Case Study in Sensitivity of Highway Economy Factors

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Several plans have been considered as possible solutions to the increasing Shirley Highway traffic crossing the Potomac River, including a reversible express lane bridge, widening of two existing structures, and a new bridge on a removed location. The study reflects the advantages of building additional capacity for the peak hour, as well as maintaining the null condition for off-peak by considering the daily traffic under three operating conditions.

Considerable emphasis has been placed on an analysis testing the sensitivity of "vestcharge" rates, the value of time and traffic growth. The benefit-cost analysis is presented graphically, in addition to rate-of-return solutions illustrating the sensitivity of varying combinations of factors. Optimal decision maps are shown, with consideration given to varying rates of traffic growth providing depth to the cost picture that will aid in forming a reasonably sound engineering decision.

•THE RAPID growth of the area around the Nation's Capital has caused increased desire for better understanding of transportation needs. Those in responsible positions are continually being called upon to make decisions concerning large capital expenditures for major transportation projects. This is particularly true regarding river crossings. The investment, impact and future implication of a new bridge has always been a source of controversy. Such a bridge or bridges are presently being contemplated to relieve expected increases in traffic generated along the Shirley Highway corridor.

The Shirley Highway is not new to the student of highway engineering. The name is synonymous with studies in speed, capacity and fuel consumption. This classic roadway has now reached its life expectancy in terms of capacity. The Virginia Department of Highways has adopted a three-two-three reversible lane redesign of the Shirley Highway and has included the freeway in the Interstate system as I-95. However, there have been several suggestions concerning roadway configurations crossing the Potomac River. The study area in Figure 1 shows the relationship of the river crossing to the presently proposed Interstate Highway System in the Washington metropolitan area.

The number of alternate solutions proposed for crossing the Potomac River have been reduced to four possibilities:

Alternative 1, Do-nothing or null condition. The two-lane reversible express roadway in Virginia is terminated in the Hayes St. area before the interchange of the Shirley Highway and US 1. There are no changes considered to take place on either the northbound Rochambeau Bridge or the southbound George Mason Bridge. The approach roadways in the District of Columbia are also to remain as they presently exist (Fig. 2).

Alternative 2, Reversible express lane bridge. The two-lane reversible express roadway is extended in a northerly direction across the Potomac River on a separate structure, one lane split to 14th St. and one lane to the Washington Channel Bridge (Fig. 3). This is the same scheme presented in a consultant's report (5) to the Virginia Department of Highways.

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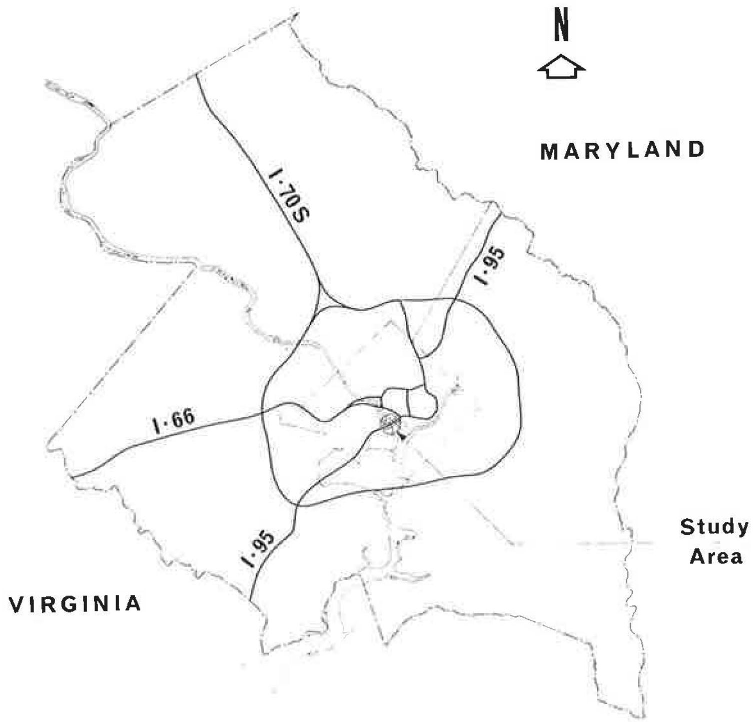

Figure 1. Study area in relation to proposed Interstate system for Washington metropolitan region.

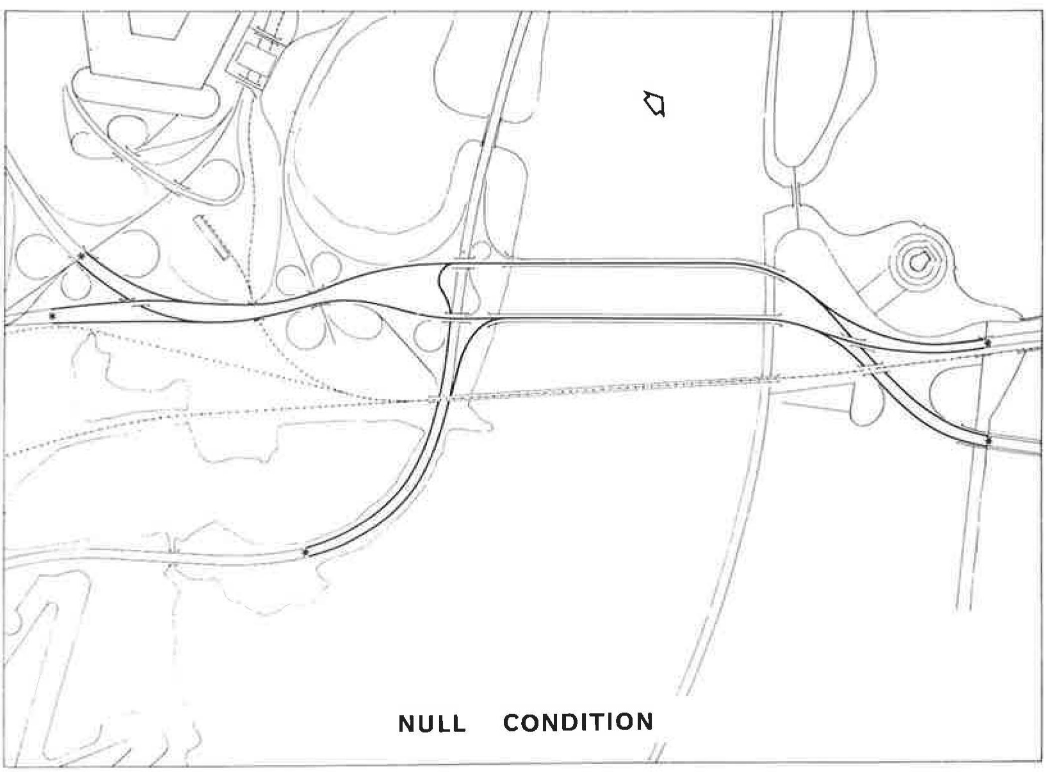

Figure 2. Alternative 1.

