENTRY FORM

Life Cycle Cost Model
Socio-Economic Branch
August 1985 Version

(1) Date: ____________________

(2) Park/Site name: ____________________

(3) Project name: ____________________

(4) Project number: ____________________

(5) Option # analysed: ____________________

(6) Discount rate: ____________________

(7) First year to be analysed: ____________________

(8) Number of years to be analysed: ____________________

BUILDINGS AND OTHER DURABLE GOODS

(9) Expenditure Types	(10) Year	(U) Economic Life	(12) Inflation	(13) Expenditures ($ Current)

RECURRING COSTS (OPERATION, MAINTENANCE, ETC.)						
(14) # Expenditure Types	(15) Year	(16) Year	(17) Cycle	(18) First Inflation Rate	(19) Second Inflation Rate	(20) Expenditures (current $)

OTHER NON-RECURRING COSTS (MAJOR MAINTENACE, ETC.)

(21) # Expenditure Types	(22) Year	(23) Inflation Rate	(24) Expenditures (Current $)

REVENUE					
(25) # Revenue Types	(26) Year	(27) Year	(28) First Inflation Rate	(29) Second Inflation Rate	(30) Amount of Revenue ($ Current)

APPENDIX 3

WORK SCREENS

Screen 1 GENERAL INFORMATION

(1) Date OCTOBER 25,1985

(2) Park/site name GROS MORNE NATIONAL PARK

(3) Project PLATEAU ACCESS SYSTEM

(4) Project number 7538-376-24855

(5) Option Analyzed # 1.0

(6) Discount rate to be used 10.0

(7) First year to be analyzed 1985

(8) Number of years to be analyzed 36

Press F1 to go to screen 2
Press F5 to return to menu
Press F7 to save data file

Screen 2 Buildings and other durable goods

(9) Type of expend.	(10) Year	(11) Econ life	(12) Inflation	(13) 1985 $
BUILDING #1	1985	40	5.0	50000

Press F1 to go to screen 3

Press F5 to return to menu
Press F7 to save data file
Press F10 to continue

Screen 3 Recurring costs (maintenance,operation,ect.)

(14) Type of expend.	(15) Year	(16) Year	(17) Cycle	(18) Inflation	(19) 1&2	(20) 1985 $
MAINTENANCE #2	1985	1990	2	.0	.0	50000

Press F1 to go to screen 4

Press F5 to return to menu
Press F7 to save data file
Press F10 to continue

Screen 4 Other non-recurring costs (major maintenance,ect.)

(21) Type of expend.	(22) Year	(23) Inflation	(24) 1985 $
MAJOR REPAIR #3	1990	5.0	50000

Press F1 to go to screen 3

Press F5 to return to menu
Press F7 to save data file
Press F10 to continue

Screen 5 Revenue

(25) Type of revenu.	(26) Year	(27) Year	(28) Inflation	(29) 1&2	(30) 1985 $
REVENUE #4	1985	1995	.0	4.0	1000

Press F5 to return to menu
Press F7 to save data file
Press F10 to continue

Enter name of file to be saved

Data file name: DATAE1

Press F5 to return to menu
Press F7 to save data file

APPENDIX 4

THE RESULTS AS PRESENTED ON THE SCREEN AND PRINTED

RESULTS ON SCREEN

OCTOBER 25,1985

* *

LIFE CYCLE COST MODEL
SOCIO-ECONOMIC BRANCH,H.Q.
AUGUST 1985 VERSION

* *

Park/site name: GROS MORNE NATIONAL PARK
Project: PLATEAU ACCESS SYSTEM
Project number: 7558-376-24855
Option Analyzed #: 1.0
Discount rate to be used: 10.0
First year to be analyzed: 1985
Number of years to be analyzed: 36

