Report

Number 9

1972

THE UNIVERSITY OF WISCONSIN SEA GRANT PROGRAM

EXTENDING THE ST. LAWRENCE SEAWAY NAVIGATION SEASON: A COST-BENEFIT

ERIC SCHENKER
Department of Economics
and

MICHAEL BUNAMO and DAVID B. SMITH
Project Assistants
University of Wisconsin–Milwaukee

Special Report #15
Center for Great Lakes Studies
University of Wisconsin–Milwaukee

WIS-SG-72-209
January 1972

SPECIAL REPORT NO. 15

EXTENDING THE ST. LAWRENCE SEAWAY NAVIGATION SEASON:

A COST-BENEFIT APPROACH

By

ERIC SCHENKER

Professor of Economics
and
Associate Director, Center for Great Lakes Studies

University of Wisconsin-Milwaukee

and

Michael Bunamo and David B. Smith

Project Assistants

January 1972

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

This research was supported in part by the University of Wisconsin Sea Grant Program, which is a part of the National Sea Grant Program maintained by the National Oceanic and Atmospheric Administration of the U. S. Department of Commerce.

Many persons have freely and generously supplied much of the information incorporated in the text. The authors gratefully acknowledge this assistance. Special thanks are due to Mrs. Faye Levner and Sally Schumacher for their patience and cooperation in editing and typing this manuscript.

LIST OF TABLES

TABLE PAGE

LIST OF FIGURES

I. EXTENDING THE ST. LAWRENCE SEAWAY NAVIGATION SEASON: A COST-BENEFIT APPROACH

A. INTRODUCTION

The St. Lawrence Seaway is prevented by winter close-down from realizing its true potential as a full service, low cost transportation route. To illustrate: significant amounts of grain and general cargo captive to the Seaway are shipped overseas via seaboard ports as a result of the close-down from mid-December to mid-April. The consequent loss of economic benefits and failure to achieve full potential have prompted discussion of extending the Seaway's navigation season. [8, p. 1]

Table 1 presents traffic pattern data by months. It is seen that no serious seasonal fluctuation in cargo movement from April to November occurred in the three years from 1966 to 1969. Rather, tonnage tapers off in December and ceases from January through March. The key constraint to frequent, regular use of the Seaway is identified as the winter close-down.

Season variability is an additional drag on the Seaway's ability to capture its hinterland's general cargo. Table 2 indicates the variability of seasons for the St. Lawrence and Welland Canals from 1958 to 1970. Other sections of the waterway are generally closed as shown below:* [8, p. 2]

---

*U. S. Steel in 1970, using the ice breaking capabilities of the Coast Guard and assistance from the Corps of Engineers, kept a fleet of seven ships running as late as February 2 on Lakes Superior and Michigan.

Table 1

ST. LAWRENCE SEAWAY TRAFFIC
MONTREAL-LAKE ONTARIO SECTION
1966-1969
(cargo tons)

Month	1966	1967	1968	1969
April	4,250,738	3,771,956	4,592,936	3,547,351
May	6,162,766	6,601,057	6,809,101	4,713,916
June	5,454,801	6,361,028	4,586,612	3,627,519
July	6,294,622	6,113,373	4,774,295	3,789,006
August	6,431,720	4,352,799	6,775,023	5,024,264
September	6,158,449	3,147,547	6,668,113	5,277,454
October	7,024,656	6,121,344	6,525,258	6,709,143
November	6,422,872	6,160,058	5,680,809	6,373,709
December	1,048,734	1,399,476	1,541,703	1,951,678

Source: The St. Lawrence Seaway Authority and St. Lawrence Seaway Development Corporation, _Traffic Report of the St. Lawrence Seaway_, Ottawa, Canada, Queen's Printer, 1968 and 1969, p. 30.

Table 2

NAVIGATION SEASON
ST. LAWRENCE AND WELLAND CANALS
1958-1970

	St. Lawrence Canal		Welland Canal	
Year	First Passage	Last Passage	First Passage	Last Passage
1958	Apr. 14	Dec. 19	Apr. 1	Dec. 18
1959	Apr. 25	Dec. 3	Apr. 6	Dec. 15
1960	Apr. 18	Dec. 3	Apr. 1	Dec. 15
1961	Apr. 11	Nov. 30	Apr. 1	Dec. 15
1962	Apr. 23	Dec. 7	Apr. 1	Dec. 15
1963	Apr. 15	Dec. 13	Apr. 7	Dec. 18
1964	Apr. 8	Dec. 7	Mar. 30	Dec. 15
1965	Apr. 8	Dec. 17	Apr. 1	Dec. 16
1966	Apr. 1	Dec. 15	Apr. 4	Dec. 15
1967	Apr. 7	Dec. 15	Apr. 1	Dec. 16
1968	Apr. 8	Dec. 14	Apr. 1	Dec. 22
1969	Apr. 7	Dec. 15	Apr. 1	Dec. 22
1970	Apr. 4	Dec. 17	Apr. 1	Dec. 30

Source: U.S. Army Corps of Engineers, Survey Report on Great Lakes and St. Lawrence Seaway Navigation Season Extension, Detroit District, December, 1969, pp. E-8.

Poe Lock	December 15 - April 5
Straits of Mackinac	December 15 - April 12
St. Clair River	December 15 - March 19
Detroit River	December 15 - February 28
Lake Michigan Ports	December 15 - April 15
Lake Huron Ports	December 15 - April 5
Lake Ontario Ports	December 15 - April 10

The winter close-down has two adverse economic impacts. First, since the high value of general cargo precludes stock-piling, shippers are forced to route general cargo overland to seaboard ports during the winter months. This winter distribution channel is more expensive, but it is the only feasible alternative. Second, high volume shippers use seaboard ports all year round to avoid the disruption inherent in the annual close-down.

The weakening of the Seaway's competitive position vis-à-vis seaboard ports is not the only effect of the winter close-down. Shippers' operating costs show marked increases. Ships must be redeployed or laid up for one third of the year. Investment in lake vessels and port facilities must be allocated over eight, rather than twelve, months. Substantial start-up and close-down costs are incurred. In addition, the region incurs social costs as employees in port related occupations must be idled, relocated or supported through the winter.

At the present time there is not sufficient data available on which to base a study into the possibility of completely eliminating the winter close-down. We do have, however, data necessary to an examination of the extension of the Seaway navigation season. Our study uses cost-benefit analysis to examine the alternative extension periods.

This report presents first a summary of the chapters to follow. Second, the cost-benefit methodology is discussed. Following that the extension alternatives are specified. The technical problems encountered and the costs of meeting them are presented and examined. We then isolate and measure the benefits due to season extension. The assumptions and methodology are detailed and the resulting estimates presented. Finally, the streams of costs and benefits are compared and conclusions presented.

B. SUMMARY OF CHAPTERS II THROUGH V

Cost-Benefit Methodology (Chapter II)

Cost-benefit analysis is a widely used technique which examines the costs and benefits of alternative projects in order to find the project which maximizes the present value of total benefits minus the present value of costs over time.

Algebraically, the technique attempts to maximize the difference between

$$\frac{b_1}{(1+i)} + \frac{b_2}{(1+i)^2} + \ldots + \frac{b_k}{(1+i)^k} + \ldots \frac{b_n}{(1+i)^n} \text{ and}$$

$$\frac{c_1}{(1+i)} + \frac{c_2}{(1+i)^2} + \ldots + \frac{c_k}{(1+i)^k} + \ldots \frac{c_n}{(1+i)^n}$$

where i = the discount rate chosen by the analyst to reflect the relative desirability of consumption at different points in time.

b_k = prospective benefits in time period k

c_k = prospective costs in time period k

$\frac{b_k}{(1+i)^k}$ = present value (discounted value) of the prospective benefits in the k^{th} time period

In estimating the prospective benefits from the season extension of the Seaway, the cost savings approach has been adopted. Theoretically, the prospective benefits should be the sum of:

1. Estimated transport cost savings on present traffic plus the increased income resulting from diverted and newly generated traffic,
2. The estimated increased economic efficiency of employed resources due to improved technology, and
3. The estimated increased employment of formerly idle resources in the region affected by the Seaway extension.

It is also assumed that cost savings are passed on through reduced charges to shippers. This results in increased regional income.

Prospective costs for this study are the sum of capital, maintenance, and operation costs which we have obtained from the U. S. Corps of Engineers and the U. S. Coast Guard.

The Cost Side (Chapter III)

While inherent technological problems make a year round Seaway season unrealistic at this time, the use of ice breaking control methods plus additional navigational construction modifications make two, four, and six week extension periods feasible.

The Corps of Engineers and the Coast Guard have both estimated the costs of season extension. The Corps identified two problems of winter navigation: keeping navigation lanes navigable for general and bulk cargo vessels, and keeping locks and terminal facilities functioning. The Corps found the use of ice breakers and barges to be the most effective technique for handling the first problem in late fall and early winter. Simple ice control techniques such as flushing ice from the lock chambers and retarding ice formation by increasing the water velocity can solve the second problem. For the St. Lambert's lock, which is especially plagued by ice due to its location, the Corps recommended cutting a new bypass channel at the entrance. The Corps estimated that for a firm December 15 closing date for the entire system capital costs would be \$68 million (to the nearest million) and yearly operating costs \$6 million; for a firm January 31 closing date the costs would be \$213 million and \$19 million respectively.

The Coast Guard cost estimates are more comprehensive and detailed than the Corps of Engineers' and for that reason are the cost estimates used in this study. Due to assumptions made to facilitate the study, the estimates will tend to overestimate the cost.