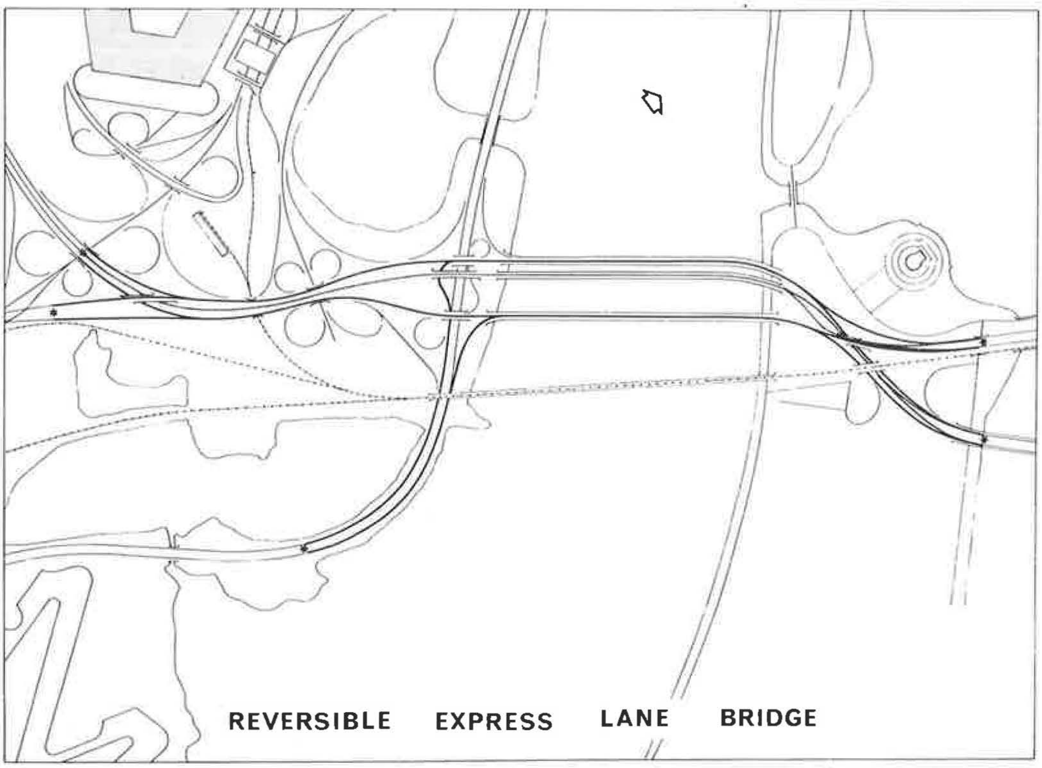

Figure 3. Alternative 2.

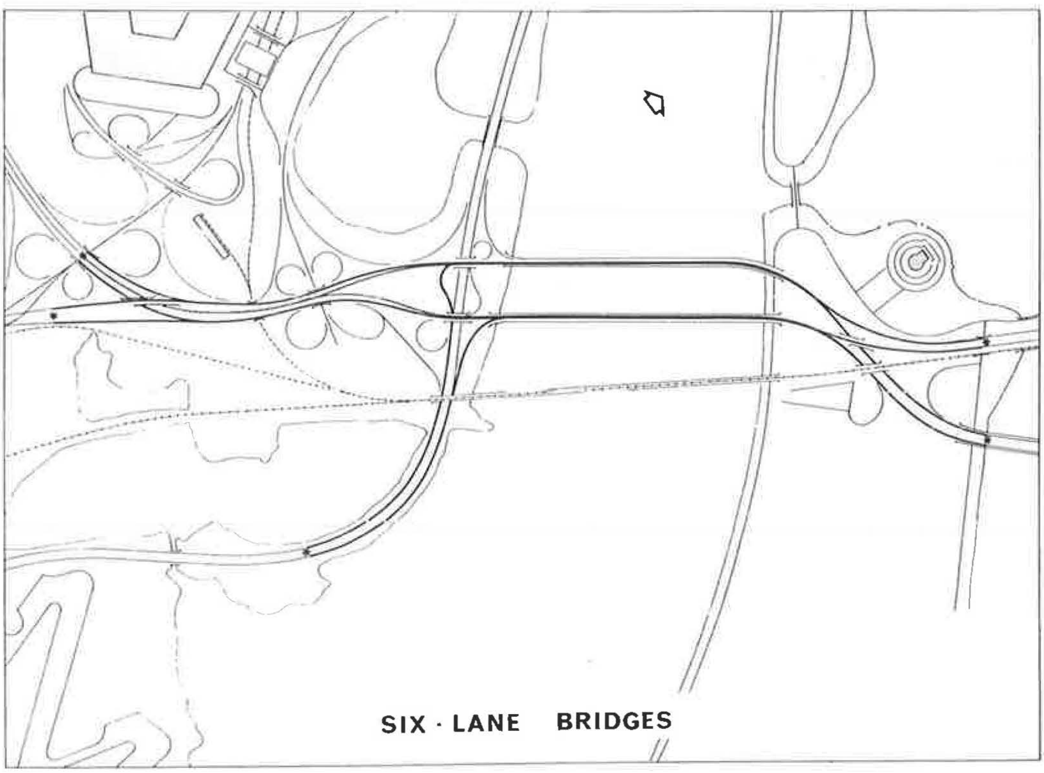

Figure 4. Alternative 3.

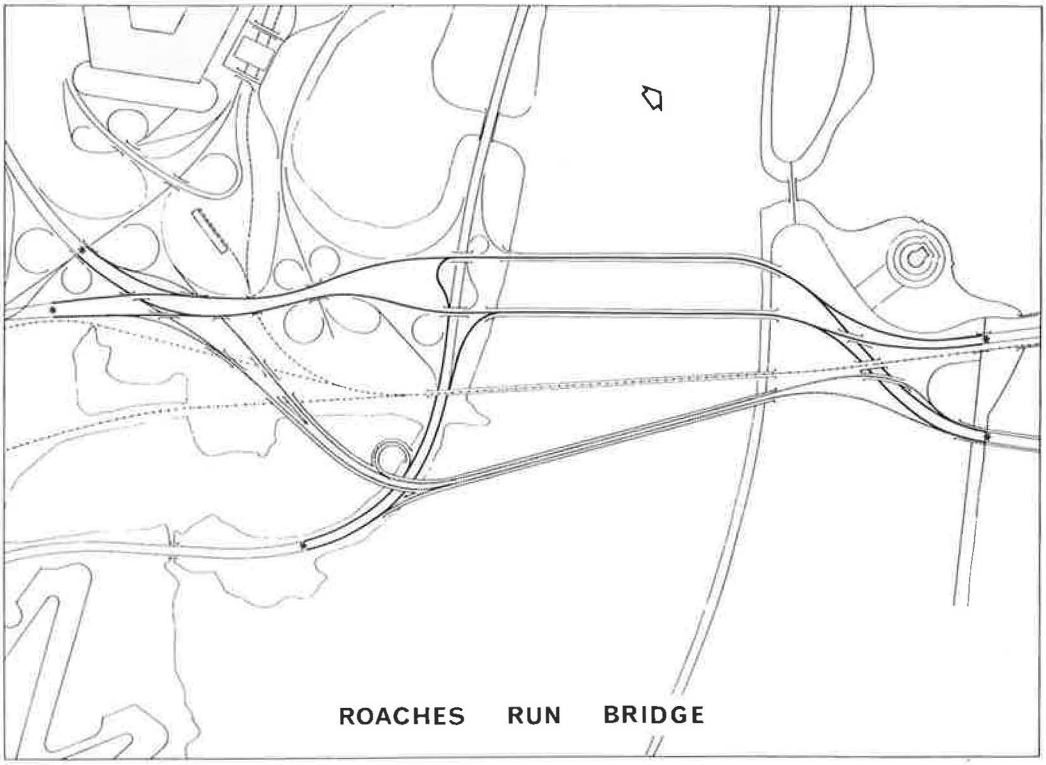

Figure 5. Alternative 4.