Press F5 to return to menu
Press F8 to print results
Press F10 to continue

SUMMARY OF RESULTS

DISCOUNTED COSTS IN 1985 DOLLARS

Buildings and other durable goods	$1,791,156
Recurring costs (maintenance,operation,ect.)	$351,112
Other non-recurring costs (major maintenance,ect.)	$13,491
TOTAL COSTS	$2,155,759
DISCOUNTED REVENUES IN 1985 DOLLARS	$796,058
TOTAL NET DISCOUNTED COSTS	$1,359,701

Press F4 to go back
Press F5 to return to menu
Press F8 to print results
Press F10 to continue

DISCOUNTED COSTS IN 1985 DOLLARS

(1) Buildings and other durable goods

Exp	Type of expend.	Year	Econ life	Inflation	$ 1985	Disc cost $ 1985
1	EQUIPMENT SUPPLY	1991	40	0.0	$875,000	$493,914
2	EQUIPMENT INSTALL.	1991	[illegible]	0.0	$500,000	$282,236
3	EQUIPMENT TERMINAL	1991	50	0.0	$200,000	$107,339
4	VISITORS TERMINAL	1991	50	0.0	$420,000	$225,412
5	CIVIL WORKS	1991	20	0.0	$100,000	$56,447
6	POWER SUPPLY	1991	30	0.0	$150,000	$84,671
7	WATER SUPPLY-SEWAGE	1991	30	0.0	$20,000	$11,289
8	ENGINEERING-CONTING.	1991	20	0.0	$730,000	$412,065
9	EQUIPMENT SUPPLY 2	2011	20	0.0	$875,000	$52,988
10	EQUIPMENT INSTALL. 2	2011	[illegible]0	0.0	$500,000	$30,278
11	CIVIL WORKS 2	2011	20	0.0	$100,000	$6,055
12	ENGINEERING-CONTING.	2011	20	0.0	$470,000	$28,462

more

Press F4 to go back
Press F5 to return to menu
Press F8 to print results
Press F10 to continue

DISCOUNTED COSTS IN 198[illegible] DOLLARS

(1) Buildings and other durable goods

Exp	Type of expend.	Year	Econ life	Inflation	$ 1985	Disc cost $ 1985

Total $1,79[illegible],[illegible]56

Press F4 to go back
Press F5 to return to menu
Press F8 to print results
Press F10 to continue

(2) Recurring costs (maintenance,operation,ect.)

Exp	Type of expend.	Year	Year	Cycle	Inflation 1	& 2	$ 1985	Disc cost $ 1985
13	MATERIAL OPE.	1991	2000	1	0.0	0.0	$1,100	$4,196
14	LABOUR OPE.	1991	2000	1	0.0	0.0	$38,400	$146,507
15	MATERIAL OPE.	2001	2010	1	0.0	0.0	$1,300	$1,912
16	LABOUR OPE.	2001	2010	1	0.0	0.0	$46,100	$67,811
17	MATERIAL OPE.	2011	2020	1	0.0	0.0	$1,100	$623
18	LABOUR OPE.	2011	2020	1	0.0	0.0	$38,400	$21,777
19	POWER OPE.	1991	2020	1	0.0	0.0	$2,700	$15,804
20	CABLE INSPEC. MAINT.	1991	2020	1	0.0	0.0	$500	$2,926
21	PAINT MAINT.	1991	2020	1	0.0	0.0	$300	$1,756
22	LABOUR MAINT.	1991	2020	1	0.0	0.0	$15,000	$87,800
Total								$351,112

Press F4 to go back
Press F5 to return to menu
Press F8 to print results
Press F10 to continue

(3) Other non-recurring costs (major maintenance,ect.)