The Coast Guard broke down Seaway extension costs into three subcategories: ice breaking costs, construction costs, and increased annual costs. Ice breaking costs were estimated by first estimating the amount of ice expected on specific dates in each main channel of the Seaway. From these estimates the magnitude of needed ice breaking assistance was determined. The annual cost of ice breaking was found as the product of the number of days in the extension, the number of sets of ice breakers required, and the sum of annual capital and operating costs for each vessel. For a two week extension, capital costs were $246 million (to the nearest million), annual operating costs $5 million; for a four week extension, $299 million and $7 million; and for a six week extension, $358 million and $10 million respectively.

Construction costs for extending the season included: replacement of floating navigational aids with fixed lighted aids, modification of locks to handle floating ice, and developments for the placement of ice booms to protect hydroelectric plants on the St. Lawrence River above Montreal. For a two week extension, the costs were $14 million, for a four week extension $46 million, and for a six week extension $144 million.

Increased annual operating costs for the United States were estimated to be $661,000 for a two week extension, $1,116,000 for a four week extension, $1,284,000 for a six week extension--the largest single expense being the operation and maintenance of more fixed aids to navigation.

The total of costs (to the nearest million) was then $266 million for a two week, $353 million for a four week, and $513 million for a six week extension.

The Benefit Side (Chapter IV)

The economic benefits of the Seaway were broken into four components: cost savings for present traffic, the increased regional income due to newly generated traffic, the impact of diverted traffic, and savings on the stockpiling of bulk cargo not shipped during the winter close-down.

In determining cost savings, because of data limitations, only a subset representing about two thirds of all commodities on the Seaway was analyzed: wheat, corn, soybeans, iron ore, and coal. General cargo could not be included because of the difficulties in obtaining an average charge for cargo movements.* Hence transportation cost savings and total benefits are underestimated. In estimating cost savings for 1968, total transportation costs were first estimated--the procedure used was to multiply the estimated 1968 tonnage of each commodity moving from specified origins to specified destinations by average charges for these movements as developed by EBS Management Consultants. In some cases, where no one rate was applicable, the authors judiciously assigned a rate they felt applicable to the movement. By then summing up all the commodities, 1968 total transportation costs were estimated.

---

*EBS has estimated the cost savings for general cargo to be between $10.2 and $12.2 million per year for a four week extension period.

Total transportation costs for 1968 were then estimated with the progressively reduced rate structures for two week, four week, and six week extension periods. The difference in total transportation costs gave the cost savings. The progressive reduction of rates was hypothesized since extensions reduce operating costs and produce economies of scale due to increased volume, and it is assumed that these savings are transferred to the shippers of commodities in the form of reduced rates. For 1968 we would have a savings of $11 million for a two week, $14 million for a four week, and $15 million for a six week extension. For cost savings in future years, estimates were made of future tonnage in each commodity subset. These future tonnages were multiplied by the rate structures and the differences in total transportation costs gave us the cost savings in future years.

The Seaway extension would generate new traffic. Shippers who ship over alternative routes during the Seaway closing would continue to use the Seaway during the extension period. In this study we assume the increases in traffic occur every fifth year only and are equal to zero in between. These increases in traffic result in a direct increase in income of $5 per ton of bulk cargo, and $24 per ton of general cargo. This direct increase in income has a multiplied effect on the Seaway hinterland. A mean estimated multiplier of 2.2679 is used on the direct increase to obtain the total increase in income resulting from new traffic: from $10.3 to $13.9 million for a two week, $21.1 to $26.0 million for a four week, and $32.2 to $38.3 million for a six week extension period during the time period 1968-1978.

The port impact of diverted traffic (traffic attracted to the Seaway for the first time by lower costs and better service), like the income from newly generated traffic is assumed to occur every fifth year. No impact was assumed for a two week extension; for the six week extension the impact was assumed to be 15 per cent greater than for the four week extension, which was calculated by EBS to go from $15.1 million in 1968 to $19.1 million in 1973 to $23.1 million in 1978.

Stockpile savings on iron ore, coal, and limestone were estimated by the Corps of Engineers for two week and six week periods. These savings increase by increments every five years and then remain unchanged until the next threshhold. For a six week extension these savings are $6.4 million during the years 1968-1972, increasing to $7.0 million for the years 1973-1977, and finally increasing to $7.6 million for the years 1978-1980.

The total undiscounted benefits (to the nearest million) were then $215 million for a two week, $404 million for a four week, and $498 million for a six week extension.

<u>Calculation of the Cost-Benefit Ratio</u> (Chapter V)

Theoretically in order to evaluate the merits of two week, four week, and six week extension periods, the series of costs occurring now and in the future is converted into a single present cost by the formula

$$c = c_o + \frac{c_1}{1+r} + \frac{c_2}{(1+r)^2} + \ldots \frac{c_n}{(1+r)^n}$$

where

c = present value of the cost stream

c_o= capital costs

$c_1 \ldots c_n$ = stream of operating costs

r = rate of interest

The same procedure is used to convert the series of benefits into a single present benefit. Finally, the differences between the present cost and the present benefit for the two, four, and six week extension periods are calculated and compared.

In calculating the present cost, capital costs were taken to be the sum of ice breaking equipment and navigation related construction costs; operating costs, the sum of ice breaking activity and increased annual costs. Capital costs were spread over 10, 15, and 25 year periods to see whether the extension alternatives could become self-liquidating in the near future. In so doing, the present cost formula was altered to take into consideration the amortization of capital costs. Operating costs for 1980 were calculated and were assumed to occur as a constant stream from 1968 on.

The present worth factors $\frac{1}{(1+r)}$, $\frac{1}{(1+r)^2}$ ... were found from interest rate tables. Three rates were used (five, seven, and eight per cent) in order to test the sensitivity of the results to present worth factors.

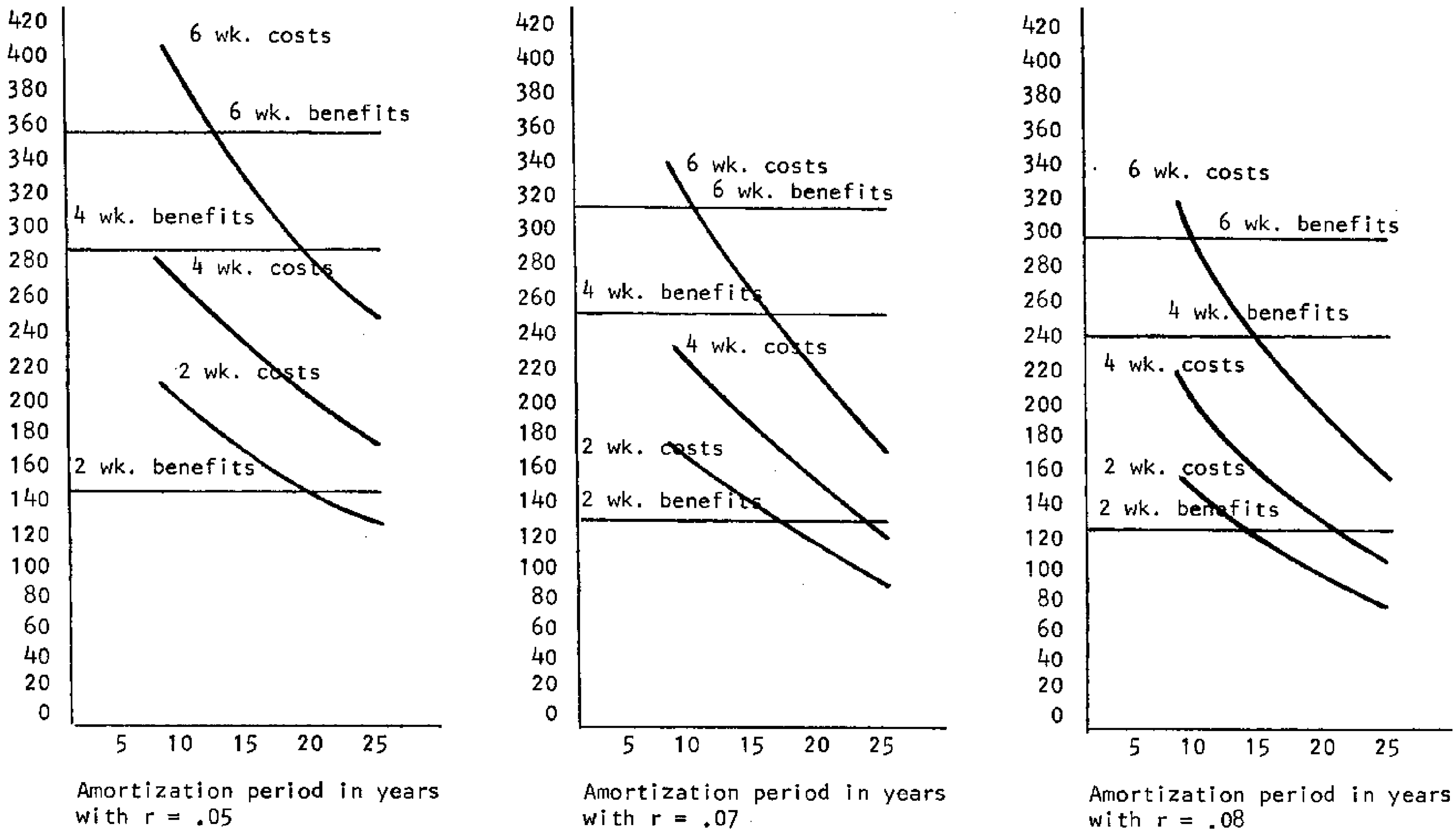
In calculating the benefits only, a commodity subset was used; hence, benefits are underestimated. This underestimation is serious in three cases: calculating transportation cost savings on general cargo, minor grains, petroleum products, animal and wood products; estimating stockpiling savings on other bulk cargoes stored during the winter; and measuring the increased regional income generated by minor grains, petroleum products, et al.