Alternative 3, Six-lane bridges. The reversible express lanes are carried in Virginia to the Potomac River where they divide connecting to both the Rochambeau and George Mason Bridges. The present structures and the approaches in the District of Columbia are to be widened from four to six lanes (Fig. 4).

Alternative 4, Roaches Run Bridge. A new four-lane bridge east of the Richmond, Fredricksburg and Potomac Railroad Bridge is connected to the Shirley Highway in the vicinity of the existing interchange with US 1. Connections are made with the Shirley Highway, the George Washington Parkway and one inbound ramp from US 1. A direct tie to the Washington Channel Bridge is coordinated with present connections in the District of Columbia (Fig. 5).

Since the choice of alternatives was clear and the limits of influence could be reasonably well defined, it was decided to make an economy study for the various river crossing proposals. The purpose of the study was twofold. One was to answer the project formulation question of which alternative should be recommended as the more economical solution of vehicular access across the river. The other, and perhaps more important, purpose was to determine the relative strengths and weaknesses of the recommendation. This could only be accomplished by testing the sensitivity of the variables involved in the problem. The study considered these three questions:

1. What is the minimum attractive rate of return for this type of investment, considering no direct monetary return will be realized?
2. What is the value of time?
3. What is the probable value of traffic volumes that will utilize these facilities?

TABLE 1

CAPITAL COSTS FOR VARIOUS ALTERNATIVES CROSSING POTOMAC RIVER (× $1,000)

Alternative	Virginia Approach	Potomac River Crossing	D. C. Approach	Total
1	0	0	0	0
2	1,890	3,936	350	6,176
3	2,390	7,029	100	9,519
4	6,766	9,586	750	17,102

HIGHWAY COSTS

Capital Costs

Estimates of cost were developed for each alternative by the respective highway departments. The capital investment necessary to build each bridge and its approach roadways is given in Table 1. The annual capital cost for each scheme given in Table 2 was calculated using a selected number of vestcharge[1] rates for an analysis period of 20 yr. No salvage value was assumed for any alternative (2).

Maintenance Cost

Maintenance costs were recognized as being those necessary to housekeep each facility. Typical items may include roadway and structure repair, snow removal, landscape and drainage maintenance, painting, lighting and necessary law enforcement. At this point it was assumed that all alternatives will incur the same annual maintenance costs.

TRAFFIC MAINTENANCE COSTS

During the period of construction, another charge may arise. In this study it is referred to as the traffic maintenance cost and can be separated into two categories, capital and operational. The capital costs are those borne by the contractor necessary to maintain traffic. Examples may be temporary roadways, drainage structures, signs and signalmen. These are assumed to be included in the capital costs and will not be discussed further. Operational traffic maintenance costs are those incurred by existing vehicles during the period of construction. They involve items of additional expense due to slowdowns, stops, detours and operating over temporary roadways. Time costs, as well as operating costs, are included in this category. In this problem, for example, Alternative 3 will probably accrue more of these costs than Alternative 4 because the plan calls for widening existing bridges which will disrupt the present traffic flow during construction. The bridge in Alternative 4 is on a new location. These costs are presently considered equal for each scheme and will not be further discussed until the conclusion.

TRAFFIC

Forecast of Growth

The traffic volumes assigned to the various alternatives were for the year 1980. The derivation of numbers was a result of trip generation by regression analysis. The basic forecast figures such as population, employment, retail sales and school acreage

[1] Vestcharge is a word coined by Robley Winfrey, U.S. Bureau of Public Roads, meaning the charge for the use of money invested in physical assets; it is in lieu of return on invested capital wherein operational money returns are received from business ventures, but the concept of vestcharge assumes that there is no direct money return. Rate of vestcharge is used in the same sense as rate of interest or rate of return.

TABLE 2

ANNUAL CAPITAL COSTS FOR VARIOUS VESTCHARGE RATES AND ALTERNATIVES
n = 20 years (x $1,000)

Alternative & Capital Cost	Vestcharge Rate				
	1%	6%	10%	15%	20%
1 - Do nothing or null condition $0	0	0	0	0	0
2 - Reversible express lane bridge $6,176,000	$ 342	$ 538	$ 725	$ 987	$1,268
3 - Six-lane bridges $9,519,000	528	830	1,118	1,521	1,955
4 - Roaches Run Bridge $17,102,000	948	1,491	2,009	2,732	3,512

were obtained from various planning agencies throughout the Washington metropolitan area. Trip distribution was made by the gravity model and assigned to the highway network by a minimum time path algorithm (7). Since the assigned volumes were for 1980, it was necessary to know something about the increase of traffic during the study period. Two methods were used to obtain the growth factor for the period 1960 to 1980 and are shown by the following equations:

Vehicle trip growth factor (1960-1980) =

$$\frac{\text{1980 zone population}}{\text{1960 zone population}} \times \frac{\dfrac{\text{1980 area vehicle registrations}}{\text{1980 area population}}}{\dfrac{\text{1960 area vehicle registrations}}{\text{1960 area population}}} \times \frac{\dfrac{\text{1980 region fuel consumption}}{\text{1980 region vehicle registrations}}}{\dfrac{\text{1960 region fuel consumption}}{\text{1960 region vehicle registrations}}} \qquad (1)$$

Minimum vehicle trip growth factor = 1.38 x 1.29 x 1.00 = 1.78

Maximum vehicle trip growth factor = 1.53 x 1.38 x 1.05 = 2.20

Average vehicle trip growth factor = 2.00

Vehicle trip growth factor (1959-1980) =

$$\frac{\text{1980 Potomac River vehicle crossings}}{\text{1959 Potomac River vehicle crossings}} = \frac{578{,}000}{264{,}000} = 2.19 \qquad (2)$$

Assuming a straight-line growth, the first method provides for a yearly increase of 5.0 percent of the 1960 volume and the second method yields 5.7 percent. Initially, it was concluded that 5.0 percent on a linear basis would be satisfactory for estimating purposes.

Equivalent Annual Traffic

To evaluate trip growth properly during the study period, the following formula (4) was used to find the equivalent annual traffic:

$$E.A.T. = a + b + \frac{b}{i} - \frac{nb}{i}(crf - i) \quad (3)$$

where

a = present or initial trips,
b = average trip increase per year,
i = interest or vestcharge rate,
crf = capital recovery factor, and
n = study period in years.

Table 3 gives the relationship between 1960, 1980 and the equivalent annual traffic volumes for selected rates of vestcharge by assuming that a = 1 = 1960 traffic volume, b = 0.05, and N = 20 yr.

If traffic grows exponentially rather than linearly, it could be assumed that the volumes compound at a rate approximately equal to 3½ percent per year. This would result in the same volume of 1980 traffic as the 5 percent linear growth. The resultant change in Table 3 would reduce all factors by less than 5 percent. However, it is the differences in alternatives that are meaningful and little change in the final recommendation would result by using an exponential growth.

