

## APPENDIX 3

### NOTES ON BINARY ARITHMETIC

Whereas decimal numbers (base ten) are made up of ten digits (0 through 9) binary numbers (base two) are made up of only two digits (0 and 1). In decimal numbers the positions of the digits have place significance. The number 549, for instance, represents

$$5 \times 10^2 + 4 \times 10^1 + 9 \times 10^0$$

Likewise in binary numbers the digits have place significance. In this case, however, the multiplier is a power of two rather than a power of ten. The binary number 11010 represents

$$1 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 12^1 + 0 \times 2^0$$

In case of decimal numbers, digits to the right of the decimal point are multiplied by appropriate negative powers of ten. Similarly, in binary numbers digits to the right of the binary point are multiplied by appropriate negative powers of two.

When the digits of a decimal number are

shifted one place to the left the number is multiplied by ten (the base of the decimal system). When the digits of a binary number are shifted one place to the left the number is multiplied by two (the base of the binary system).

Addition in binary notation becomes very simple. The complete list of combinations is as follows:

$$\begin{aligned} 0 + 0 &= 00 \\ 0 + 1 &= 01 \\ 1 + 1 &= 10 \end{aligned}$$

An overflow in one position (as in  $1 + 1 = 10$ ) is carried to the next position to the left and added in the appropriate manner.

Equally simple rules may be written for multiplication, division, square root, etc. Many automatic computers are designed to operate in the binary system because of the resulting simplicity of equipment design.

## Allocation of Traffic to the Hampton Roads Bridge-and-Tunnel System

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● IN December 1953 the Virginia Highway Department gave us the interesting and important assignment of estimating traffic and revenues for the proposed Hampton Roads Bridge and Tunnel System and the James River Bridge System, assuming removal of the Newport News-Pine Beach and the Old Point-Willoughby Ferries. The studies formed the basis for the refinancing of the existing bridges and the financing of the proposed new facility through the issuance of \$95,000,000 of revenue bonds.<sup>1</sup>

Figure 1 shows the location of the present and proposed toll facilities in relation to major highways in southeast Virginia.

<sup>1</sup> The financing of the Rappahannock River Bridge and the refinancing of the York River Bridge was also included in this bond issue.

When the proposed Bridge and Tunnel System is completed, traffic from the peninsula will cross Hampton Roads on either the Bridge and Tunnel System or the James River Bridge System. Motorists presently have a choice of three facilities.

It is quite obvious that with such a drastic change in alternate routes, a detailed analysis would be necessary to determine how this change would affect the motorists' selection of future routes of travel.

It was decided to make a complete study of all major factors influencing a motorist's selection of his present routes of travel. Origin-destination surveys were conducted by the Virginia Department of Highways in conjunction with the consultants at five locations, namely the James River Bridge, the Newport