Some of the results of our study are shown in Figure 1 and Figure 2. From examining any one of the three graphs in Figure 1, we see that as we increase the length of the extension period both the costs and benefits increase. By looking at the three graphs from left to right, we see that as the interest rate increases the present value of both costs and benefits decrease for every extension period. From Figure 2 we see that the four week extension period is the most consistently profitable. The six week extension period is more profitable than the four week extension, however, under the conditions of a 25 year capital amortization scheme and a seven or eight per cent interest rate. The two week extension period's net present value shows it to be the least desirable of the three extension projects.

Thus, in conclusion, it has been found that: limited extensions of the Seaway season are technologically feasible; the costs of such extensions are known; the benefits generated by such extensions can be estimated to approximate total real benefits of extending the season under different schemes; and the longer limited extensions are economically justified.

Figure 1

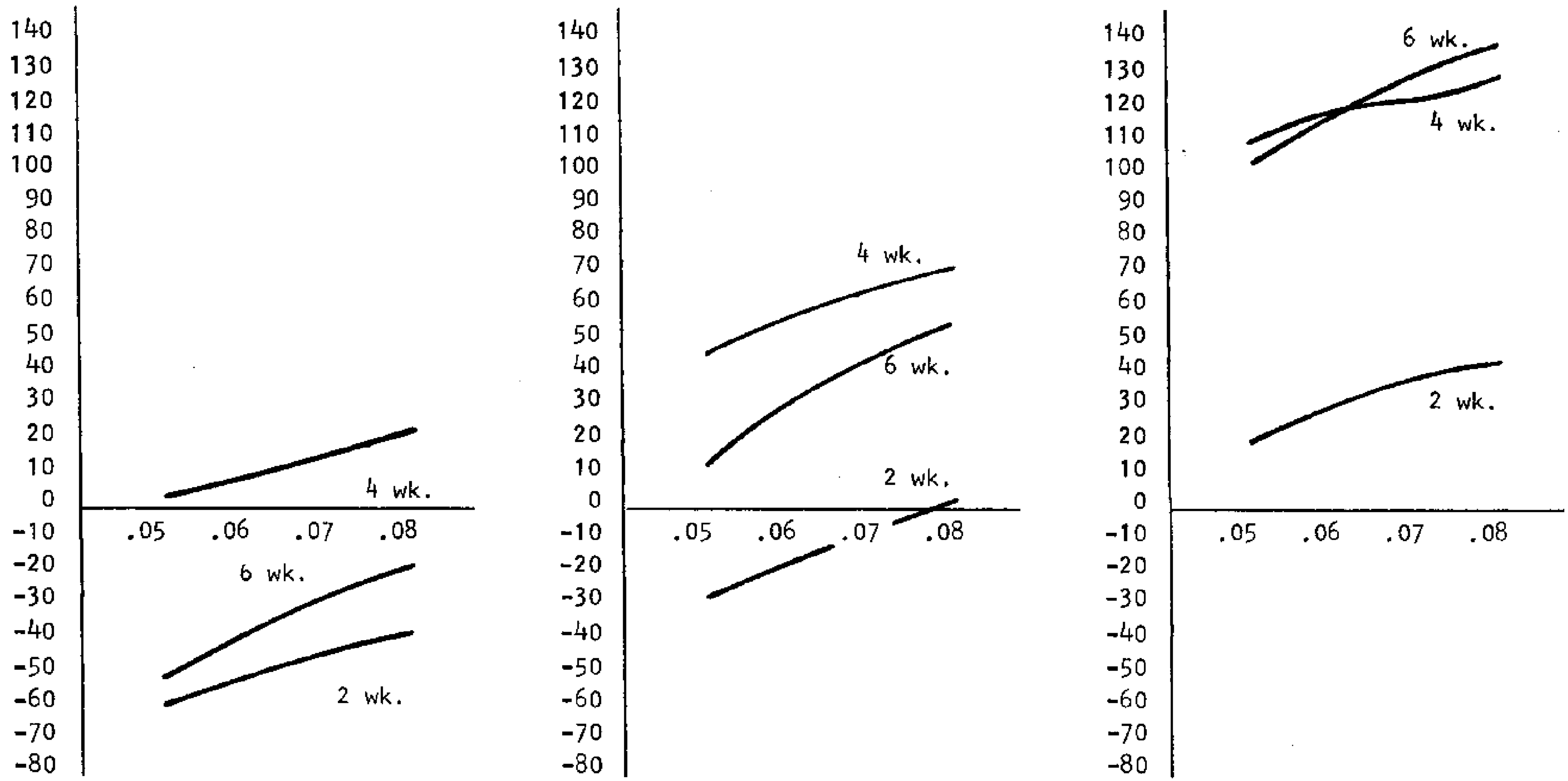
SUM OF DISCOUNTED COSTS AND BENEFITS OF EXTENDING THE ST. LAWRENCE SEAWAY NAVIGATION SEASON (1968-1980)
(in millions of dollars)



Source: Derived from Table 22.

Figure 2

NET PRESENT VALUE OF EXTENDING
THE ST. LAWRENCE SEAWAY NAVIGATION SEASON
(in millions of dollars)



Discount rates with 10 year amortization period

Discount rates with 15 year amortization period

Discount rates with 25 year amortization period

Source: Derived from Table 22.

II. COST-BENEFIT METHODOLOGY

Cost-benefit analysis has become a well known tool of applied welfare economics. The technique was developed by the Corps of Engineers to select the most efficient water resource projects. In brief, the method selects those projects whose benefits are greater than their costs. Today the method is used to examine the financial costs and prospective benefits of large scale private and public investment projects.

The technique sets out in a systematic framework the factors which must be considered in making choices between alternative projects. The method enumerates most of the relevant costs and benefits. The resulting data answer two questions: (1) Is the project economically justified? and (2) Given alternatives, is the project the most efficient choice? Since the choice among alternatives involves some type of maximization, it is assumed that the aim of the undertaking agency is to maximize the present value of total benefits accruing to the region less costs over time.

Algebraically, the decision criteria are presented as follows. The agency selects all projects where the present value of the benefits exceeds the present value of the costs:

$$\frac{b_1}{(1+i)} + \frac{b_2}{(1+i)^2} + \ldots + \frac{b_n}{(1+i)^n} > \frac{c_1}{(1+i)} + \frac{c_2}{(1+i)^2} + \ldots + \frac{c_n}{(1+i)^n} \quad (1)$$

where

$b_1 \ldots b_n$ = the stream of prospective benefits

$c_1 \ldots c_n$ = the stream of prospective costs

i = rate of discount

Alternatively, the agency selects all projects where the ratio of the present value of benefits to present value of costs exceeds unity:

$$\frac{\dfrac{b_1}{(1+i)} + \dfrac{b_2}{(1+i)^2} + \ldots + \dfrac{b_n}{(1+i)^n}}{\dfrac{c_1}{(1+i)} + \dfrac{c_2}{(1+i)^2} + \ldots + \dfrac{c_n}{(1+i)^n}} > 1 \quad (2)$$

Third, the agency chooses that project with the largest discounted net benefit, v^o. This rule is based on the difference between the discounted present value of future benefits and costs:

$$v^o = b^o - c^o \quad (3)$$

The project selected makes the maximum contribution to benefits under a given set of circumstances. [5, p. 116] The criteria are equivalent. The nature of the problem dictates the functional form chosen.

The discount rate calculations make benefits occurring at different points in time commensurate by assigning to them present values. The present value is calculated by discounting at a social time preference rate, i.e., a rate reflecting the government's evaluation of the relative desirability of consumption at different points in time. Eckstein suggests a rate of 7 to 7 1/2 per cent as the proper cost of government funds. [4, p. 10]

Operational criteria are needed to estimate the economic impact of regional transportation projects. The cost savings approach is the framework adopted for estimating the benefits from season extension. The expected increase in regional income attributable to the investment is the primary measure of benefits. The approach simply breaks down the increased regional income into components which can be observed and measured. Any important noneconomic benefits are described as specifically as possible. [4, p. 50]

Assuming that the investment results in no major changes in land use and production patterns, the total benefit from the investment is the sum of:

1. Transport cost savings on present traffic plus increased income resulting from diverted and newly generated traffic;
2. Increased economic efficiency of employed resources due to improved technology; and
3. Increased employment of formerly idle resources in the region. [4, p. 52]

Further, it is assumed that cost savings are passed on, through reduced charges, to shippers. This results in increased regional income. If carriers appropriate the profits, the beneficial effect on the regional economy will be negated.

The cost side is more difficult for the economist to estimate. Performing engineering cost studies is beyond his competence. Instead, the economist is concerned with investment planning. The purpose of investment planning is the efficient allocation of resources in order to maximize regional, social, and economic objectives. [5, p. 82]

Generally, the capital, maintenance, and operation costs are developed by engineering studies. The economist accepts the engineering cost data as accurate and attempts to determine a feasible solution, applying the principles of economic costing to determine the least-cost solution.

This section provides a brief description of the general methodology. The scope of the study and techniques suggested are the ideal. Time, data, and cost limitations preclude perfect realization of analytical goals. It is believed that the techniques applied and the analysis that follows, by selective emphasis, give a reasonable description of the costs and benefits incurred in season extension.