Trip Distribution

Since the same basic traffic was used in each alternative, it was felt that the study should show the benefit of building extra bridges for peak volumes as well as that of not building additional capacity for off-peak trips. Several distribution curves plotted for the existing Potomac River bridges had generally standard shapes. Figure 6 was plotted from data gathered during the first 10 mo of 1963. The "best curve" showed that 9.2 percent of the traffic occurred in the peak hour. It also showed less than 1 percent occurred in the 24th hour. Judging by the general shape of the distribution curve, the following breakdown of time was used:

High 4 hr = 34.5 percent,
Next 8 hr = 42.5 percent, and
Low 12 hr = 23.0 percent.

In terms of 1980 Potomac River crossings, this would mean that 13,989 veh/hr cross in the highest 4 hr. Likewise, 9,232 and 3,331 veh/hr cross in the next 8 and lowest 12 hr, respectively, for a total of 173,784 veh/day.

Each alternative was broken into the three study periods reflecting different operating conditions. Each roadway section volume was converted to a per lane basis and a

TABLE 3

EQUIVALENT ANNUAL TRAFFIC FACTORS IN TERMS OF 1960 AND 1980 VOLUMES FOR LINEAR TRIP INCREASE OF 5 PERCENT OF 1960 TRAFFIC PER YEAR

Vestcharge Rate	1960 Traffic	1980 Traffic
1	1.508	0.754
6	1.430	0.715
10	1.375	0.688
15	1.318	0.659
20	1.273	0.637

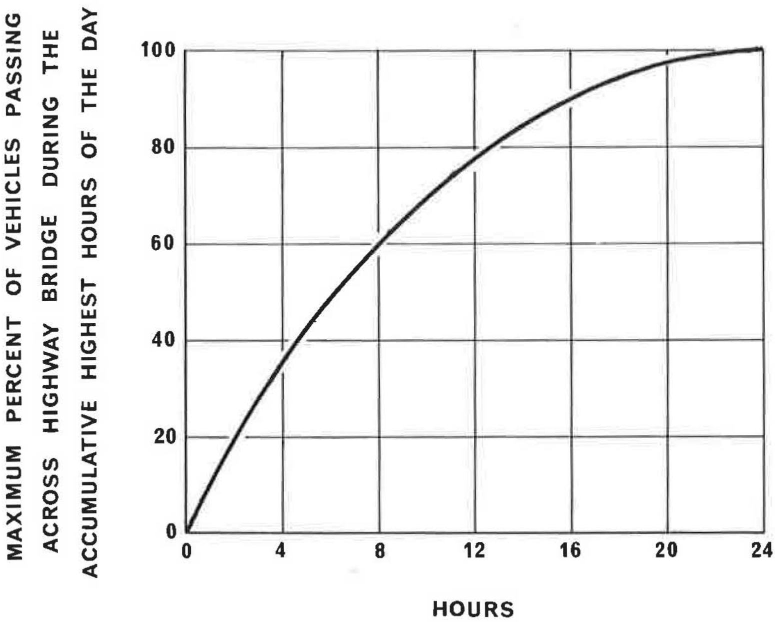

Figure 6. Maximum percent of vehicles passing across highway bridge during accumulative highest hours of day.

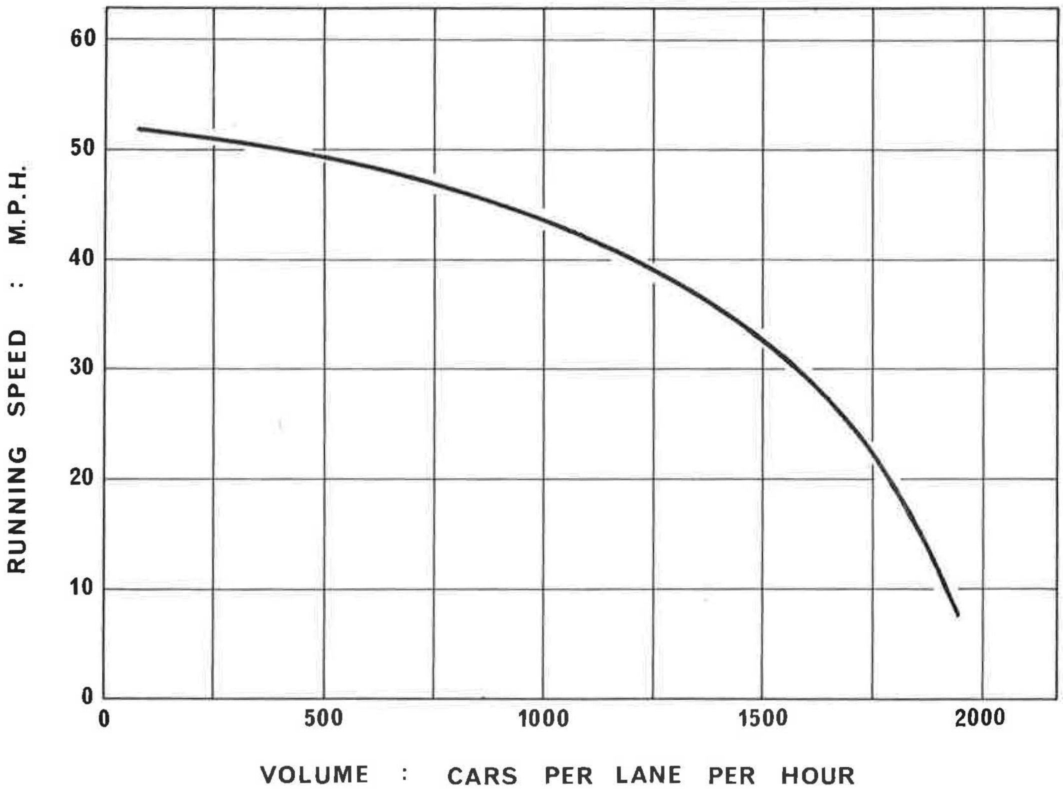

Figure 7. Roadway capacity.

corresponding speed was assigned according to Figure 7. Constrictions in lane design were examined in obtaining operating conditions. For example, if a roadway contained three lanes for the majority of its length but necked down at the outbound end to two lanes because of a ramp connection, two lanes were considered to be the capacity of that section. In general, this had its greatest effect on traffic operation during the high 4-hr period, causing some trips to divert to optional routing.

In the case of alternatives utilizing express lanes, the reversible roadway was assumed closed for 2 hr each day, one during the 8-hr period and one during the low 12-hr period.

Commercial Traffic

Trucks and buses were considered in the problem and again the peak condition reflected a different situation than the off-peak. Table 4 reveals that approximately 13 percent of the traffic using the Shirley Highway between Glebe Rd and the Pentagon network was commercial. However, only 7 percent occurred during the peak hour. The following breakdown of commercial traffic was used in the problem:

High 4 hr = 7 percent,
Next 8 hr = 14 percent, and
Low 12 hr = 20 percent.

In all cases, no trucks were assigned to the George Washington Memorial Parkway or its connecting ramps.

So that unit automobile operating costs could be used in this problem, a truck-car cost relationship was established. A ratio was developed based on the operating costs of trucks and automobiles at different speeds. The resultant curve is shown in Figure 8. This should not be confused with truck-car ratios concerning space or headway requirements.