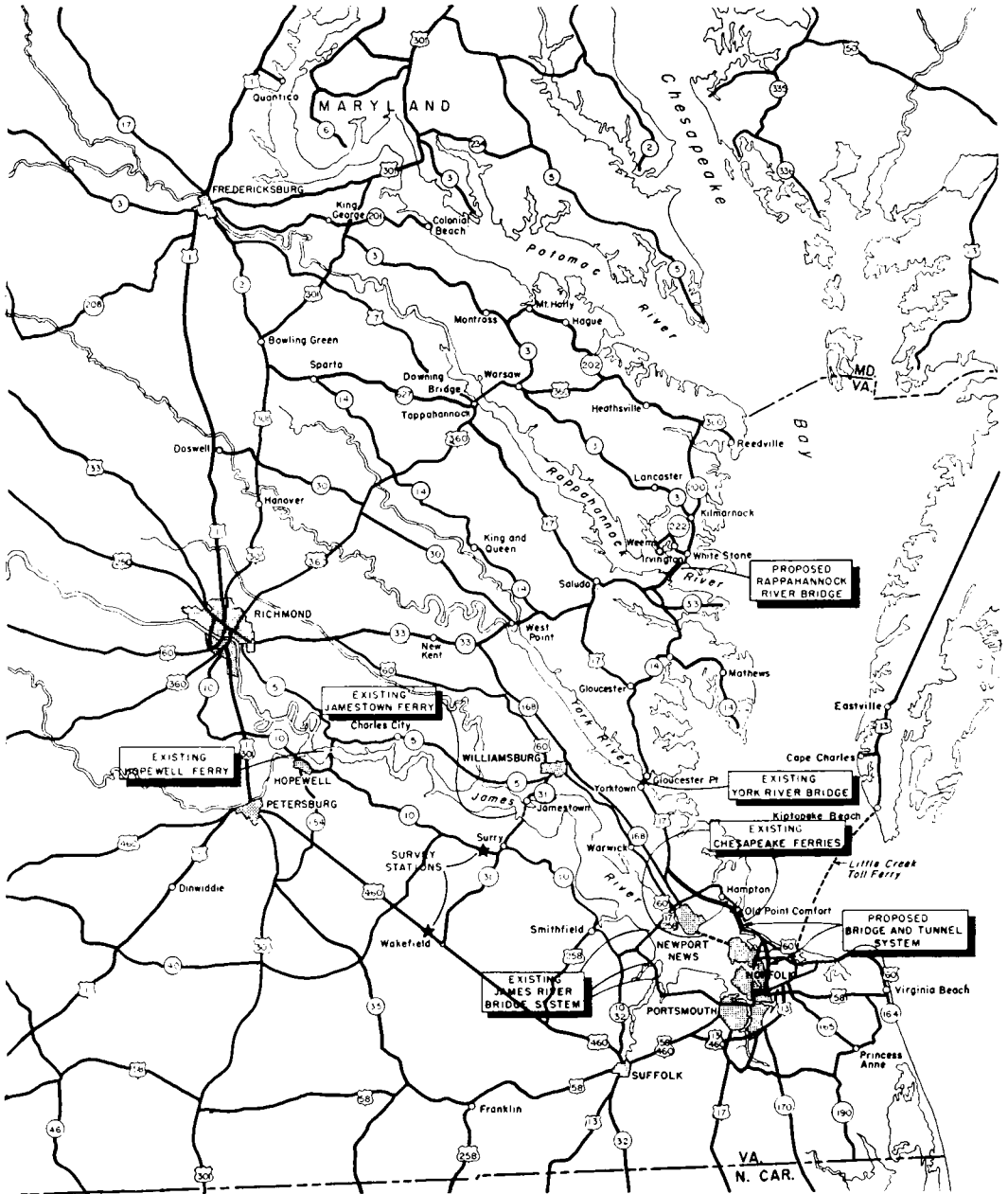


Figure 1

TABLE 1  
 COMPUTATIONS TO DETERMINE MONETARY COSTS FOR MOTORISTS CROSSING HAMPTON ROADS VIA ALTERNATE ROUTES, NEWPORT NEWS FERRY TRIP COSTS COMPARED WITH JAMES RIVER BRIDGE TRIP COSTS AND NEWPORT NEWS FERRY TRIP COSTS COMPARED WITH OLD POINT FERRY TRIP COSTS

Between Zones*	Volumes				Mileage		Minutes		Costs						Savings									
	JRB	NN	OP	JRB + NN + OP		JRB	NN	OP	JRB	NN	James River Bridge			Newport News Ferry			Old Point Ferry			NN over JRB	NN over OP			
				Tot	% NN						Dis.	Toll	Total	Dis.	Toll	Total	Dis.	Toll	Total					
01-20	37	206	15	85	221	93	30.5	10.7	19.7	69	97	\$1.22	\$1.14	\$3.51	\$0.43	\$1.38	\$5.14	\$0.79	\$1.94	\$1.33	\$4.06	\$0.37	\$0.32	
01-21	9	62	0	71	87	100	32.0	10.1	13.4	61	67	1.28	1.22	3.65	0.40	1.34	3.07	0.40	0.78	1.33	3.46	0.58	0.98	
01-24	4	12	15	75	27	44	36.6	15.0	19.4	68	77	1.47	1.36	3.98	0.60	1.51	3.47	0.54	1.72	1.33	3.59	0.51	0.12	
01-25	2	16	20	18	89	36	44	39.3	16.5	11.9	74	82	1.51	1.48	4.20	0.66	1.64	3.63	0.48	1.62	1.33	3.43	0.57	-0.20
01-26	1	5	46	6	83	51	41.1	19.5	10.9	79	88	1.61	1.58	4.15	0.78	1.76	3.87	0.43	1.54	1.33	3.30	0.50	-0.57	
01-27	8	20	0	28	71	20	100	29.3	11.9	20.0	55	54	1.20	1.10	3.44	0.58	1.42	3.23	0.80	1.33	4.09	0.21	0.86	
01-30	11	21	2	32	66	23	91	29.7	14.5	21.9	54	76	1.17	1.08	3.40	0.48	1.52	3.33	0.43	1.33	4.15	-0.03	0.72	
01-32	6	19	18	25	76	37	51	37.4	19.7	68	88	1.50	1.36	4.01	0.79	1.76	3.88	0.86	1.94	1.33	3.88	0.13	0.00	
01-35	14	35	5	49	71	35	100	39.3	23.6	31.0	67	88	1.84	1.50	4.06	0.94	1.76	3.33	0.24	2.18	1.33	4.75	0.03	0.72
01-37	17	55	12	72	76	67	82	46.0	30.3	33.3	75	95	1.10	1.04	3.15	0.21	1.90	3.33	0.33	2.20	1.33	4.86	0.05	0.42
01-38	22	130	32	152	86	162	80	53.7	37.9	45.3	88	108	1.84	1.50	4.15	0.55	1.50	3.33	0.51	2.58	1.33	5.72	0.05	0.71
02-20	14	13	2	31	42	15	87	46.0	33.3	26.7	57	79	1.06	1.20	3.51	0.46	1.33	3.46	0.92	2.12	1.33	4.37	0.05	0.91
02-37	18	13	2	31	42	15	87	46.0	33.3	26.7	57	79	1.06	1.20	3.51	0.46	1.33	3.46	0.92	2.12	1.33	4.37	0.05	0.91
03-20	3	24	0	27	89	24	7	31.4	11.5	20.5	59	74	1.02	1.18	4.49	0.33	2.48	3.76	0.47	2.38	1.33	4.10	-0.27	0.82
03-20	210	5	2	215	4	0	100	28.5	14.1	23.2	46	80	1.08	0.92	3.50	0.56	1.60	3.84	0.63	2.04	1.33	4.77	-1.04	0.86
04-21	72	3	0	75	4	0	100	28.5	13.5	22.0	50	78	1.14	1.00	3.80	0.54	1.56	3.78	0.32	2.16	1.68	4.76	-0.84	0.98
04-23	25	3	0	28	11	3	100	33.9	17.2	18.0	55	88	1.36	1.16	3.92	0.89	1.76	4.13	0.73	2.04	1.68	4.45	-0.81	0.32