III. COST SIDE

The length of the Seaway navigation season is governed by natural climate changes in the Great Lakes region. There are three possibilities to explore in considering an extension. First, the status quo can remain unchanged. The season will continue to be governed by natural climate changes and shippers will seek alternative distribution routes during the winter months. Second, one can seek year round operation; however, the technological problems make year round sailing unrealistic at this time. Third, one can seek partial season extension. The use of ice breaking control methods plus additional navigational modifications make two, four, and six week extension periods feasible. This paper focuses on the costs and benefits underlying partial extension.

Both the Corps of Engineers and the Coast Guard have estimated the costs of season extension. The Corps identified two problems of winter navigation: (1) specific problems encountered by general and bulk cargo vessels in attempting to move through navigation lanes; and (2) critical features of locks and terminal facilities that might hinder winter operation. [113, p. 31]

The Corps found that the use of ice breakers and barges is the most effective method in clearing ice clogged navigation lanes in late fall and early winter. In addition, technological methods of preventing ice packs from forming must be employed for later extensions. Ice control techniques could include:

1. Using compressed air bubble systems or submerged pumps to circulate warm bottom water to the surface.
2. Spreading a layer of protein base on the ice to prevent heat loss.
3. Using submerged oil burning heaters.
4. Sinking atomic wastes.
5. Constructing dams to prevent rapids, plus other methods to prevent heat loss in shallow water areas. [18, p. 41]

The most desirable method of overcoming the effect of ice on navigation in the later extensions is to prevent its formation or reduce its thickness, strength and extent so that it is not a significant obstacle to the movement of vessels.

It appears that not all of these ice control techniques are desirable. Sinking of atomic wastes might have adverse effects on the lakes' ecology and impose huge social costs. A number of compressed air systems have proven successful in preventing ice from forming in relatively small areas. The results of small area experiments are inapplicable to the Seaway system. Finally, disturbing the ice formations in the St. Lawrence River above Montreal has adverse effects on the area's hydro electric plants. These plants are designed for winter operation assuming an ice cover.

In regard to lock operations, the Corps concluded: "Although present locks involved in the Great Lakes-St. Lawrence System were not designed specifically for extended winter operation. . .such operation is practical using expedient means of operation and some minor modifications." [113, p. 451] Effective ice control techniques include:

1. Flushing ice from lock chambers.
2. Introducing warmer upstream water into the locks.
3. Retarding ice formation by increasing the water velocity.
4. Using ice booms to clear ice.
5. Preventing ice formation on lock gates with coatings of anti-ice chemicals and application of infrared lights.

[18, p. 31]

In addition, since the St. Lambert and Cote St. Catherine locks represent the season's first ice problem, the Corps recommended cutting a new bypass channel at the entrance to the St. Lambert's lock.

Table 3 presents the Corps estimates of federal and nonfederal navigation season extension costs. They are based on two assumptions: (1) Successful winter navigation depends on providing maximum ice operating capabilities for merchant ships, supported by strategically placed ice breakers; and (2) The principal problem in the connecting channels will be disposal of ice formed or entering from the lakes. [113, p. 731] The costs are based on engineering studies and do not separate public from private costs.

Table 3

SUMMARY OF FEDERAL AND NON-FEDERAL COSTS
OF NAVIGATION SEASON EXTENSION
(thousands of dollars)

	Firm December 15 Closing		Firm January 31 Closing	
Lakes S-M-H-E-O	Capital	Operating	Capital	Operating
Icebreaking	48,000	4,140.5	130,000	10,190.0
Non-Icebreaking	4,195	477.7	24,425	4,018.7
50 yr. Amortization	---	225.3	---	1,312.0
Total	52,195	4,843.5	154,425	15,520.7
Entire System S-M-H-E-O-SW				
Icebreaking	57,000	4,673.0	130,000	10,190
Non-Icebreaking	10,920	563.7	82,525	5,087
50-yr. Amortization	---	586.4	---	4,104
Total	67,920	5,823.1	212,525	19,381

Source: U.S. Army Corps of Engineers, Survey Report on Great Lakes and St. Lawrence Seaway Navigation Season Extension: Detroit District, 1969, p. 66.

The Coast Guard study indicated that the majority of the larger merchant vessels now using the system are capable of navigating in ice without assistance for periods up to two weeks. Further operation calls for ice breaking assistance. The study then developed a method of ice classification using the ability of a representative vessel to navigate unassisted through various thicknesses of ice.

Ice thickness in each lake was determined by analyzing historical data on the dates of freezing. Then the amount of ice expected on specific dates for each main channel was predicted. Based on these estimates, the magnitude of ice breaking assistance which would be needed was gauged. The number of ice breakers required was based on the presumed speed of the vessel through ice and the distance travelled in each main channel.

In the lakes, three types of ships were selected: the WAGB (12,500 SHP), the WAGB (7,500 SHP) and WAGL (3,000 SHP). The first two are ice breakers, and the third is a combination of buoy tender and ice breaker. Based on the number of vessels required for each lake, typical vessel capital and operation costs were computed. These costs are presented in Table 4. The annual cost of ice breaking was found as the product of the number of days in the extension, the number of sets of ice breakers required, and the sum of annual capital and operating costs. A detailed statement of ice breaking costs is presented in Table 5.

Table 4

SUMMARY OF ICE BREAKING AND ICE CLEARING VESSEL COSTS

	Purchase	Operation*
WAGL (3,000 SHP)	$ 5,000,000	$ 33,000/month
WAGB (7,500 SHP)	18,000,000	1,065,000/year
WAGB (12,500 SHP)	30,000,000	710,000/year per ship per lake

*Includes 30-year amortization cost

Source: U.S. Coast Guard, Report of the Technical Subgroup, Submitted to Department of Transportation St. Lawrence Seaway Task Force, 1968, p. 213.

Table 5

SUMMARY OF ICE BREAKING COSTS
FOR SEASON EXTENSION OF PRESENT SYSTEM
(millions of dollars)

		2 Week	4 Week	6 Week
Lake Superior	A*	1.924	2.062	4.331
	C**	75.000	75.000	111.000
Lake Michigan	A	.809	1.986	2.079
	C	37.000	60.000	60.000
Lake Huron	A	.736	.853	.974
	C	22.000	37.000	60.000
Lake Erie	A	.739	.859	.940
	C	22.000	37.000	37.000
Lake Ontario	A	.753	.799	.849
	C	27.000	27.000	27.000
St. Lawrence River	A	.113	.227	.340
	C	35.000	35.000	35.000
Welland Canal	A	.023	.045	.068
	C	7.000	7.000	7.000
St. Clair River	A	.045	.091	.136
	C	14.000	14.000	14.000
St. Mary's River	A	.023	.045	.068
	C	7.000	7.000	7.000
Total	A	5.165	6.967	9.785
	C	246.000	299.000	358.000

* A = Annual operating cost
** C = Capital cost

Source: U.S. Coast Guard, Report of the Technical Subgroup, submitted to Department of Transportation St. Lawrence Seaway Task Force, 1968, p. 217.

The construction costs for extending the season include: (1) replacement of floating aids to navigation with fixed lighted aids, (2) modification of the locks to handle floating ice, and (3) provision of a guaranteed means of placing ice booms to protect the hydro electric plants above Montreal in order to insure sufficient water flow to these facilities. [14, p. 176] The estimated construction costs, presented in Table 6, reflect the fact that extension beyond four weeks requires major engineering construction projects. For example, the quantities of broken ice that would move downstream in late winter would necessitate construction of bypass canals to carry the water and marine traffic around the ice. [14, p. 177]

Finally, the Coast Guard determined increased annual operating costs. The major increase in operating costs arose due to the necessity of replacing floating navigational aids with fixed lighted aids. Estimates of the number of fixed navigational aids required were found to vary directly with the length of extension. Approximately one quarter of the number of fixed structures required for a six week extension would be needed for a two week extension. Also included in these increased operating costs were costs arising from longer operation of navigational aids, maintenance requirements of fixed navigational aids, longer tending of ice booms and increased buoy tender operations. The estimates are given in Table 7.

Table 6

SUMMARY OF ESTIMATED CONSTRUCTION COSTS
TO EXTEND SEASON OF PRESENT SYSTEM
(thousands of dollars)

Consolidated Summary	2 Week	4 Week	6 Week
Aids to Navigation (including dredging)	$12,330	$20,440	$24,495
Ice Control Works (lock improvements, ice booms, diversion booms, bypass canals, etc.)	---	24,000	118,100
Subtotals	12,330	44,440	142,595
Ports and Harbors Aids to Navigation	1,460	1,460	1,460
Totals	$13,790	$45,900	$144,055

Source: U.S. Coast Guard, Report of the Technical Subgroup, Submitted to Department of Transportation St. Lawrence Seaway Task Force, 1968, p. 182.

Table 7

INCREASE IN ANNUAL COSTS FOR EXTENDING NAVIGATION SEASON FOR THE UNITED STATES

Item	Estimated Increase in Costs — Extension Period: 2 Week	4 Week	6 Week
1. Higher buoy losses*	$252,000	$ 168,000	---
2. Longer operation of fixed aids to navigation	20,000	40,000	$ 60,000
3. More tending of ice booms	63,000	126,000	189,000
4. Longer tender operation for aids to navigation	50,000	101,000	151,000
5. Operation and maintenance of more fixed aids to navigation	276,000	681,000	884,000
Totals**	$661,000	$1,116,000	$1,284,000

* As the extension period increases, floating buoys are replaced by fixed navigational aids. Hence, fewer floating buoys are lost and costs in Item 1 decline.