ROAD-USER COSTS

Unit operating costs (8) were assumed for passenger cars and specifically refer to gasoline, oil, tires, maintenance and depreciation attributable to mileage for composite 1 percent grades. Unit accident costs (3) for this study were assumed to have a direct relationship to operating speed. Both curves are shown by Figure 9 and reveal that the most economical operating speed occurs between 35 and 40 mph. It was felt that all

TABLE 4

COMMERCIAL TRAFFIC ON SHIRLEY HIGHWAY BETWEEN GLEBE ROAD (Va. Rt. 120) AND PENTAGON NETWORK[a]

Year	Percent
1955	12
1956	13
1957	--
1958	10
1959	13
1960	13
1961	12
1962	13

[a]Calculated from: Commonwealth of Virginia Department of Highways, Average Daily Traffic Volumes on Interstate and Rural Primary Routes.

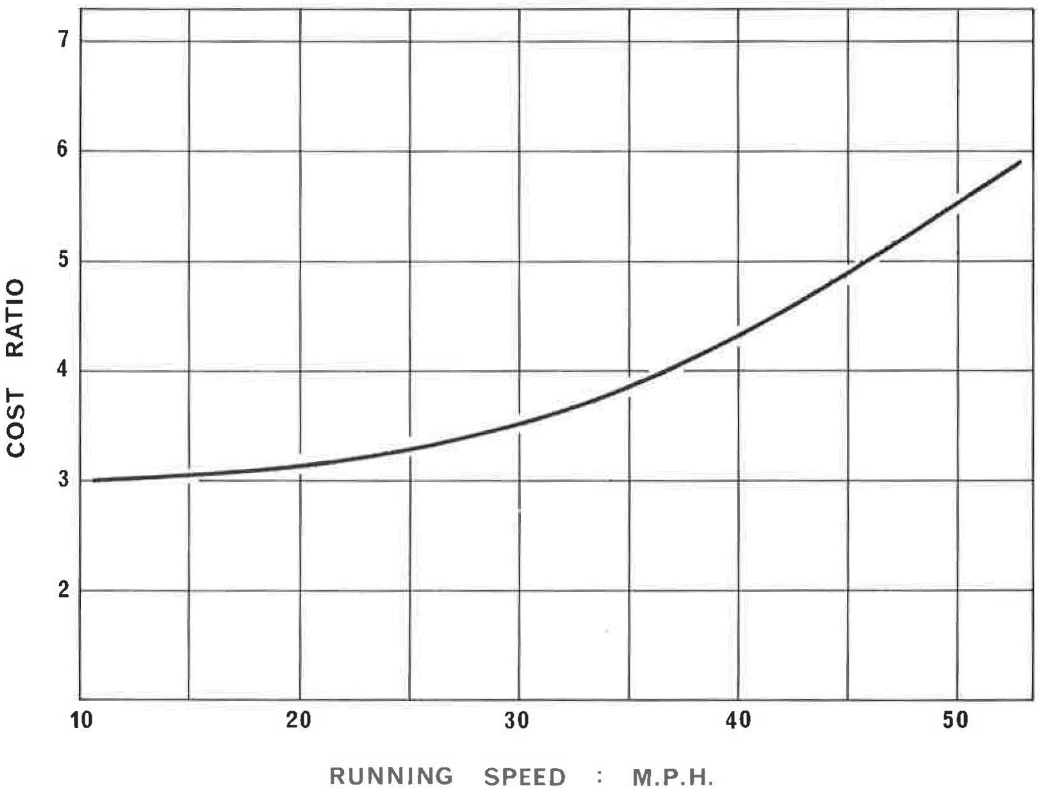

Figure 8. Truck-car cost ratio for divided highways with grades averaging flatter than 2 percent.

alternatives exhibited generally the same grades, curvature and potential accident hazards and, therefore, no detailed breakdown of operating and accident costs was used. The 1980 annual operating and accident costs for the four alternatives are given in Table 5.

The value of time and the appropriate vestcharge rate are two rather elusive but very important factors in determining the proper selection of alternatives. Utilizing the factors developed in Table 3 for the selected vestcharge rates and the four values of time, the equivalent annual vehicular cost for each alternative was computed (Table 6).

ECONOMIC ANALYSIS

The benefit-cost ratio method of analysis was initially employed in the study through use of the following equation:

$$\text{B. C. R.} = \frac{(Ub - Up) - (Dp - Db)}{Iap - Iab} \tag{4}$$

where

Ub = base user costs,
Up = proposed user costs,
Db = base maintenance costs,
Dp = proposed maintenance costs,
Iab = base annual capital costs, and
Iap = proposed annual capital costs.

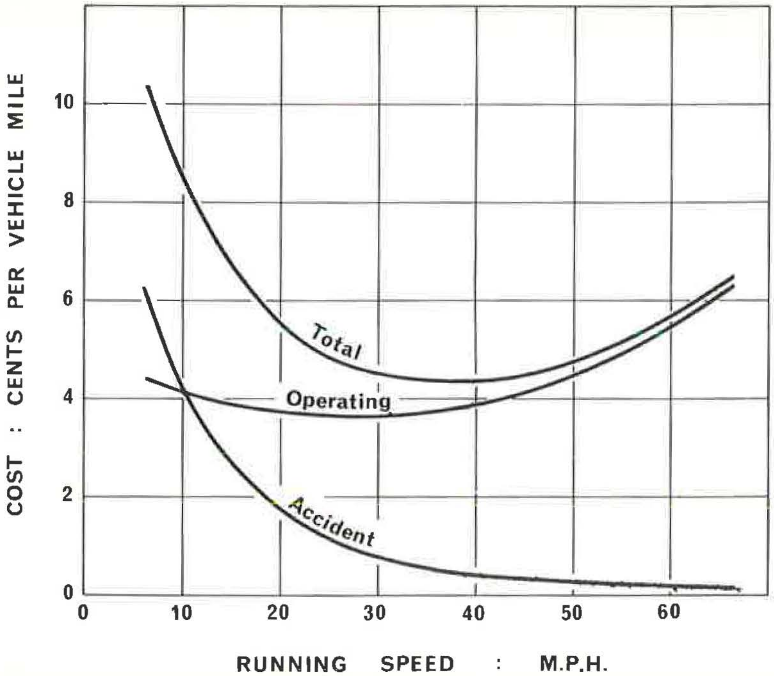

Figure 9. Automobile operating and accident costs.

Table 7 shows the benefit-cost ratios for the various alternatives compared to the null condition utilizing different rates of vestcharge and values of time. If the ratios are plotted graphically and the value of 1.0 is interpolated for each condition, a series of curves will result (Fig. 10). Analyzing each curve separately or comparing the proposed facility against the existing condition shows that it would be unacceptable to recommend any scheme for combinations of values that fall beneath the curve. If any combination of values converge above the curve, it would mean that the proposed facility has benefits in excess of the capital investment and might be recommended. Judging by the more or less acceptable ranges of time values and vestcharge rates, only Alternative 4 does not appear in a favorable position. Alternative 2 exhibits higher ratios than Alternative 3 for any combination of values and, therefore, should be the choice solution. However, since Alternative 3 does show favorably, it was decided to see if the additional investment of $3,343,000 ($9,519,000 - $6,176,000) provides any benefits over Alternative 2. Table 8 shows the benefit-cost ratios for Alternatives 3 and 4 compared to the new base condition of Alternative 2. These values are plotted in Figure 11 and reveal that neither the six-lane bridges or the Roaches Run Bridge is acceptable.