04-25	24	4	0	24	0	0	100	32.2	18.4	15.7	63	87	1.33	1.20	3.27	0.74	1.68	4.18	0.68	1.94	1.68	4.30	-0.91	0.32
04-27	46	0	0	46	0	0	100	28.2	15.3	23.5	44	82	1.43	0.88	3.80	0.80	1.56	3.93	0.82	1.84	1.68	4.14	-1.85	-0.20
04-30	39	1	2	40	3	3	33	33.9	17.9	25.1	43	87	1.05	0.86	3.80	0.69	1.74	3.68	0.72	1.74	1.68	4.80	-1.45	0.71
04-32	39	1	2	40	3	3	33	33.9	23.1	20.7	51	99	1.36	1.14	3.80	0.92	1.98	3.50	0.82	2.08	1.68	4.59	-1.28	0.01
04-35	39	1	9	40	3	1	100	35.8	27.0	34.3	56	99	1.43	1.12	3.80	1.08	1.98	3.68	1.08	2.40	1.68	4.56	-1.39	0.72
04-37	186	3	2	186	2	5	60	42.5	33.7	36.8	64	106	1.70	1.28	4.80	1.35	2.16	4.50	1.37	2.22	1.68	5.37	-1.37	0.22
04-38	122	2	2	127	4	7	71	50.2	41.3	48.3	77	119	2.01	1.54	4.80	1.65	2.38	4.68	1.95	2.80	1.68	6.43	-1.36	0.72
05-20	2	38	0	40	95	38	100	32.3	10.5	17.1	64	94	1.29	1.28	3.72	0.42	1.28	3.33	0.33	2.80	1.33	3.85	0.69	0.82
05-37	3	20	3	23	87	23	87	47.8	30.1	31.5	82	90	1.91	1.64	4.15	0.70	1.80	3.33	0.26	2.04	1.33	4.63	0.37	0.30
06-20	18	210	0	228	92	220	95	32.9	8.1	20.0	67	60	0.95	0.32	1.34	0.30	1.14	3.33	0.30	1.90	1.33	4.02	1.16	1.25
06-24	1	13	15	14	93	28	46	39.1	12.4	13.7	78	68	1.56	1.56	4.15	0.56	1.36	3.19	0.56	1.68	1.33	3.56	1.08	0.37
06-25	1	5	25	6	83	30	17	43.5	16.9	11.1	84	73	1.74	1.68	4.15	0.68	1.58	3.35	0.44	1.50	1.33	3.38	1.15	-0.02
06-30	5	23	0	28	82	23	100	31.7	11.1	22.2	63	66	0.94	1.27	2.56	0.56	1.48	3.33	0.56	1.50	1.33	3.27	1.08	-0.32
06-32	2	20	13	22	91	33	61	39.8	17.1	17.5	78	79	1.59	1.26	4.15	0.68	1.58	3.13	0.89	1.80	1.33	4.10	0.55	0.97
06-35	7	20	2	27	74	22	91	41.7	21.0	33.3	77	79	1.67	1.54	4.15	0.84	1.68	3.33	0.59	1.70	1.33	3.83	0.71	0.24
06-37	8	55	2	63	87	57	96	48.4	27.7	33.6	84	86	1.67	1.68	4.15	0.77	1.11	3.75	1.25	2.14	1.33	4.81	0.61	0.65
06-38	11	82	8	93	88	90	91	56.1	35.3	45.6	97	99	2.27	2.24	4.14	1.41	1.98	3.13	0.63	2.54	1.33	5.70	0.61	0.98
07-20	2	88	0	90	98	88	100	35.6	5.4	17.3	72	54	1.42	1.44	4.15	0.22	1.68	3.23	0.79	1.78	1.33	3.80	1.35	1.17
07-37	11	94	3	105	90	97	97	51.1	25.0	30.9	89	93	2.04	1.78	4.15	0.56	1.30	3.63	0.93	2.04	1.33	4.61	1.04	0.68
07-38	5	88	0	93	95	88	100	58.8	32.6	42.9	103	80	2.35	2.06	4.15	1.30	1.86	3.33	0.93	2.42	1.33	5.47	1.07	0.98
08-20	2	42	15	44	95	57	74	37.3	8.8	12.9	65	67	1.49	1.50	4.15	0.35	1.20	3.33	0.88	1.72	1.33	4.49	1.26	0.55
08-37	1	21	10	22	95	31	68	52.8	28.4	26.5	83	87	2.11	1.86	4.15	1.14	1.74	2.81	1.14	1.84	1.33	4.25	0.91	0.04
08-38	2	19	8	21	90	27	70	60.5	36.0	38.5	106	100	2.42	2.12	4.15	1.44	2.00	3.33	1.44	2.22	1.33	5.09	0.92	0.32