** Totals for both the United States and Canada are $866,000; $1,318,000; and $1,384,000 respectively.

Source: U. S. Coast Guard, Report of the Technical Subgroup, Submitted to Department of Transportation St. Lawrence Seaway Task Force, 1968, p. 190.

A consolidated cost sheet of the Coast Guard estimates is presented in Table 8. It is found that it is relatively inexpensive to extend the season up to two weeks. The increase in costs in extending the season from two to four weeks is relatively small when compared to longer extensions. These are the cost estimates used in this study. They are more comprehensive and detailed than the Corps estimates.

The limitations in the data must be pointed out. The Coast Guard notes, "Because of the restrictive time schedule, many sensitive assumptions were made to facilitate the study to meet the deadline imposed." [14, p. 1] In developing costs for each phase, the Subgroup exploited many sources of information but, ". . .the major problem encountered involved verifying the accuracy of the data." [14, p. 3] The estimates were considered to be within the level of accuracy required but subject to an upward bias.

Table 8

CONSOLIDATED COST SHEET FOR EXTENDING
NAVIGATION SEASON FOR THE UNITED STATES

	Extension		
	2 week	4 week	6 week
Ice breaking costs ..A	$ 5,165,000	$ 6,967,000	$ 9,785,000
...C	246,000,000	299,000,000	358,000,000
Construction costs	13,790,000	45,900,000	144,000,000
Increased annual costs	661,000	1,116,000	1,284,000
Total	265,616,000	352,983,000	513,069,000

Source: Tables 5, 6, 7.

IV. THE BENEFIT SIDE

The calculation of the benefits resulting from an extended season is based on the cost savings approach. Four components are estimated:

1. Cost savings for present traffic;
2. Increased regional income due to newly generated traffic;
3. The impact of diverted traffic;
4. Stockpiling savings on certain bulk cargo not shipped during the winter close down.

The methodology used in measuring each component is as follows: First, the total transport cost of moving present traffic was determined. Theoretically, the procedure classifies traffic by commodity. Next, the actual rate for each movement was specified. Multiplying volume by the rate gave the transport cost. Summing up all cargo classifications gave the total cost. A number of simplifications were used to make calculations tractable.

The data for traffic movement by type of cargo are available. The breakdown of shipments by type of cargo is presented in Table 9. In this analysis only a subset of all commodities has been analyzed; viz., wheat, corn, soybeans, iron ore and coal. Data limitations dictated this selection.

Table 9

TRAFFIC BY CLASSIFICATION AND TYPE OF CARGO
MONTREAL-LAKE ONTARIO SECTION, 1968
(cargo tons)

Commodity	Total Cargo Tonnage
I. Agricultural Commodities	
Wheat	6,570,701
Corn	3,171,767
Soybeans and Soybean Meal	1,503,961
Barley and Rye	697,798
Oats	257,325
Flaxseed	345,320
Other Agricultural Products	989,157
Total	13,536,029
II. Animal Products	
Packing House Products	68,478
Hides	82,928
Other	212,615
Total	364,021
III. Mine Products	
Coal and Coke	1,474,908
Iron Ore	17,932,875
Other Ores and Stone	1,701,828
Total	21,109,611
IV. Forest Products	
Pulpwood	291,102
Other	131,225
Total	422,327
V. Petroleum Products	
Gasoline	365,824
Fuel Oil	2,129,742
Lubricating Oil and Greases	131,975
Other	65,578
Total	2,693,119
VI. Manufacturing and Miscellaneous	
Chemicals	239,487
Pig Iron	259,316
Iron and Steel	5,487,061
Machinery	136,026
Newsprint	240,683
Food Products	364,016
Scrap Iron and Steel	436,348
Other	2,161,694
Total	9,324,631
Grand Total	47,449,738

Source: The St. Lawrence Seaway Authority and St. Lawrence Seaway Development Corporation, _Traffic Report of the St. Lawrence Seaway_: Ottawa, Canada, Queen's Printer, 1968, p. 22.

For each specified commodity origin and destination movement were isolated. This information is given in the St. Lawrence Seaway Traffic Report. Based on this information the percentage of the commodity moving to each destination was computed. [12, vii-21] Total transport costs were calculated by multiplying actual tonnage moving to selected destinations by average charges, developed by EBS, on moving commodities on the Seaway system to these destinations.

EBS estimated these average rates. Their estimates are presented in Table 10. Unfortunately these rates did not correspond exactly with the origin and destination movements. To illustrate: Canadian domestic wheat represents 69.6% of all wheat moving on the Seaway system. There is no one rate applicable to this movement. Therefore, we assigned the rate EBS developed for wheat movement from Duluth to Buffalo as the average rate applicable for this trade. The actual assignments of rates were based on the authors' reasoned opinion. The assignment scheme is seen in Table 11, as well as the estimated transport costs for each commodity subset via the Seaway in 1968.

Once the present costs were known, the effect of two, four, and six week extensions on these costs was determined. It is assumed a longer season would result in lower rates. This assumption is based on two facts. An extended season

Table 10

CHARGES ON MOVING SELECTED COMMODITY GROUPS ON THE SEAWAY SYSTEM
(cost per ton)

Commodity	Origin/Destination Movement	Present Rate Structure*	
Wheat	Lakehead to Lower St. Lawrence	$ 4.10	(1a)
	Duluth to Buffalo	3.20	(1b)
Corn	Chicago to Lower St. Lawrence	5.31	(2a)
	Toledo to Lower St. Lawrence	2.98	(2b)
Soybeans	Chicago to Lower St. Lawrence	8.73	(3a)
	Toledo to Lower St. Lawrence	4.77	(3b)
Iron Ore	Mesabi to Lake Erie	1.90	(4a)
	Quebec-Labrador to Lake Erie	1.49	(4b)
Coal	Sandusky to Detroit	.60	(5a)
	Toledo to Duluth	3.00	(5b)

*Cost item is vessel movement

Source: EBS Management Consultants, An Economic Analysis of Improvement Alternatives to the St. Lawrence Seaway System. Final Report submitted to U. S. Department of Transportation, January 1969, pp. vii-21.

Table 11

ESTIMATED TRANSPORTATION COST, SELECTED COMMODITY SUBSET, AND COST SAVINGS VIA ST. LAWRENCE SEAWAY, 1968

		Actual Tonnage	Percentage Breakdown	Rate Structure	Total Transport Cost	Two Week Extension	Four Week Extension	Six Week Extension
I.	Wheat							
	Canadian Domestic	4,577,601	69.6	1b	$14,648,323	$12,359,522	$11,810,210	$11,581,330
	U.S. - Canada	972,803	14.8	1b	3,112,969	2,626,568	2,509,831	2,461,191
	Canada - Foreign	302,391	4.7	1a	1,378,902	1,378,902	1,357,735	1,342,616
	U.S. - Foreign	717,906	10.9	1a	3,273,651	3,273,651	3,223,397	3,187,504
	Total	6,570,701			22,413,845	19,638,643	18,901,173	18,572,639
II.	Corn							
	Canadian Domestic	9,710	.4	2b	28,935	28,644	28,256	27,770
	U.S. - Canada	1,301,202	41.0	2b	3,877,581	3,838,545	3,786,497	3,721,437
	U.S. - Foreign	1,860,855	58.6	2a	9,881,140	9,788,097	9,620,620	9,508,969
	Total	3,171,767			13,787,656	13,655,286	13,435,373	13,258,176
III.	Barley and Rye							
	Canadian Domestic	445,827	63.8	2b	1,328,564	1,315,189	1,297,356	1,275,065
	Canada - U.S.	8,790	1.2	2b	26,194	25,930	25,578	25,139
	U.S. - Canada	32,971	4.7	2b	98,253	97,264	95,945	94,297
	Canada - Foreign	64,498	9.2	2a	342,484	339,259	333,454	329,584
	U.S. - Foreign	127,101	18.2	2a	674,906	668,551	657,112	649,486
	Foreign - U.S.	18,611	2.9	2a	98,824	97,893	96,218	95,102
	Total	697,798			2,569,225	2,544,086	2,505,663	2,468,673
IV.	Soybeans/Meal							
	Canadian Domestic	54,631	3.6	3b	260,589	257,898	254,034	249,117
	Canada - Foreign	100,174	6.7	3a	874,519	865,503	851,479	840,459
	U.S. - Canada	479,155	31.9	3b	2,285,569	2,261,611	2,228,070	2,184,946
	U.S. - Foreign	870,271	57.8	3a	7,597,465	7,519,141	7,397,303	7,301,573
	Total	1,504,231			11,018,242	10,904,153	10,730,886	10,576,095
V.	Coal							
	U.S. Domestic	790,270	65.8	5a	474,162	347,718	331,913	324,010
	U.S. - Canada	410,519	34.2	5b	1,231,557	857,984	833,353	804,617
	Total	1,200,789			1,705,719	1,205,702	1,165,266	1,128,627
VI.	Iron Ore							
	U.S. Domestic	3,075,304	17.1	4a	5,843,077	6,734,915	6,427,385	6,304,373
	Canada - U.S.	14,857,571	82.9	4b	22,137,780	14,114,692	12,628,935	12,034,632
	Total	17,932,875			27,980,857	20,849,607	19,056,320	18,339,005
	Total I-VI				79,475,514	68,797,477	65,794,681	64,343,21[illegible]
VII.	Cost Saving Resulting from Extension				----------	10,678,037	13,680,833	15,132,299

reduces shippers' operating costs, which are passed on in the form of lower rates to Midwest customers. Further, there are economies of scale due to increased volume, which result in additional cost reductions. The forecast rate structure is presented in Table 12.