TABLE 5

1980 ANNUAL OPERATING AND ACCIDENT COSTS (x $1,000)

Alternative	Annual Operating Cost	Annual Accident Cost	Total Annual Operating & Accident Cost
Alternative 1			
High 4 hours	$1,364	$ 676	$2,040
Next 8 hours	2,260	212	2,473
Low 12 hours	1,705	107	1,812
Total	$5,329	$ 995	$6,324
Alternative 2			
High 4 hours	$1,389	$ 280	$1,668
Next 8 hours	2,346	210	2,556
Low 12 hours	1,719	106	1,825
Total	$5,454	$ 596	$6,050
Alternative 3			
High 4 hours	$1,413	$ 215	$1,628
Next 8 hours	2,411	192	2,603
Low 12 hours	1,719	105	1,824
Total	$5,543	$ 513	$6,056
Alternative 4			
High 4 hours	$1,462	$ 243	$1,705
Next 8 hours	2,442	196	2,638
Low 12 hours	1,729	106	1,835
Total	$5,633	$ 545	$6,179

TABLE 6

EQUIVALENT ANNUAL VEHICULAR COSTS FOR SELECTED VESTCHARGE RATES AND VALUES OF TIME FOR THE PERIOD 1960 TO 1980 (x $1,000)
(Growth Rate = 5 Percent of 1960 Traffic per Year)

Values of Time in Dollars per Passenger Car Hour	1980 Annual Cost	Equivalent		Annual		Cost
		i = 1%	i = 6%	i = 10%	i - 15%	i = 20%
Alternative 1						
Time = $0.00	$ 6,324	$ 4,768	$ 4,522	$ 4,349	$ 4,168	$ 4,026
= 0.50	8,302	6,260	5,936	5,710	5,472	5,285
= 1.55	12,456	9,392	8,906	8,566	8,210	7,930
= 3.00	18,219	13,737	13,027	12,529	12,008	11,598
Alternative 2						
Time = $0.00	$ 6,050	$ 4,561	$ 4,326	$ 4,160	$ 3,987	$ 3,851
= 0.50	7,677	5,789	5,489	5,280	5,060	4,887
= 1.55	11,093	8,364	7,931	7,628	7,311	7,062
= 3.00	15,812	11,923	11,306	10,874	10,422	10,066
Alternative 3						
Time = $0.00	$ 6,056	$ 4,566	$ 4,330	$ 4,165	$ 3,991	$ 3,855
= 0.50	7,562	5,701	5,407	5,200	4,984	4,814
= 1.55	10,824	8,161	7,739	7,443	7,134	6,890
= 3.00	15,285	11,525	10,929	10,512	10,074	9,731
Alternative 4						
Time = $0.00	$ 6,179	$ 4,659	$ 4,418	$ 4,249	$ 4,072	$ 3,933
= 0.50	7,756	5,848	5,545	5,333	5,112	4,937
= 1.55	11,067	8,345	7,913	7,611	7,295	7,046
= 3.00	15,643	11,795	11,184	10,757	10,310	9,958

At this point it should be sufficient considering the data and results to recommend Alternative 2, the reversible express lane bridge. However, it was decided to test the sensitivity of a change in the growth of traffic volumes. This was done by assuming rates of growth for the study period different than the first assumption of 5 percent. The two alternate growths chosen were 4 and 6 percent. This would indicate a ± 20 percent difference in 1980 traffic volumes.

The manner in which this was accomplished was approximate and does not reflect true operational characteristics for the different volumes. Instead of reevaluating actual volumes, speeds, truck-car ratios and costs, a relationship of the different rates of growth was established by substituting appropriate values into Eq. 3. The results are shown by Table 9.

TABLE 7

BENEFIT-COST RATIO OF VARIOUS ALTERNATE SOLUTIONS COMPARED TO ALTERNATIVE 1

Values of time in Dollars per Passenger Car Hour	Vestcharge			Rate	
	1%	6%	10%	15%	20%
Alternative 2					
Time = $0.00	0.60	0.36	0.26	0.18	0.14
= 0.50	1.38	0.83	0.59	0.42	0.31
= 1.55	3.00	1.81	1.29	0.91	0.68
= 3.00	5.29	3.20	2.28	1.61	1.21
Alternative 3					
Time = $0.00	0.38	0.23	0.17	0.12	0.09
= 0.50	1.06	0.64	0.46	0.32	0.24
= 1.55	2.33	1.41	1.00	0.71	0.53
= 3.00	4.19	2.53	1.80	1.27	0.96
Alternative 4					
Time = $0.00	0.12	0.07	0.05	0.04	0.03
= 0.50	0.44	0.26	0.19	0.13	0.10
= 1.55	1.10	0.67	0.48	0.34	0.25
= 3.00	2.05	1.24	0.88	0.62	0.47

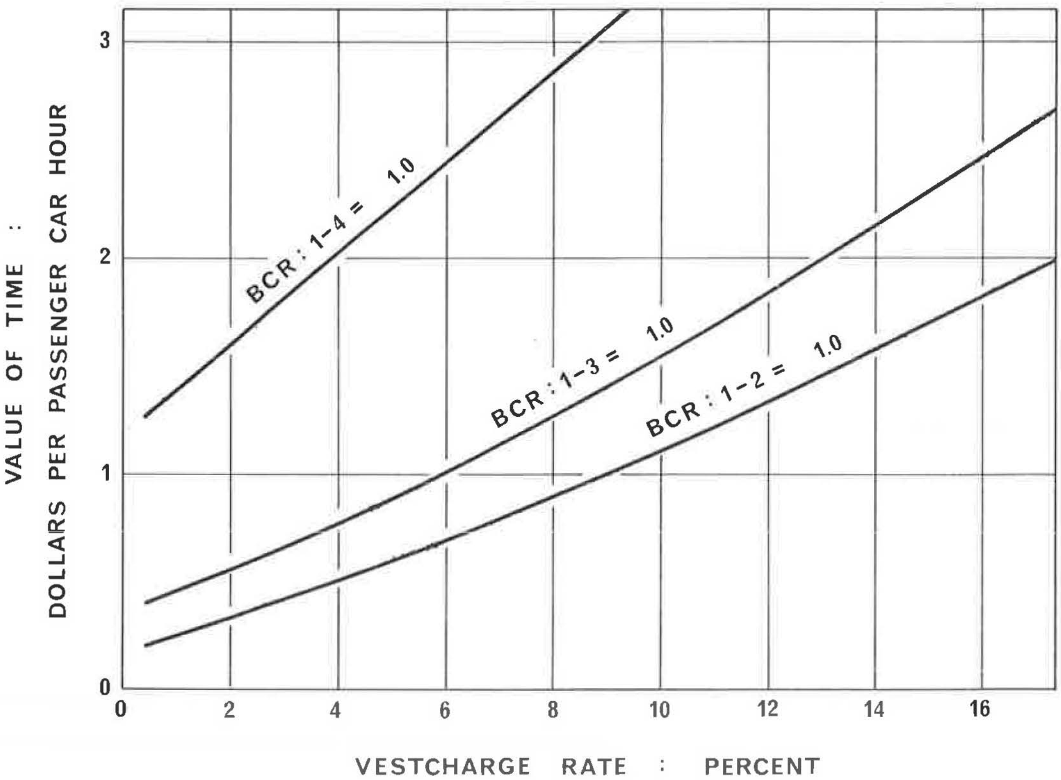

Figure 10. Benefit-cost ratio, base condition = Alternative 1.