\* Only those zone-to-zone movements with 25 trips or more are shown.

09-20	6	82	2	88	93	84	98	36.6	10.4	17.8	66	65	88	1.46	1.32	1.15	3.93	0.42	1.30	1.33	3.05	0.71	1.75	1.33	3.80	0.88	0.75
09-21	3	39	0	42	93	39	100	38.1	10.1	17.5	70	63	89	1.52	1.40	1.15	4.07	0.40	1.26	1.33	2.99	0.70	1.78	1.33	3.81	1.08	0.82
09-25	5	38	3	43	88	41	93	45.4	23.6	29.1	77	84	101	1.82	1.54	1.15	4.51	0.94	1.68	1.33	3.95	1.16	2.02	1.33	4.51	0.56	0.56
09-37	7	43	5	50	86	48	90	52.1	30.3	31.4	84	91	101	2.08	1.68	1.15	4.91	1.21	1.82	1.33	4.36	1.26	2.02	1.33	4.61	0.55	0.25
09-38	8	55	12	63	87	67	82	59.8	37.9	43.4	97	104	121	2.39	1.94	1.15	5.48	1.52	2.08	1.33	4.93	1.74	2.42	1.33	5.49	0.55	0.56
10-20	4	40	7	44	91	47	85	47.9	27.0	33.9	85	91	114	1.92	1.70	1.15	4.77	1.08	1.82	1.33	4.23	1.36	2.28	1.33	4.97	0.54	0.74
10-37	7	32	12	39	82	44	73	63.4	46.6	47.5	103	118	127	2.54	2.06	1.15	5.75	1.88	2.36	1.33	5.55	1.90	2.54	1.33	5.77	0.20	0.22
10-38	8	16	8	24	67	24	67	71.1	54.2	59.6	116	131	146	2.84	2.32	1.15	6.31	2.17	2.62	1.33	6.12	2.38	2.92	1.33	6.63	0.19	0.51

News-Pine Beach Ferry, the Old Point-Willoughby Ferry, U. S. Route 460 west of Wakefield, and Virginia Route 10 west of Surry. Factors were developed so that the completed zone-to-zone tabulations showed traffic movements for an average annual day for the year ending August 31, 1954.