The procedure for calculation of total costs, assuming an extended season, is identical to the one used above. Table 11 shows the resulting estimates for the three extension periods. This table also shows the benefits that accrue to present traffic as a result of extension.

There are a number of methods of projecting future benefits. The above benefits could have been projected to occur each year in the future. We could have assumed that the above benefits would increase by a certain annual percentage. In order to provide more satisfactory estimates, however, we developed estimates of future tonnage and calculated total transport costs for each commodity subgroup based on the above two rate structures.

The method used in calculating total future costs on moving these commodities on the Seaway system is identical with the above procedures. First, estimates on the cost of moving future traffic on the present system were made. These are based on projected future commodity tonnage. This was developed by applying the projected rates of annual growth for each group to the base year tonnage. These growth rates were developed by the Stanford Research Institute and are presented in Table 13. By

Table 12

FORECAST CHARGES ON MOVING SELECTED COMMODITY GROUPS ON THE SEAWAY SYSTEM WITH AN EXTENDED SEASON, PRESENT SYSTEM (cost per ton)

Commodity	Origin/Destination Movement	Rate Struc.	1980		
			2 week	4 week	6 week
Wheat	Lakehead to Lower St. Lawrence	(1a)	$ 4.56	$ 4.49	$ 4.44
	Duluth to Buffalo	(1b)	2.70	2.58	2.53
Corn	Chicago to Lower St. L.	(2a)	5.26	5.17	5.11
	Toledo to Lower St. L.	(2b)	2.95	2.91	2.86
Soybeans	Chicago to Lower St. L.	(3a)	8.64	8.50	8.39
	Toledo to Lower St. L.	(3b)	4.72	4.65	4.56
Iron Ore	Mesabi to Lake Erie	(4a)	2.19	2.09	2.05
	Quebec-Labrador to Lake Erie	(4b)	.95	.85	.81
Coal	Sandusky to Detroit	(5a)	.44	.42	.41
	Toledo to Duluth	(5b)	2.09	2.03	1.96

Source: EBS Management Consultants, An Economic Analysis of Improvement Alternatives to the St. Lawrence Seaway System. Final Report submitted to U. S. Department of Transportation, January 1969, pp. vii 16-28.

Table 13

PROJECTED ANNUAL RATE OF GROWTH
IN TOTAL CARGO TONNAGE BY COMMODITY GROUP

Commodity	1970-75	1975-80	1980-2000
Iron Ore	+ 4.1% * + 2.4	+ 1.7% + 2.1	+ 0.8% * + 0.4
Coal and Coke	- 5.9 - 5.9	+ 5.2 + 1.8	+ 2.2 + 2.5
Petroleum and Petroleum Products	+ 2.7 + 2.1	+ 2.3 + 2.0	+ 1.0 + 0.2
Wheat, Coarse Grains and Soybeans	+ 2.4 + 1.8	+ 2.3 + 1.8	+ 1.8 + 0.9
Minor Bulk	+ 3.9 + 2.4	+ 3.3 + 1.6	+ 2.7 + 1.9
General Cargo	+ 4.1 + 3.6	+ 2.6 + 2.7	+ 2.0 + 1.4

*For each commodity top and bottom figures are high and low estimates respectively.

Source: Stanford Research Institute, Economic Analysis of St. Lawrence Seaway Cargo Movements and Forecasts of Future Cargo Tonnage. Prepared for the Under-Secretary for Transportation, U. S. Department of Commerce, November 1965, Table 3.

assuming that the relative movement to each destination remains unchanged in the future, we calculated volume moving to each destination for the period 1969 to 1980. Then we multiplied the estimates by the two assigned rate structures. Once total costs were found, the benefits resulting from an extended season were easily derived.

Once the benefits accruing to present and future traffic were quantified, the second step was to estimate the benefits due to increased traffic. The assumption that traffic would increase as a result of an extension is based on two facts. Shippers who currently use the system, but route goods to other ports during the winter months, would ship these goods via the Seaway during the season extension. In addition, an extended season would induce high volume shippers to use the low cost transportation route. This traffic we call diverted traffic.

The increased income resulting from the traffic being shipped during the season extension is estimated with the aid of techniques developed in a previous study. It is assumed that the average direct incomes generated by servicing a ton of bulk and general cargo are \$5 and \$24 respectively. These estimates were multiplied by the projected increases in bulk and general cargo traffic as developed by EBS in order to obtain the direct income resulting from increased traffic. (See Table 14.) It is known that this direct income has a multiplied effect on the hinterland. Thus, the mean regional income multiplier is

Table 14

INCREASE IN SEAWAY TRAFFIC WITH SEASON EXTENSION, 1980
PRESENT SYSTEM
(1000 tons)

Commodity	2 week	4 week	6 week
Wheat	165	285	410
Barley and Rye	75	75	75
Corn	50	250	455
Soybeans	360	515	675
Total Grain	650	1,125	1,615
U. S. General Cargo			
Exports	88	176	264
Imports	34	68	103
Total General Cargo	122	244	367

Source: EBS Management Consultants, An Economic Analysis of Improvement Alternatives to the St. Lawrence Seaway System. Final Report submitted to U. S. Department of Transportation, January 1969, p. vii-36 and p. vii-31.

applied to this direct income to produce the total dollar impact of newly generated Seaway traffic on the hinterland's economy. The mean multiplier is derived from a former study. [19, p. 641] Tables 15-17 present the total increase in income due to increased Seaway traffic under each extension period.

The port impact of diverted traffic is given by EBS for a four week extension only. [2, viii-4] Since only a commodity subgroup was analyzed (wheat, coarse grain, iron ore, and general cargo), the impact is underestimated. The EBS derivation of this result is not discussed nor is the source of their data given. In our calculations we assume that there is no impact under a two week extension and that the impact under a six week extension is 15 per cent higher than under four weeks. These estimates are given in the consolidated benefit statements.

Stockpiling savings on iron ore, coal, and limestone were estimated by the Corps of Engineers. (See Table 18.) We assume a firm December 15 closing date to be equivalent to a two week extension and a firm January 31 closing date equivalent to a six week extension. The estimates for a four week extension are a weighted average of the two and six week periods, the weights being .35 and .65 respectively. Further, it is assumed that there is a threshhold effect. Every five years stockpiling benefits increase and this continues unchanged until the beginning of the next five year period. These estimates are presented in the consolidated benefit statement.

Table 15

TOTAL INCREASE IN INCOME DUE TO INCREASED SEAWAY TRAFFIC
DURING THE TWO WEEK SEASON EXTENSION, PRESENT SYSTEM

Commodity		Estimated Increase In Cargo Tonnage (1)	Direct Increase In Income (2)	Total Increase In Income (3)
Wheat	1968	100,000 tons	$ 500,000	$ 1,133,950
	1973	130,000	650,000	1,474,135
	1978	165,000	825,000	1,871,017
Barley and Rye	1968	50,000	250,000	566,975
	1973	65,000	325,000	737,067
	1978	75,000	375,000	850,462
Corn	1968	30,000	150,000	340,185
	1973	40,000	200,000	453,580
	1978	50,000	250,000	566,975
Soybeans	1968	250,000	1,250,000	2,834,875
	1973	300,000	1,500,000	3,401,850
	1978	360,000	1,800,000	4,082,220
General Cargo	1968	100,000	2,400,000	5,442,960
	1973	110,000	2,640,000	5,987,256
	1978	120,000	2,880,000	6,531,552
Total	1968	530,000 tons	$ 4,550,000	$ 10,318,945
	1973	645,000	5,315,000	12,053,888
	1978	770,000	6,130,000	13,902,226

(1) Based on EBS estimates. We do not assume total increase in 1980 occurs immediately, so earlier years are appropriately reduced. We assume the total increase in income occurs as a once-and-for-all impact every five years and is equal to zero in between. We assume rate structure remains unchanged. Hence, we are underestimating the total increase in income.

(2) We assume bulk cargo produces $5/ton direct income, while general cargo produces $24/ton. Further, we assume no reduction in direct income for containerized cargo. Hence, estimates might show an upward bias.

(3) Total increase in income is calculated by multiplying Direct Increase in Income by the multiplier, 2.2679, which is the mean of multipliers calculated for the Great Lakes States.

Source: Derived from Table 14.

Table 16

TOTAL INCREASE IN INCOME DUE TO INCREASED SEAWAY TRAFFIC DURING THE FOUR WEEK EXTENSION, PRESENT SYSTEM

Commodity		Estimated Increase in Cargo Tonnage (1)	Direct Increase in Income (2)	Total Increase in Income (3)
Wheat	1968	200,000 tons	$ 1,000,000	$ 2,267,900
	1973	240,000	1,200,000	2,721,480
	1978	285,000	1,425,000	3,231,757
Barley and Rye	1968	50,000	250,000	566,975
	1973	65,000	325,000	737,067
	1978	75,000	375,000	850,462
Corn	1968	200,000	1,000,000	2,267,900
	1973	225,000	1,125,000	2,551,387
	1978	250,000	1,250,000	2,834,875
Soybeans	1968	450,000	2,250,000	5,102,775
	1973	480,000	2,400,000	5,442,960
	1978	515,000	2,575,000	5,839,842
General Cargo	1968	200,000	4,800,000	10,885,920
	1973	220,000	5,280,000	11,974,512
	1978	244,000	5,856,000	13,280,822
Total	1968	1,100,000 tons	$ 9,300,000	$ 21,091,470
	1973	1,230,000	10,330,000	23,427,406
	1978	1,369,000	11,481,000	26,037,758

(1) Based on EBS estimates. We do not assume total increase in 1980 occurs immediately, so earlier years are appropriately reduced. We assume the total increase in income occurs as a once-and-for-all impact every five years and is equal to zero in between. We assume rate structure remains unchanged. Hence, we are underestimating the total increase in income.