Exp	Type of expend.	Year	Inflation	$ 1985	Disc cost $ 1985
23	LINER MAINT.	2001	0.0	$17,000	$3,699
24	LABOUR LINER MAINT.	2001	0.0	$10,000	$2,176
25	MAJOR REPAIRS MAINT.	2001	0.0	$15,000	$3,264
26	LABOUR MR MAINT.	2001	0.0	$20,000	$4,352
Total					$13,491

TOTAL COSTS $2,155,759

Press F4 to go back
Press F5 to return to menu
Press F8 to print results
Press F10 to continue

DISCOUNTED REVENUES IN 1985 DOLLARS

Rev	Type of revenu.	Year	Year	Inflation 1 & 2		$ 1985	Disc rev. $ 1985
1	TICKET SALES	1991	2020	0.0	0.0	$136,000	$796,058
Total							$796,058

TOTAL NET DISCOUNTED COSTS $1,359,701

Press F4 to go back
Press F5 to return to menu
Press F8 to print results

PRINTED RESULTS

OCTOBER 25.1985

* *

LIFE CYCLE COST MODEL
SOCIO-ECONOMIC BRANCH,H.Q.
AUGUST 1985 VERSION

* *

Park/site name: GROS MORNE NATIONAL PARK
Project: PLATEAU ACCESS SYSTEM
Project number: 7558-376-24855
Option Analyzed #: 1.0
Discount rate to be used: 10.0
First year to be analyzed: 1985
Number of years to be analyzed: 36

SUMMARY OF RESULTS

DISCOUNTED COSTS IN 1985 DOLLARS

Buildings and other durable goods	$1,791,156
Recurring costs (maintenance,operation,ect.)	$351,112
Other non-recurring costs (major maintenance,ect.)	$13,491
TOTAL COSTS	$2,155,759
DISCOUNTED REVENUES IN 1985 DOLLARS	$796,058
TOTAL NET DISCOUNTED COSTS	$1,359,701

* *

OCTOBER 25,1985

* *

LIFE CYCLE COST MODEL
SOCIO-ECONOMIC BRANCH,H.Q.
AUGUST 1985 VERSION

* *

Park/site name: GROS MORNE NATIONAL PARK
Project: PLATEAU ACCESS SYSTEM
Project number: 7558-376-24855
Option Analyzed #: 1.0
Discount rate to be used: 10.0
First year to be analyzed: 1985
Number of years to be analyzed: 36

DISCOUNTED COSTS IN 1985 DOLLARS

(1) Buildings and other durable goods

Exp	Type of expend.	Year	Econ life	Inflation	$ 1985	Disc cost $ 1985
1	EQUIPMENT SUPPLY	1991	20	0.0	$875,000	$493,914
2	EQUIPMENT INSTALL.	1991	20	0.0	$500,000	$282,236
3	EQUIPMENT TERMINAL	1991	50	0.0	$200,000	$107,339
4	VISITORS TERMINAL	1991	50	0.0	$420,000	$225,412
5	CIVIL WORKS	1991	20	0.0	$100,000	$56,447
6	POWER SUPPLY	1991	30	0.0	$150,000	$84,671
7	WATER SUPPLY-SEWAGE	1991	30	0.0	$20,000	$11,289
8	ENGINEERING-CONTING.	1991	20	0.0	$730,000	$412,065
9	EQUIPMENT SUPPLY 2	2011	20	0.0	$875,000	$52,988
10	EQUIPMENT INSTALL. 2	2011	20	0.0	$500,000	$30,278
11	CIVIL WORKS 2	2011	20	0.0	$100,000	$6,055
12	ENGINEERING-CONTING.	2011	20	0.0	$470,000	$28,462

Total $1,791,156

(2) Recurring costs (maintenance,operation,ect.)

Exp	Type of expend.	Year	Year	Cycle	Inflation 1	Inflation 2	$ 1985	Disc cost $ 1985
13	MATERIAL OPE.	1991	2000	1	0.0	0.0	$1,100	$4,196
14	LABOUR OPE.	1991	2000	1	0.0	0.0	$38,400	$146,507
15	MATERIAL OPE.	2001	2010	1	0.0	0.0	$1,300	$1,912
16	LABOUR OPE.	2001	2010	1	0.0	0.0	$46,100	$67,811
17	MATERIAL OPE.	2011	2020	1	0.0	0.0	$1,100	$623
18	LABOUR OPE.	2011	2020	1	0.0	0.0	$38,400	$21,777
19	POWER OPE.	1991	2020	1	0.0	0.0	$2,700	$15,804
20	CABLE INSPEC. MAINT.	1991	2020	1	0.0	0.0	$500	$2,926
21	PAINT MAINT.	1991	2020	1	0.0	0.0	$300	$1,756
22	LABOUR MAINT.	1991	2020	1	0.0	0.0	$15,000	$87,800
Total								$351,112

(3) Other non-recurring costs (major maintenance,ect.)