Running time studies were conducted by the floating car method on all highways in the area that might be termed in competition with or tributary to the present ferries, the James River Bridge and the proposed Bridge and Tunnel System. Various trucking firms were contacted as to routes now used, present operating schedules, and opinions as to how the proposed Bridge and Tunnel System would affect trucking operations. The Highway Department also procured and furnished information on the number of vehicles parked and duration of stay in the parking lot at the Newport News Ferry landing.

As was expected, it was found that the proportionate use of alternate routes varied with the relative advantages of the two routes. The major measurable items were time, distance, and toll charge. The average automobile charge is \$0.80 for the James River Bridge and \$1.33 for the ferries. On some of the trips it was necessary for the motorists to pay an additional toll averaging \$0.35 to use the Elizabeth River Tunnel. All tolls were figured for an automobile carrying one extra passenger.

Numerous graphs were plotted that compared time and distance differentials. These differentials were plotted as absolute values and as ratios. Since there was such a great variation in times, distances and tolls it was impossible to obtain consistency with any ratio type of analysis, so this method was discarded.

Since all facilities are toll, the major factors influencing a motorist's choice were reduced to a common denominator by assigning different monetary values for time and distance to be added algebraically to the toll before plotting points.

We reasoned that the correct curve would show traffic equally divided between two alternate routes when total trip costs were approximately equal. It was soon determined that time, distance, and tolls must all be considered in estimating trip costs or distorted results would appear. Our problem was to find the equivalent monetary value that the average motorist in the study area places on time

and distance. The toll cost, of course, was known.

The trip time involving use of the ferry included waiting, loading, crossing, and unloading. The total of all these times was found to be 40 minutes for users of the Newport News-Pine Beach Ferry and 50 minutes for the Old Point-Willoughby Ferry. The mileage for the actual ferry crossing was not included since the automobile was not being operated while the boat was in motion. Mileage was measured for the land portion of all trips included in the comparison, and summaries of the running time studies were prepared and applied.

We made two separate comparisons. We first compared the James River Bridge with the Newport News-Pine Beach Ferry. We then compared the Newport News-Pine Beach Ferry with the Old Point-Willoughby Ferry.

The comparison of the Newport News Ferry with the James River Bridge gave us an excellent opportunity to ascertain the relative weight to be applied to time and distance since for many trips the ferry was shorter in distance but longer in time.

The curve for automobile trips which agreed most closely with actual habits under present conditions was obtained by computing the motorists' time at two cents per minute and the distance at four cents per mile.

Table 1 shows the computations for determining the monetary savings on the favored facility. Figure 2 shows the distribution of points for motorist choosing between the two ferry routes, while Figure 3 shows the same type of distribution for motorists having a choice between the James River Bridge System and the Newport News Ferry. Both of these two figures show the curve that we selected as agreeing most closely with actual habits.

Truck movements were analyzed in much the same manner (see Table 2 and Figures 4 and 5).

The most accurate curve for truck trips was derived when time was computed at five and one-half cents per minute and distance at nine cents per mile. This is for an average truck as found in these studies. Since the relative advantages between alternate routes remained approximately the same for trucks of all classifications, it was correct within the necessary degree of accuracy for this study to base computations on an "average" truck. The present toll schedules were used when analyz-