(2) We assume bulk cargo produces \$5/ton direct income, while general cargo produces \$24/ton. Further, we assume no reduction in direct income for containerized cargo. Hence, estimates might show an upward bias.

(3) Total increase in income is calculated by multiplying Direct Increase in Income by the multiplier, 2.2679, which is the mean of multipliers calculated for the Great Lakes States.

Source: Derived from Table 15.

Table 17

TOTAL INCREASE IN INCOME DUE TO INCREASED SEAWAY TRAFFIC DURING THE SIX WEEK EXTENSION, PRESENT SYSTEM

Commodity		Estimated Increase in Cargo Tonnage (1)	Direct Increase in Income (2)	Total Increase in Income (3)
Wheat	1968	350,000 tons	$ 1,750,000	$ 3,968,825
	1973	380,000	1,900,000	4,309,010
	1978	410,000	2,050,000	4,649,195
Barley and Rye	1968	50,000	250,000	566,975
	1973	65,000	325,000	737,067
	1978	75,000	375,000	850,462
Corn	1968	400,000	2,000,000	4,535,800
	1973	425,000	2,125,000	4,819,287
	1978	455,000	2,275,000	5,159,472
Soybeans	1968	600,000	3,000,000	6,803,700
	1973	640,000	3,200,000	7,257,280
	1978	675,000	3,375,000	7,654,162
General Cargo	1968	300,000	7,200,000	16,328,880
	1973	330,000	7,920,000	17,961,768
	1978	367,000	8,800,000	19,957,520
Total	1968	1,700,000 tons	$ 14,200,000	$ 32,204,180
	1973	1,840,000	15,470,000	35,084,412
	1978	1,982,000	16,875,000	38,270,811

(1) Based on EBS estimates. We do not assume total increase in 1980 occurs immediately, so earlier years are appropriately reduced. We assume the total increase in income occurs as a once-and-for-all impact every five years and is equal to zero in between. We assume rate structure remains unchanged. Hence, we are underestimating the total increase in income.

(2) We assume bulk cargo produces $5/ton direct income, while general cargo produces $24/ton. Further, we assume no reduction in direct income for containerized cargo. Hence, estimates might show an upward bias.

(3) Total increase in income is calculated by multiplying Direct Increase in Income by the multiplier, 2.2679, which is the mean of multipliers calculated for the Great Lakes States.

Source: Derived from Table 16.

Table 18

SUMMARY OF STOCKPILING SAVINGS ON IRON ORE, COAL AND LIMESTONE FROM EXTENSION OF ST. LAWRENCE SEAWAY NAVIGATION SEASON
(Thousands of dollars)

	1968	1980	2000
I. Lakes S-M-H-E-O, Welland Canal and St. Lawrence Seaway			
15 December	$ 828	$ 1,000	$ 1,335
31 January	6,362	7,660	10,351
Year round	16,969	20,427	27,636
II. Lakes S-M-H-E-O and Welland Canal			
15 December	699	846	1,123
31 January	5,236	6,308	8,492
Year round	13,921	16,770	22,608
III. Lakes S-M-H-E			
15 December	648	784	1,048
31 January	4,928	5,945	8,034
Year round	13,129	15,831	21,423

Source: U. S. Army Corps of Engineers, Survey Report on Great Lakes and St. Lawrence Seaway Navigation Season Extension: Detroit District, December 1969, p. E-20.

Table 19 presents the consolidated statement of the benefits. These are the benefits that are discounted and compared to the appropriately discounted stream of costs. While the estimation procedure is based on a number of sensitive assumptions, we feel they are well within reasonable ranges of accuracy.

Table 19

CONSOLIDATED STATEMENT OF BENEFITS
FROM NAVIGATION SEASON EXTENSIONS

		2 week extension	4 week extension	6 week extension
1968	Transport cost savings	$ 10,678,037	$ 13,680,833	$ 15,132,299
	Stockpiling savings	828,000	4,424,000	6,362,000
	Increased traffic	10,318,945	21,091,470	32,204,180
	Diverted traffic		15,100,000	17,365,000
1969	Transport cost savings	11,141,617	14,251,922	15,755,216
	Stockpiling savings	828,000	4,424,000	6,362,000
	Increased traffic			
	Diverted traffic			
1970	Transport cost savings	11,472,056	14,684,864	16,233,413
	Stockpiling savings	828,000	4,424,000	6,362,000
	Increased traffic			
	Diverted traffic			
1971	Transport cost savings	11,858,774	15,180,058	16,846,699
	Stockpiling savings	828,000	4,424,000	6,362,000
	Increased traffic			
	Diverted traffic			
1972	Transport cost savings	12,216,170	15,642,090	17,306,654
	Stockpiling savings	828,000	4,424,000	6,362,000
	Increased traffic			
	Diverted traffic			
1973	Transport cost savings	12,607,806	16,152,662	17,848,016
	Stockpiling savings	908,000	4,842,000	6,962,000
	Increased traffic	12,053,888	23,427,406	35,084,412
	Diverted traffic		19,100,000	21,965,000
1974	Transport cost savings	13,191,051	16,854,514	18,602,310
	Stockpiling savings	908,000	4,842,000	6,962,000
	Increased traffic			
	Diverted traffic			
1975	Transport cost savings	13,514,269	17,249,931	19,033,810
	Stockpiling savings	908,000	4,842,000	6,962,000
	Increased traffic			
	Diverted traffic			
1976	Transport cost savings	13,541,493	17,350,245	19,170,564
	Stockpiling savings	908,000	4,842,000	6,962,000
	Increased traffic			
	Diverted traffic			
1977	Transport cost savings	13,810,222	17,693,505	19,551,025
	Stockpiling savings	908,000	4,842,000	6,962,000
	Increased traffic			
	Diverted traffic			
1978	Transport cost savings	14,082,461	18,037,963	19,929,789
	Stockpiling savings	988,000	5,260,000	7,562,000
	Increased traffic	13,902,226	26,037,758	38,270,811
	Diverted traffic		23,100,000	26,565,000

Table 19 (continued)

		2 week extension	4 week extension	6 week extension
1979	Transport cost savings	$ 14,365,890	$ 18,402,893	$ 20,337,280
	Stockpiling savings	988,000	5,260,000	7,562,000
	Increased traffic			
	Diverted traffic			
1980	Transport cost savings	14,954,586	19,070,795	21,044,835
	Stockpiling savings	988,000	5,260,000	7,562,000
	Increased traffic			
	Diverted traffic			
Sum of Undiscounted Benefits		215,353,491	404,218,909	497,552,313

Source: Derived from Tables 11, 15, 16, 17, 18.

V. CALCULATION OF THE COST-BENEFIT RATIO

The purpose of pre-investment appraisal is threefold: (1) to establish engineering feasibility; (2) to provide cost estimates; and (3) to determine, from a broad range of alternatives, that project which will result in the maximum gain to the region. This section focuses on the third objective.

Transport systems require substantial capital investment. The main decision to be made with respect to any transportation project is whether or not to make the necessary initial investment to build, with the implied further commitment of resources to operate, the facility. Since funds are not unlimited, there must be some criteria which will point out that project which makes the largest contribution to the regional benefit account. The cost-benefit methodology is appropriate for answering both questions.

The starting point for the analysis is the comparison of the costs of the investment with the benefits generated. The estimation of costs and benefits has been discussed; the operational technique for calculating the cost-benefit ratio is specified below.

The formula for converting a series of costs to a single present cost, when attempting to find the least cost solution by the principles of economic costing, is as follows:

$$c = c_o + \frac{c_1}{(1+r)} + \frac{c_2}{(1+r)^2} + \ldots + \frac{c_n}{(1+r)^n}$$

where

c = present value of the cost stream

c_o = capital costs

$c_1 \ldots c_n$ = stream of operating costs

r = rate of interest

Capital costs, in our study, are the sum of the costs of ice breaking equipment and navigation related construction costs. Operating costs are the sum of ice breaking activity costs and increased annual costs.

Capital costs are generally distributed over a 25 to 50 year period. Since the extension alternatives do not require massive construction outlays, we felt that it would be unrealistic to distribute costs over a 50 year period. In the actual calculations, the capital costs are distributed over 10, 15, and 25 year periods. Thus, the present cost formula has been altered to take into account the amortization of capital costs. Although these are strict assumptions, they are designed to determine whether extension alternatives can become self-liquidating in the near future.

Operating costs are presented for 1980 only. Since the extension alternatives can be implemented quickly, we assume these operating costs occur as a constant stream in each year from 1968. Although it is general practice to reduce operating costs for earlier years, it was thought that our assumption would not bias the results.

The present worth factors $\frac{1}{(1+r)}$, $\frac{1}{(1+r)^2}$ ... were found from standard interest rate tables. Three rates of interest were used in the calculations, i.e., five, seven and eight per cent. These are higher than long term government bond rates which are generally applied in transportation projects, but are in accord with contemporary thinking about the proper cost of government funds. Moreover, using three rates will test the sensitivity of the results to the present worth factors. The stream of discounted costs under each extension alternative for the different combinations of interest rates and capital amortization schemes are presented in Table 20.