The rate-of-return method of analysis was employed for this part of the study utilizing the following equation:

$$[(Ip - Ib) - (pwf' - i - n)(Sp - Sb)](crf - i - n) = (Ub - Up) - (Dp - Db) \quad (5)$$

TABLE 8

INCREMENTAL ANALYSIS, BENEFIT COST RATIO OF VARIOUS ALTERNATE SOLUTIONS COMPARED TO ALTERNATIVE 2

Values of Time in Dollars per Passenger Car Hour	Vestcharge Rate 1%	6%	10%	15%	20%
Alternative 3					
Time = $0.00	-	-	-	-	-
= 0.50	0.47	-	-	-	-
= 1.55	1.09	0.66	0.47	-	-
= 3.00	2.15	1.30	0.92	0.65	-
Alternative 4					
Time = $0.00	-	-	-	-	-
= 0.50	-	-	-	-	-
= 1.55	0.03	-	-	-	-
= 3.00	0.21	0.13	-	-	-

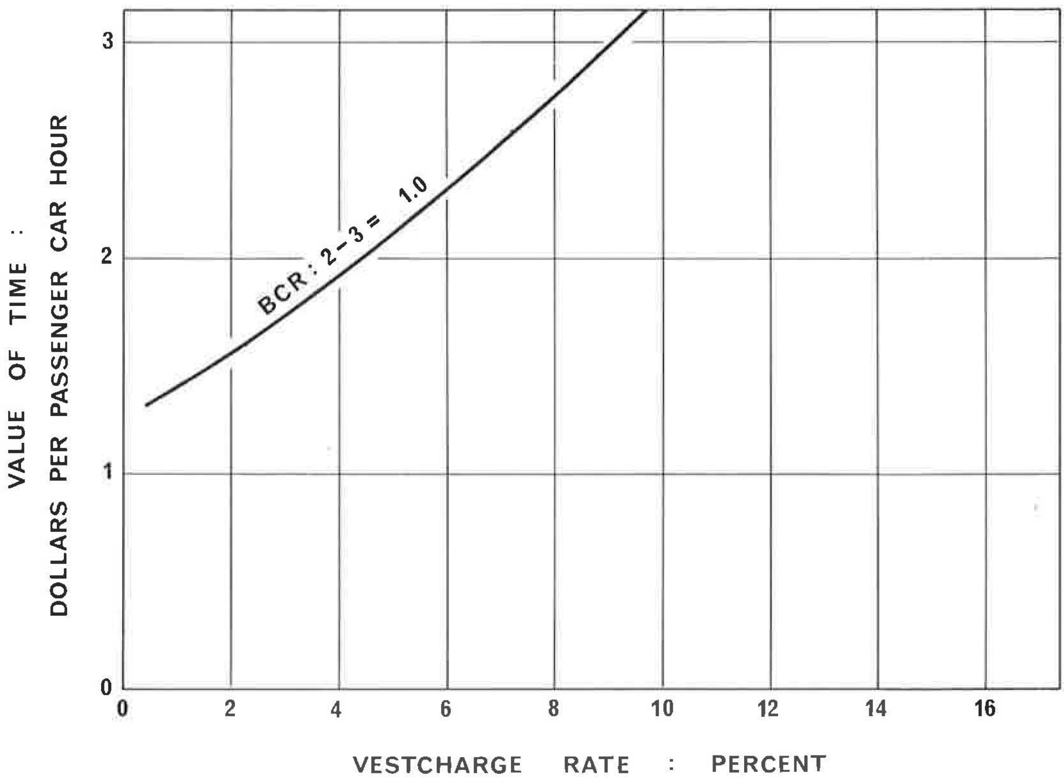

Figure 11. Benefit-cost ratio, base condition = Alternative 2.

where

Sb = base salvage value,
Sp = proposed salvage value,
Ib = base capital costs, and
Ip = proposed capital costs.

The results of the calculations given in Table 10 revealed that in each case Alternative 2 exhibited the higher rates of return over the base condition of Alternative 1. An

TABLE 9

EQUIVALENT ANNUAL TRAFFIC FOR VARIOUS LINEAR GROWTH RATES IN TERMS OF 1960 VOLUMES

Vestcharge Rate	Linear Traffic Growth per Year		
	4%	5%	6%
1%	1.406	1.508	1.610
6%	1.344	1.403	1.516
10%	1.300	1.375	1.451
15%	1.255	1.318	1.382
20%	1.219	1.273	1.328

TABLE 10

RATE OF RETURN OF VARIOUS POTOMAC RIVER CROSSING ALTERNATIVES COMPARED TO ALTERNATIVE 1

Value of Time in Dollars per Passenger Car Hour	Alternative 2 Reversible Express Lane Bridge	Alternative 3 Six-Lane Bridges	Alternative 4 Roaches Run Bridge
Traffic Growth: 4%			
Time = $0.00	less than 1%	less than 1%	less than 1%
= 0.50	3.25%	less than 1%	less than 1%
= 1.55	12.75%	9.29%	1.24%
= 3.00	20+%	17.27%	7.67%
Traffic Growth: 5%			
Time = $0.00	less than 1%	less than 1%	less than 1%
= 0.50	3.93%	1.47%	less than 1%
= 1.55	13.53%	10.28%	1.84%
= 3.00	20+%	19.13%	8.39%
Traffic Growth: 6%			
Time = $0.00	less than 1%	less than 1%	less than 1%
= 0.50	4.57%	2.03%	less than 1%
= 1.55	14.29%	10.72%	2.40%
= 3.00	20+%	19.94%	9.07%