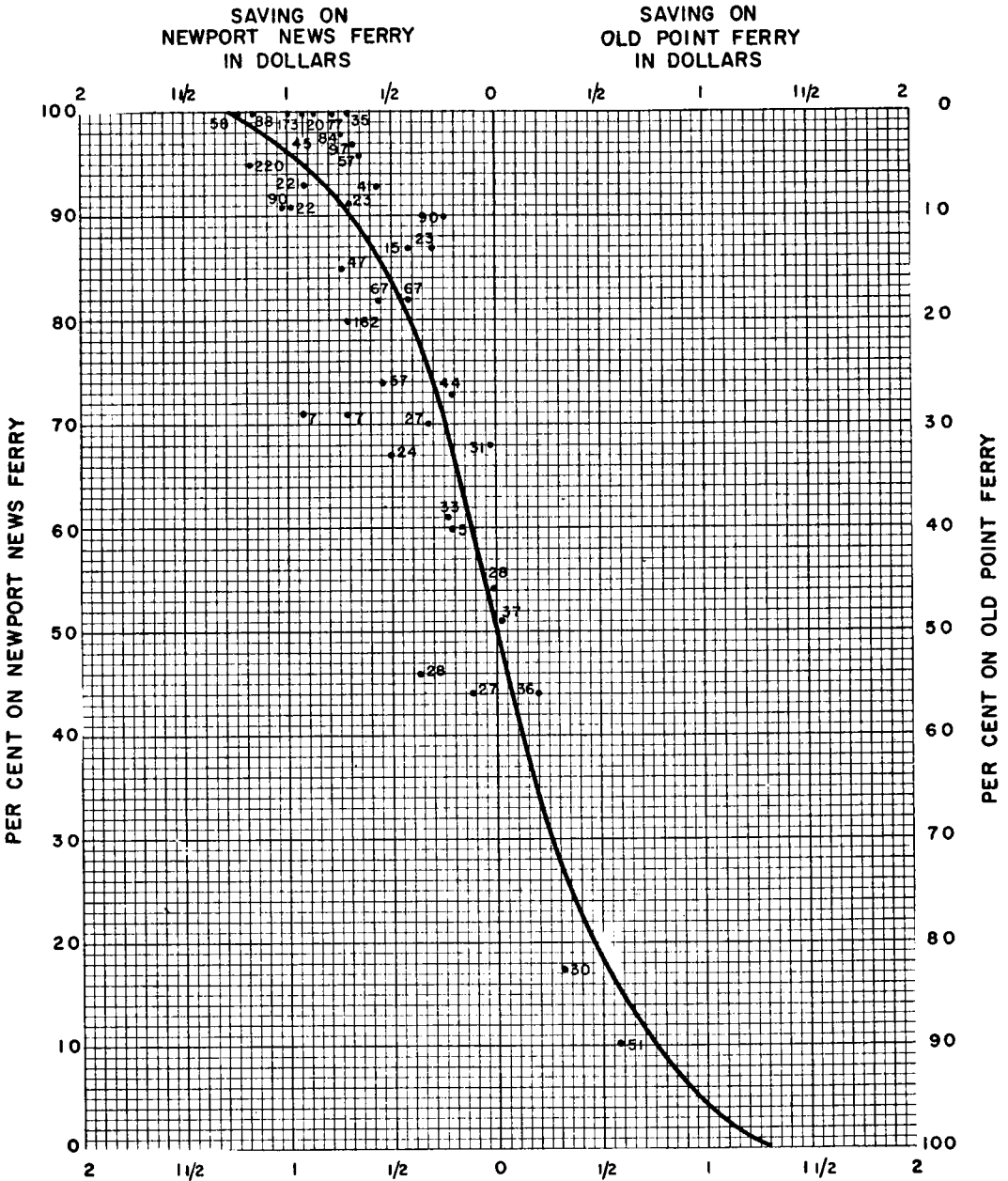


Figure 2. Newport News automobile trip costs and usage compared with Old Point Ferry automobile trip costs and usage. Based on time at 2 cents per minute, distance at 4 cents per mile and average automobile toll at \$1.33 on each ferry. Light trucks are included as automobiles. Number of trips shown beside each point.

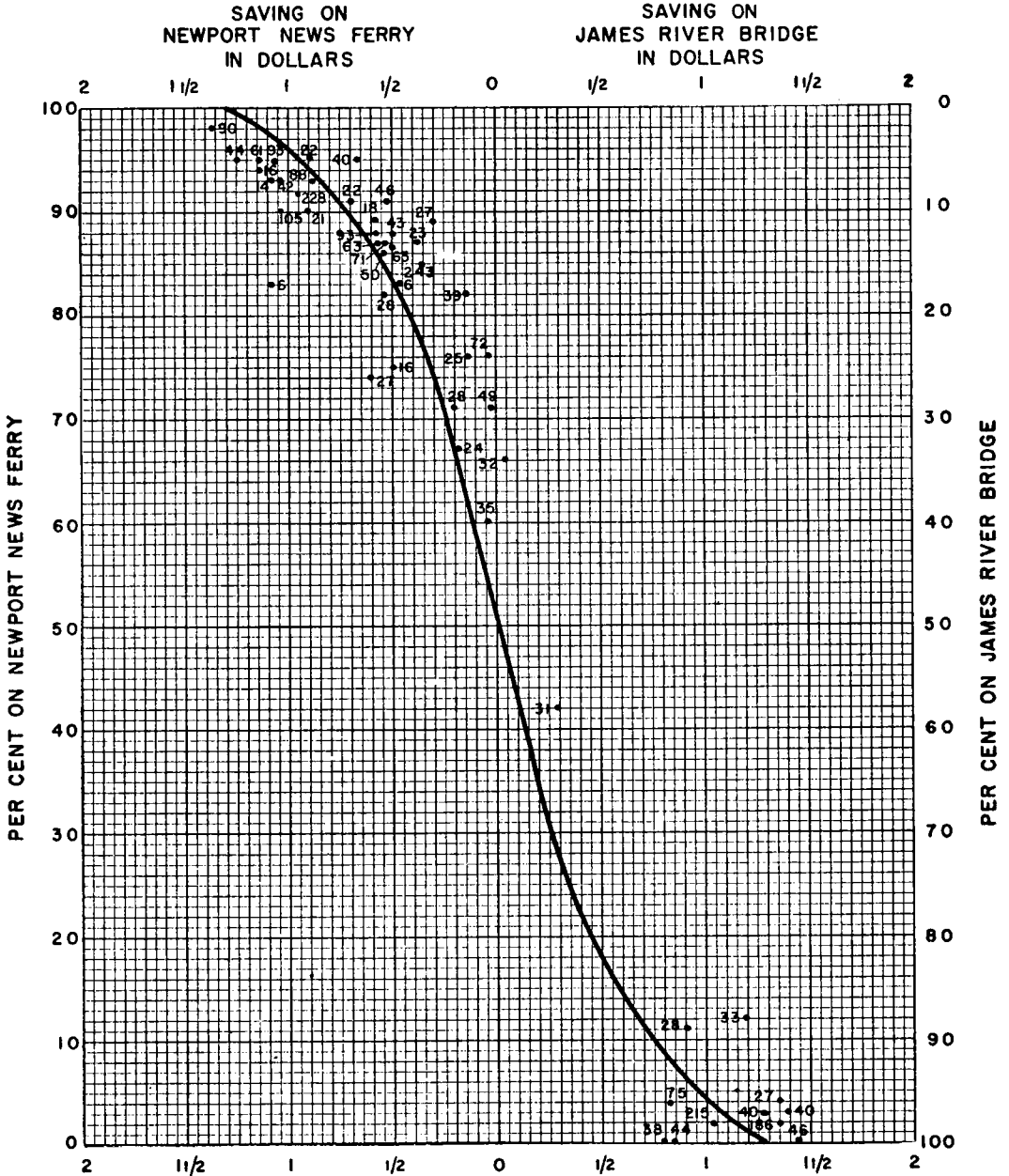


Figure 3. Newport News Ferry automobile trip costs and usage compared with James River Bridge automobile costs and usage. Based on time at 2 cents per minute, distance at 4 cents per mile, Newport News average automobile toll of \$1.33 and James River Bridge average toll of \$0.80. Light trucks are included as automobiles. Number of trips shown beside points.