The same type of procedure was applied to discount the future benefit stream. For the commodity subset under consideration, the four components of the estimated transportation cost savings were appropriately discounted. The formula is exactly analogous to the formula for the discounting of costs:

$$b = \frac{b_1}{(1+r)} + \frac{b_2}{(1+r)^2} + \ldots + \frac{b_n}{(1+r)^n}$$

The rates of interest used here were also five, seven and eight per cent. Table 21 presents the total discounted

Table 20

STREAM OF DISCOUNTED COSTS OF EXTENSION
OF ST. LAWRENCE SEAWAY NAVIGATION SEASON, PRESENT SYSTEM*

	Interest Rate		
	r = .05	r = .07	r = .08
I. Two week extension			
10 years	$ 214,215,479	$ 180,755,735	$ 166,380,436
15 years	179,690,388	142,851,525	127,944,040
25 years	131,443,663	96,557,767	83,981,389
II. Four week extension			
10 years	287,666,930	242,884,561	223,641,656
15 years	241,831,048	192,562,523	172,613,083
25 years	177,777,175	131,102,433	114,247,795
III. Six week extension			
10 years	412,161,911	347,702,180	320,010,028
15 years	345,448,043	274,458,738	245,738,229
25 years	252,219,450	185,003,924	160,787,882

*Several schemes were considered for the amortization of capital costs. None of them was completely satisfactory. It was decided, therefore, to use the simplest amortization scheme possible for these capital costs.

Table 21

STREAM OF DISCOUNTED BENEFITS OF EXTENSION
OF ST. LAWRENCE SEAWAY NAVIGATION SYSTEM

	Interest Rate		
	r = .05	r = .07	r = .08
I. Two week extension	$ 154,081,621	$ 136,636,484	$ 129,022,473
II. Four week extension	291,352,441	259,582,155	245,095,989
III. Six week extension	359,556,128	320,169,546	302,961,626

benefits under each extension alternative and rate of interest.

Since only a commodity subset was analyzed (representing about two thirds of total Seaway traffic) the benefits are underestimated. This underestimation is serious in three cases: (1) gauging transportation cost savings on minor grains, petroleum products, animal and wood products, plus general cargo; (2) estimating stockpiling savings on other bulk cargoes that are stored during the winter; and (3) measuring the increased regional income that would be generated by minor grains, animal and wood products, et al. No attempt was made to estimate the above benefits. Rather, it was felt that the best procedure was to point out that benefits are underestimated and indicate the areas where this is a serious problem.

There are a number of methods for performing the actual calculations. The most common is to compute the ratio of total discounted benefits to total discounted costs, i.e., b^o/c^o. Alternatively, one can compute the ratio of an increment in discounted costs to an increment in discounted benefits, i.e., $\Delta b^o/\Delta c^o$. However, it has been shown that these methods may be a misleading guide to investment choice. Projects with the highest cost-benefit ratio do not necessarily show the largest net benefit to the region. [5, p. 118]

Since we assumed the objective of the undertaking agency would be to maximize net benefits, we calculated the difference between the discounted value of benefits and costs, i.e., $v^o = b^o - c^o$. This is the simplest computational procedure and selects that project which will make the maximum contribution to the regional benefit account. Table 22 presents the calculated net present value for each extension alternative under each set of assumptions.

It is found that the magnitude of both benefits and costs is directly related to the length of the extension period and inversely related to the rate of interest. Further, it is seen that although the two week extension can be implemented rather cheaply, it does not generate the necessary transportation cost savings to justify itself. The four week extension shows the most consistent profit in the regional benefit account. It seems that a four week extension is the minimum necessary to generate significant transportation cost savings. The six week extension shows a positive profit account except under a ten year capital amortization scheme. The question that must be addressed is whether the increased costs for very long extensions justify the increment in benefits.

In addition to the direct benefits of an extended season, the indirect or external benefits, i.e., benefits not directly measured as reduced transport costs, should also be mentioned. For example, it is assumed that some competitive reductions in rail, truck and barge rates will

Table 22

STREAM OF DISCOUNTED COSTS AND BENEFITS 1968-1980
AND CALCULATIONS OF NET PRESENT VALUE

2 week		r = .05	r = .07	r = .08	Net Present Value
Benefits		$ 154,081,621	$ 136,634,484	$ 129,022,473	$
Costs	10 yrs.	214,215,479			(60,133,858)
	15	179,690,388			(25,608,767)
	25	131,443,663			22,637,958
	10		180,755,735		(44,121,251)
	15		142,851,525		(6,217,041)
	25		96,557,767		40,076,717
	10			166,380,436	(37,357,953)
	15			127,944,040	2,078,433
	25			83,981,389	45,041,084
4 week					
Benefits		291,352,441	259,582,155	245,095,989	
Costs	10 yrs.	287,666,930			3,685,511
	15	241,831,048			49,521,393
	25	177,777,175			113,575,266
	10		242,884,561		16,697,594
	15		192,562,523		67,019,632
	25		131,102,433		128,479,722
	10			223,641,656	21,454,333
	15			172,613,083	72,482,906
	25			114,247,795	130,848,194
6 week					
Benefits		359,556,128	320,169,546	302,961,626	
Costs	10 yrs.	412,161,911			(52,605,783)
	15	345,448,043			14,108,085
	25	252,219,450			107,336,678
	10		347,702,180		(27,532,634)
	15		274,458,738		45,710,808
	25		185,003,924		135,165,622
	10			320,010,028	(17,048,402)
	15			245,738,229	57,223,397
	25			160,787,882	142,173,744

Source: Tables 20, 21.

occur. Railroads, truckers, and barge operators did lower their rates in response to the opening of the Seaway. It is reasonable to assume that they might also lower rates if a season extension would divert significant amounts of cargo to the Seaway system.

A second externality that should be considered is the more efficient utilization of Seaway and port facilities made possible by longer operation. Some of these benefits will result in lower shipping costs and are measured as such. Others may not directly affect transportation charges. These would include the delaying of congestion induced expansion of Seaway and port facilities, a slight reduction of annual close down and start up costs, plus a reduction in the cost of having men, equipment, and facilities idled for one third of a year.

VI. CONCLUSION

In conclusion, it has been found that: (1) limited extensions of the Seaway season are technologically feasible; (2) the costs of such extensions are known; (3) the benefits generated by such extensions can be estimated to approximate the total real benefits of extending the season under different schemes; and (4) the longer, limited extensions are economically justified.

Selecting the actual type of season extension is much more difficult and the decision rests with the undertaking agency. It should be pointed out that a four week extension is the minimum necessary to generate significant transportation cost savings. The choice must consider, however, trade offs between technological feasibility and economic benefits, and between the regional net present value account and the increase in costs needed to generate any increment in benefits.

BIBLIOGRAPHY

1. D. Wm. Carr & Associates, Ltd., Review Report of EBSMC Study of Alternative Seaway Improvements. Submitted to the St. Lawrence Seaway Authority, May 30, 1969.

2. EBS Management Consultants, Inc., An Economic Analysis of Improvement Alternatives to the St. Lawrence Seaway System. Final Report submitted to U. S. Department of Transportation, January 1969.

3. ______, An Economic Analysis of Improvement Alternatives to the St. Lawrence Seaway System. Appendices to the Final Report submitted to U. S. Department of Transportation, January 1969.

4. Eckstein, Otto, Statements before Subcommittee on Economy in Government, Joint Economic Committee, Washington D. C., July 31, 1968.

5. Harrall, Clell G., Preparation and Appraisal of Transport Projects. Washington D. C.: Transport Research Program of the Brookings Institution, October 1965.

6. Prest, A. R. and R. Turvey, "Cost Benefit Analysis: A Survey." The Economic Journal, Vol. LXXV, No. 300, 1965.

7. Schenker, Eric and James Kochan, Extending the St. Lawrence Seaway Navigation Season: A Benefit-Cost Approach. Center for Great Lakes Studies, University of Wisconsin-Milwaukee, 1969.

8. _______, Preliminary Investigation--Extending the Shipping Season on the St. Lawrence Seaway. University of Wisconsin Sea Grant Program, Technical Report No. 2, Madison, Wisconsin, 1970.

9. _______, Overseas Shipping at Great Lakes Ports: Projections for the Future, Center for Great Lakes Studies, Special Report No. 10, University of Wisconsin-Milwaukee, 1970.

10. Schenker, Eric, The Port of Milwaukee: An Economic Review, University of Wisconsin Press, Madison, 1967.

11. Stanford Research Institute, Economic Analyses of St. Lawrence Seaway Cargo Movements and Forecasts of Future Cargo Tonnage. Prepared for the Under Secretary for Transportation, U. S. Department of Commerce, November 1965.

12. The St. Lawrence Seaway Authority and St. Lawrence Seaway Development Corporation, Traffic Report of the St. Lawrence Seaway: Ottawa, Canada, Queen's Printer, 1965-1969.

13. U. S. Army Corps of Engineers, Survey Report on Great Lakes and St. Lawrence Seaway Navigation Season Extension: Detroit District, December 1969.

14. U. S. Coast Guard, Report of the Technical Subgroup. Submitted to Department of Transportation St. Lawrence Seaway Task Force, November 1968.

15. U. S. Department of the Interior, Transportation of Iron Ore, Limestone and Bituminous Coal on the Great Lakes Waterway System. Bureau of Mines Information Circular 8461, 1970.

16. Water Resources Council, Procedures for Evaluation of Water and Related Land Resources Projects, Washington D. C., June 1969.