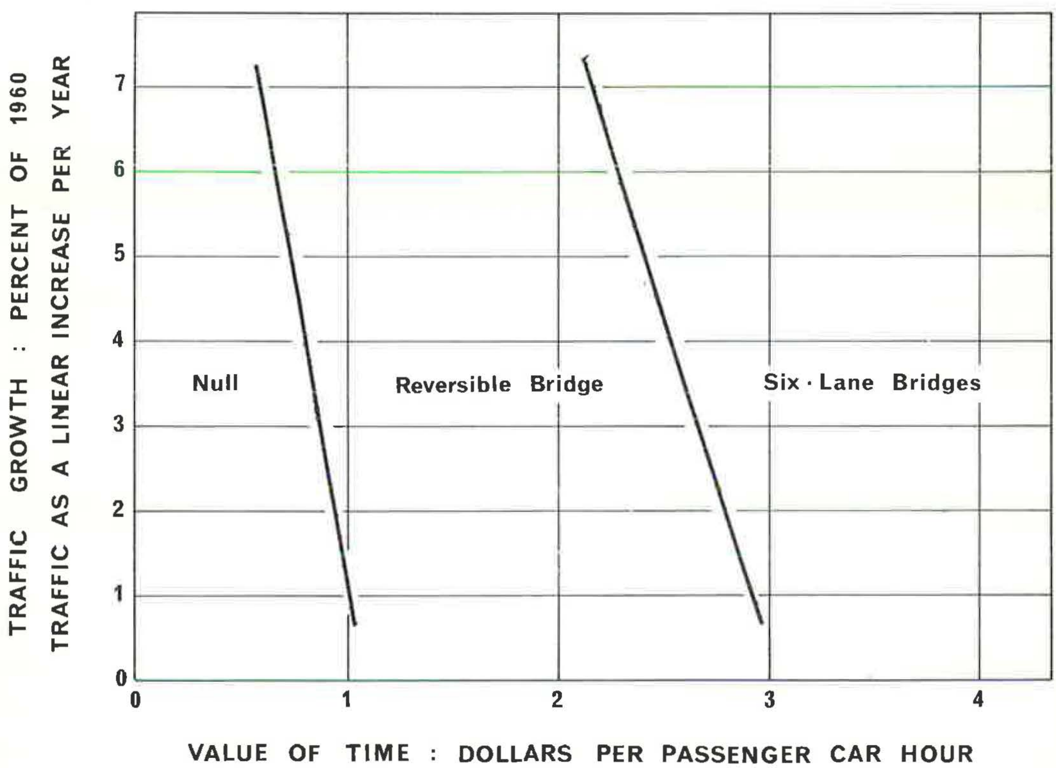

Figure 12. Optimal decision map, minimum attractive rate of return = 6 percent.

incremental analysis comparing Alternatives 3 and 4 to Alternative 2 showed merit in their consideration for certain values of time, vestcharge rate and traffic volumes. The problem of limiting values for the choice of Alternative 2 prompted the following questions:

1. If the minimum attractive rate of return is known, at what minimum value of time would Alternative 3 still be acceptable over Alternative 2?
2. If the minimum attractive rate of return is known, at what maximum value of time would Alternative 1 still be acceptable over Alternative 2?

The answers to these questions were readily available through interpolation of the incremental analysis. Assuming two separate and acceptable values for the minimum attractive rate of return (1), optimal decision maps (6) were plotted (Figs. 12 and 13), revealing that the choice of Alternative 2 still remains valid for generally accepted values of time and limits of probable traffic volumes.

CONCLUSIONS

The information contained in the figures of this study presents many interesting results. For example, the lowest annual operating costs were achieved by the null condition. This was primarily due to a lower operating speed which, according to the figures used, optimized around 25 mph. However, it should be remembered that the low speeds are probably in the stop-and-start category and, therefore, the costs are probably unjustifiably low. Of the other three more comparable alternatives, Table 5 reveals that the reversible express lane bridge offers approximately the same operating cost conditions as those of the two six-lane bridges.

An examination was made of vehicle-hours. This could possibly be interpreted as an indication of service level. Table 11 compares time for each alternative by study

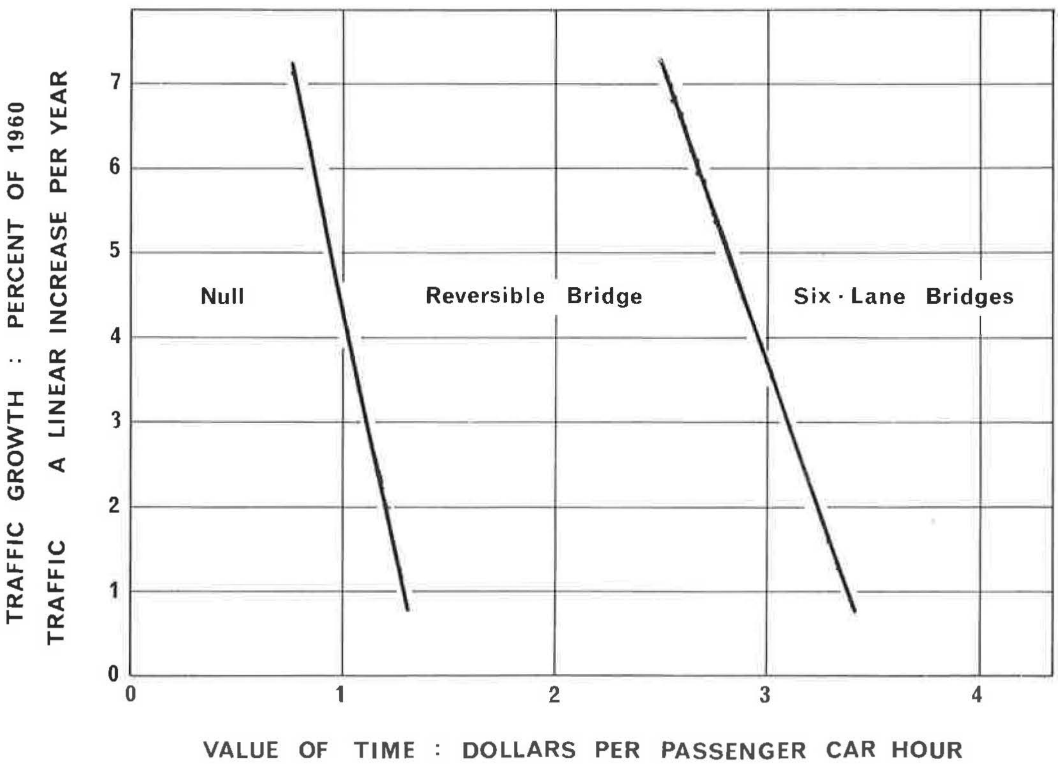

Figure 13. Optimal decision map, minimum attractive rate of return = 8 percent.

TABLE 11

1980 DAILY VEHICLE-HOURS

Alternative	Daily Vehicle Hours	Relative Service Level by Percent
Alternative 1		
High 4 hours	5,609	57
Next 8 hours	4,083	95
Low 12 hours	2,300	99
Total	11,992	78
Alternative 2		
High 4 hours	3,544	90
Next 8 hours	4,032	95
Low 12 hours	2,285	100
Total	9,861	95
Alternative 3		
High 4 hours	3,195	100
Next 8 hours	3,859	100
Low 12 hours	2,278	100
Total	9,332	100
Alternative 4		
High 4 hours	3,372	95
Next 8 hours	3,908	99
Low 12 hours	2,281	100
Total	9,561	98

period. The dark hours showed no particular advantage to any scheme in terms of service level. Alternative 3 proved to be the better choice during the daylight hours with Alternative 4 a close second.

In summary, high capital investment is probably the chief reason why Alternative 3 is rejected. This study, as is usually the case, showed that low vestcharge rates tend to benefit high capital investment. The better service in terms of vehicle-hours offered by the two six-lane bridges was not great enough to override the initial cost differential with Alternative 2. The Roaches Run Bridge showed no significant benefit attached to any feature studied. High capital costs coupled with high operating costs eliminates this alternative. Since Alternative 2 is the apparent best recommendation, the questions of maintenance and traffic operational maintenance costs previously discussed are now relatively easy to answer. In both cases, the preferred alternative exhibits the least costs and thereby lends weight to the decision. The selection of the reversible bridge alternative can be attributed to two factors: low capital investment and low operating costs directly related to the efficient express lanes carried across the Potomac River and into the District of Columbia.

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