TABLE 2  
 COMPUTATIONS TO DETERMINE MONETARY COSTS FOR COMMERCIAL VEHICLES CROSSING HAMPTON ROADS VIA ALTERNATE ROUTES.  
 NEWPORT NEWS FERRY TRIP COSTS COMPARED WITH JAMES RIVER BRIDGE TRIP COSTS AND NEWPORT NEWS FERRY TRIP  
 COSTS COMPARED WITH OLD POINT FERRY TRIP COSTS

Between Zones*	Volumes				Mileage		Minutes		Costs						Savings												
	JRB	NN	OP	JRB + NN		JRB	NN	OP	JRB	NN	James River Bridge			Newport News Ferry			Old Point Ferry			NN over JRB	NN						
				Tot	% NN						Dis.	Time	Toll	Total	Dis.	Time	Toll	Total	Dis.			Time	Toll	Total			
01-20	4			51	92	84	30.5	10.7	19.7	60	70	99	\$2.75	\$3.30	\$2.12	\$8.17	\$0.96	\$3.85	\$1.93	\$6.74	\$1.78	\$5.45	\$1.93	\$9.16	\$1.43	\$2.42	
01-21				5	83	83	32.0	10.1	19.4	64	68	99	2.88	3.52	2.12	8.95	0.91	3.74	1.93	6.58	1.79	5.45	1.93	9.17	1.94	2.59	
01-22	2	3		5	100	8	33.7	11.9	16.8	69	74	97	3.03	3.80	2.12	8.95	1.07	4.07	1.93	7.07	1.51	5.34	1.93	8.78	1.88	1.71	
01-23				4	100	8	39.3	16.5	11.9	78	84	90	3.54	4.29	2.12	9.95	1.49	4.62	1.93	8.04	0.97	4.57	1.93	7.57	1.91	-0.47	
01-24				4	100	13	41.1	19.7	10.8	83	90	78	3.70	4.57	2.12	10.39	1.76	4.95	1.93	8.64	0.97	4.29	1.93	7.19	1.75	-0.47	
01-25				4	100	8	50	37.4	19.7	2.1	61	80	91	3.37	3.91	2.12	8.17	1.28	4.46	1.93	8.66	1.55	5.23	1.93	8.71	0.74	0.05
02-20	1	4		15	73	11	100	30.5	13.7	23.2	70	81	109	2.75	3.30	2.12	8.52	1.18	4.35	1.93	7.62	2.08	6.00	10.01	10.03	2.39	2.39
02-21	1	5		16	83	5	100	32.0	13.1	22.8	64	79	110	2.88	3.52	2.12	8.52	1.18	4.35	1.93	7.46	2.05	6.00	10.03	10.03	1.06	2.57
02-22	3	1		4	25	3	100	39.3	37.4	22.6	71	101	122	3.54	3.91	2.12	9.51	2.39	5.56	1.93	9.53	1.85	5.78	10.33	10.33	0.03	1.86
02-23	3	3		6	50	3	100	53.7	40.9	34.4	70	101	122	4.83	5.06	2.12	12.01	3.68	6.71	1.93	12.32	3.10	6.71	11.74	11.74	-0.37	1.92
02-24	3	5		8	100	5	100	31.4	11.5	20.5	62	76	105	2.83	3.41	2.12	8.36	1.04	4.18	1.93	7.15	1.85	5.78	10.33	10.33	0.31	1.86
03-20	17	6		23	96	7	100	27.0	14.1	23.2	48	82	111	2.43	2.64	1.77	6.84	1.22	4.51	1.93	7.15	1.85	5.78	10.33	10.33	0.31	1.86
04-20	5	1		6	17	1	100	28.5	13.5	22.9	53	80	111	2.57	2.92	1.77	7.26	1.22	4.40	2.28	7.90	2.06	6.11	10.48	10.48	0.31	1.86
04-21	5	1		6	17	1	100	33.2	18.4	16.9	60	91	99	2.99	3.30	1.77	8.06	1.66	5.01	2.28	7.90	2.06	6.11	10.48	10.48	0.31	1.86
04-22	5	1		6	17	2	50	33.9	23.1	20.7	60	102	107	3.05	3.30	1.77	8.12	2.08	5.61	2.28	8.95	1.52	5.45	9.25	9.25	0.30	2.55
04-23	5	1		6	17	0	35.8	27.0	34.5	59	102	124	3.23	3.25	1.77	8.24	2.43	5.61	2.28	9.97	1.86	5.89	12.21	12.21	0.85	0.06	
04-24	5	3		8	38	3	100	42.5	33.7	36.8	67	109	125	3.83	3.69	1.77	9.29	3.03	6.00	2.28	11.31	3.11	6.82	12.47	12.47	0.85	0.06
04-25	8	3		11	50	0	50.2	41.3	48.9	81	123	145	4.52	4.46	1.77	10.75	3.72	6.77	2.28	12.77	4.40	7.98	14.66	14.66	2.02	1.16	
04-26	9	0		9	0	0	50.2	41.3	48.9	81	123	145	4.52	4.46	1.77	10.75	3.72	6.77	2.28	12.77	4.40	7.98	14.66	14.66	2.02	1.16	
04-27	46	4		50	92	46	32.9	8.1	20.0	70	61	97	2.96	3.85	2.12	8.93	0.73	3.36	1.93	6.00	1.78	5.34	9.07	9.07	2.91	3.05	
04-28	13	10		23	100	13	100	34.4	7.5	19.7	74	58	97	3.10	4.07	2.12	9.29	0.73	3.36	1.93	6.00	1.78	5.34	9.07	9.07	2.91	3.05
04-29	7	7		14	100	7	100	39.1	6.3	20.3	67	63	98	2.89	3.69	2.12	8.70	0.84	3.47	1.93	6.24	1.83	5.39	9.15	9.15	2.46	2.91
04-30	7	7		14	100	7	100	31.7	11.9	22.2	66	67	96	2.89	3.63	2.12	8.60	1.07	3.69	1.93	6.69	2.00	5.28	9.21	9.21	2.46	2.91
04-31	14	3		17	82	17	82	30.8	17.1	17.5	82	81	110	3.58	4.51	2.12	10.21	1.54	4.46	1.93	7.93	1.58	5.06	8.57	8.57	2.28	0.84
05-30	1	5		6	100	1	100	41.7	21.0	31.3	81	110	124	4.17	4.46	2.12	11.32	2.50	4.84	1.93	9.27	3.02	6.05	11.00	11.00	2.05	2.82
05-31	1	5		6	100	1	100	48.4	27.7	33.6	88	110	146	4.36	4.46	2.12	11.32	2.50	4.84	1.93	9.27	3.02	6.05	11.00	11.00	2.05	2.82
06-32	1	14		15	92	14	100	48.4	27.7	33.6	88	110	146	4.36	4.46	2.12	11.32	2.50	4.84	1.93	9.27	3.02	6.05	11.00	11.00	2.05	2.82
06-33	1	14		15	92	14	100	48.4	27.7	33.6	88	110	146	4.36	4.46	2.12	11.32	2.50	4.84	1.93	9.27	3.02	6.05	11.00	11.00	2.05	2.82
07-20	1	14		15	92	14	100	48.4	27.7	33.6	88	110	146	4.36	4.46	2.12	11.32	2.50	4.84	1.93	9.27	3.02	6.05	11.00	11.00	2.05	2.82
07-21	1	14		15	92	14	100	48.4	27.7	33.6	88	110	146	4.36	4.46	2.12	11.32	2.50	4.84	1.93	9.27	3.02	6.05	11.00	11.00	2.05	2.82
07-22	1	14		15	92	14	100	48.4	27.7	33.6	88	110	146	4.36	4.46	2.12	11.32	2.50	4.84	1.93	9.27	3.02	6.05	11.00	11.00	2.05	2.82
07-23	1	14		15	92	14	100	48.4	27.7	33.6	88	110	146	4.36	4.46	2.12	11.32	2.50	4.84	1.93	9.27	3.02	6.05	11.00	11.00	2.05	2.82
07-24	1	14		15	92	14	100	48.4	27.7	33.6	88	110	146	4.36	4.46	2.12	11.32	2.50	4.84	1.93	9.27	3.02	6.05	11.00	11.00	2.05	2.82
07-25	1	14		15	92	14	100	48.4	27.7	33.6	88	110	146	4.36	4.46	2.12	11.32	2.50	4.84	1.93	9.27	3.02	6.05	11.00	11.00	2.05	2.82
07-26	1	14		15	92	14	100	48.4	27.7	33.6	88	110	146	4.36	4.46	2.12	11.32	2.50	4.84	1.93	9.27	3.02	6.05	11.00	11.00	2.05	2.82
07-27	1	14		15	92	14	100	48.4	27.7	33.6	88	110	146	4.36	4.46	2.12	11.32	2.50	4.84	1.93	9.27	3.02	6.05	11.00	11.00	2.05	2.82
07-28	1	14		15	92	14	100	48.4	27.7	33.6	88	110	146	4.36	4.46	2.12	11.32	2.50	4.84	1.93	9.27	3.02	6.05	11.00	11.00	2.05	2.82
07-29	1	14		15	92	14	100	48.4	27.7	33.6	88	110	146	4.36	4.46	2.12	11.32	2.50	4.84	1.93	9.27	3.02	6.05	11.00	11.00	2.05	2.82
07-30	1	14		15	92	14	100	48.4	27.7	33.6	88	110	146	4.36	4.46	2.12	11.32	2.50	4.84	1.93	9.27	3.02	6.05	11.00	11.00	2.05	2.82
08-20	2	5		7	86	6	100	7	26.6	10.0	69	66	91	3.29	3.80	2.12	11.95	0.96	3.51	1.93	6.52	1.60	5.01	10.49	10.49	2.02	1.80
08-21	2	5		7	86	6	100	7	26.6	10.0	69	66	91	3.29	3.80	2.12	11.95	0.96	3.51	1.93	6.52	1.60	5.01	10.49	10.49	2.02	1.80
08-22	2	5		7	86	6	100	7	26.6	10.0	69	66	91	3.29	3.80	2.12	11.95	0.96	3.51	1.93	6.52	1.60	5.01	10.49	10.49	2.02	1.80
08-23	2	5		7	86	6	100	7	26.6	10.0	69	66	91	3.29	3.80	2.12	11.95	0.96	3.51	1.93	6.52	1.60	5.01	10.49	10.49	2.02	1.80
08-24	2	5		7	86	6	100	7	26.6	10.0	69	66	91	3.29	3.80	2.12	11.95	0.96	3.51	1.93	6.52	1.60	5.01	10.49	10.49	2.02	1.80
08-25	2	5		7	86	6	100	7	26.6	10.0	69	66	91	3.29	3.80	2.12	11.95	0.96	3.51	1.93	6.52	1.60	5.01	10.49	10.49	2.02	1.80
08-26	2	5		7	86	6	100	7	26.6	10.0	69	66	91	3.29	3.80	2.12	11.95	0.96	3.51	1.93	6.52	1.60	5.01	10.49	10.49	2.02	1.80
08-27	2	5		7	86	6	100	7	26.6	10.0	69	66	91	3.29	3.80	2.12	11.95	0.96	3.51	1.93	6.52	1.60	5.01	10.49	10.49	2.02	1.80
08-28	2	5		7	86	6	100	7	26.6	10.0	69	66	91	3.29	3.80	2.12	11.95	0.96	3.51	1.93	6.52	1.60	5.01	10.49	10.49	2.02	1.80
08-29	2	5		7	86	6	100	7	26.6	10.0	69	66	91	3.29	3.80	2.12	11.95	0.96	3.51	1.93	6.52	1.60	5.01	10.49	10.49	2.02	1.80
08-30	2	5		7	86	6	100	7	26.6	10.0	69	66	91	3.29	3.80	2.12	11.95	0.96	3.51	1.93	6.52	1.60	5.01	10.49	10.49	2.02	1.80
08-31	2	5		7	86	6	100	7	26.6	10.0	69	66	91	3.29	3.80	2.12	11.95	0.96	3.51	1.93							