Exp	Type of expend.	Year	Inflation	$ 1985	Disc cost $ 1985
23	LINER MAINT.	2001	0.0	$17,000	$3,699
24	LABOUR LINER MAINT.	2001	0.0	$10,000	$2,176
25	MAJOR REPAIRS MAINT.	2001	0.0	$15,000	$3,264
26	LABOUR MR MAINT.	2001	0.0	$20,000	$4,352
Total					$13,491

TOTAL COSTS $2,155,759

DISCOUNTED REVENUES IN 1985 DOLLARS

Rev	Type of revenu.	Year	Year	Inflation 1	Inflation 2	$ 1985	Disc rev. $ 1985
1	TICKET SALES	1991	2020	0.0	0.0	$136,000	$796,058
Total							$796,058

TOTAL NET DISCOUNTED COSTS $1,359.701
(Total costs-Total revenues)

* *

APPENDIX 5

DATA ENTRY FORM FOR OPTION 1

DATA ENTRY FORM

Life Cycle Cost Model
Socio-Economic Branch
August 1985 Version

(1) Date: October 25, 1985

(2) Park/Site name: Gros Morne

(3) Project name: Plateau Access System

(4) Project number: 7558-376-24855

(5) Option # analysed: Gondola - 4 types

(6) Discount rate: 10.0

(7) First year to be analysed: 1985

(8) Number of years to be analysed: 36

BUILDINGS AND OTHER DURABLE GOODS				
(9) # Expenditure Types	(lo) Year	(11) Economic Life	(12) Inflation	(13) Expenditures
Equipment Purchases	1991	20		875 000
Equipment Installatior	1991	20		500 000
Equipment Terminal	1991	50		200 000
Visitor Terminal	1991	50		420 000
Civil Work	1991	20		100 000
Electric Station	1991	30		150 000
Water and Sewer	1991	30		20 000
Engineering & Risk	1991	20		730 000
Equipment Purchase2	2011	20		875 000
Equip. Installation	2011	20		500 000
Civil Works2	2011	20		100 000
Engineeering & Risk2	2011	20		470 000

RECURRING COSTS (OPERATION, MAINTENANCE, ETC.)						
(14) # Expenditure Types	(15) Year	(16) Year	(17) Cycle	(18) First Inflation Rate	(19) Second Inflation Rate	(20) Expenditures (current $)
Parts for Operation	1991	2000	1			1 100
Labour for Operation	1991	2000	1			38 400
Parts for Operation	2001	2010	1			1 300
Labour for Operation	2001	2010	1			46 100
Parts for Operation	2011	2020	1			1 100
Labour for Operation	2011	2020	1			38 400
Energy-Operation	1991	2020	1			2 700
Inspection-Mainten.	1991	2020	1	-		500
Paint-Maintenance	1991	2020	1	-		300
Labour-Maintenance	1991	2020	1			15 000

OTHER NON-RECURRING COSTS (MAJOR MAINTENACE, ETC.)			
# (21) Expenditure Types	(22) Year	(23) Inflation Rate	(24) Expenditures (Current $)
Maint emnce - Pullev Cable	2001		17 000
Labour - BP-EN	2001		10 000
Major Repair - Maintenance	2001		15 000
Labour for MR - Maintenance	2001		20 000

REVENUE					
# (25) Revenue Types	(26) Year	(27) Year	(28) First Inflation Rate	(29) Second Inflation Rate	(30) Amount of Revenue ($ Current)
Ticket Sales	1991	2020	-		136 000