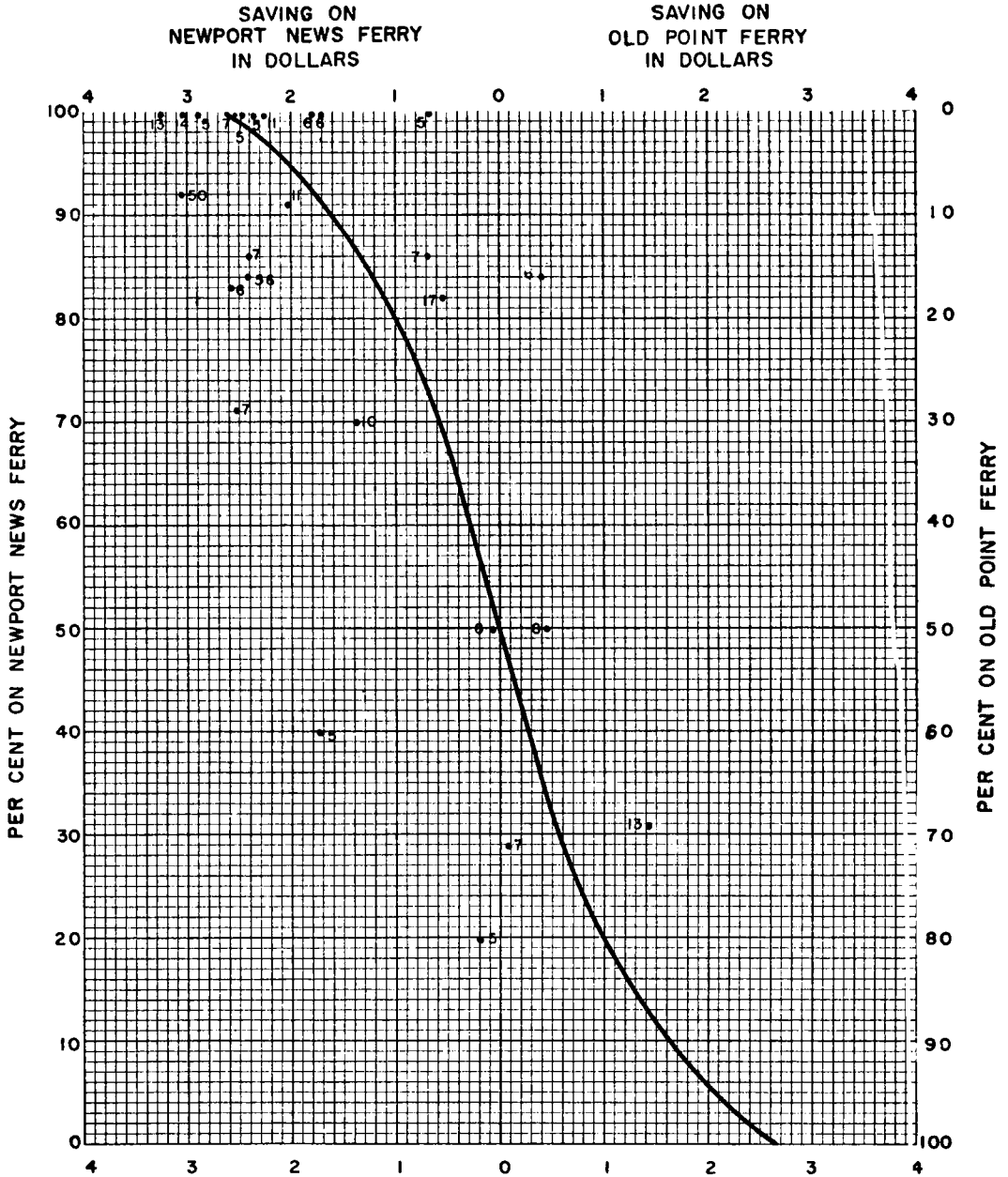


Figure 4. Newport News Ferry commercial vehicle trip costs and usage compared with Old Point Ferry commercial vehicle trip costs and usage. Based on time at 5½ cents per minute, distance 9 cents per mile and average commercial vehicle toll of \$1.93 on each ferry. Light trucks have been excluded. Number of trips shown beside each point.

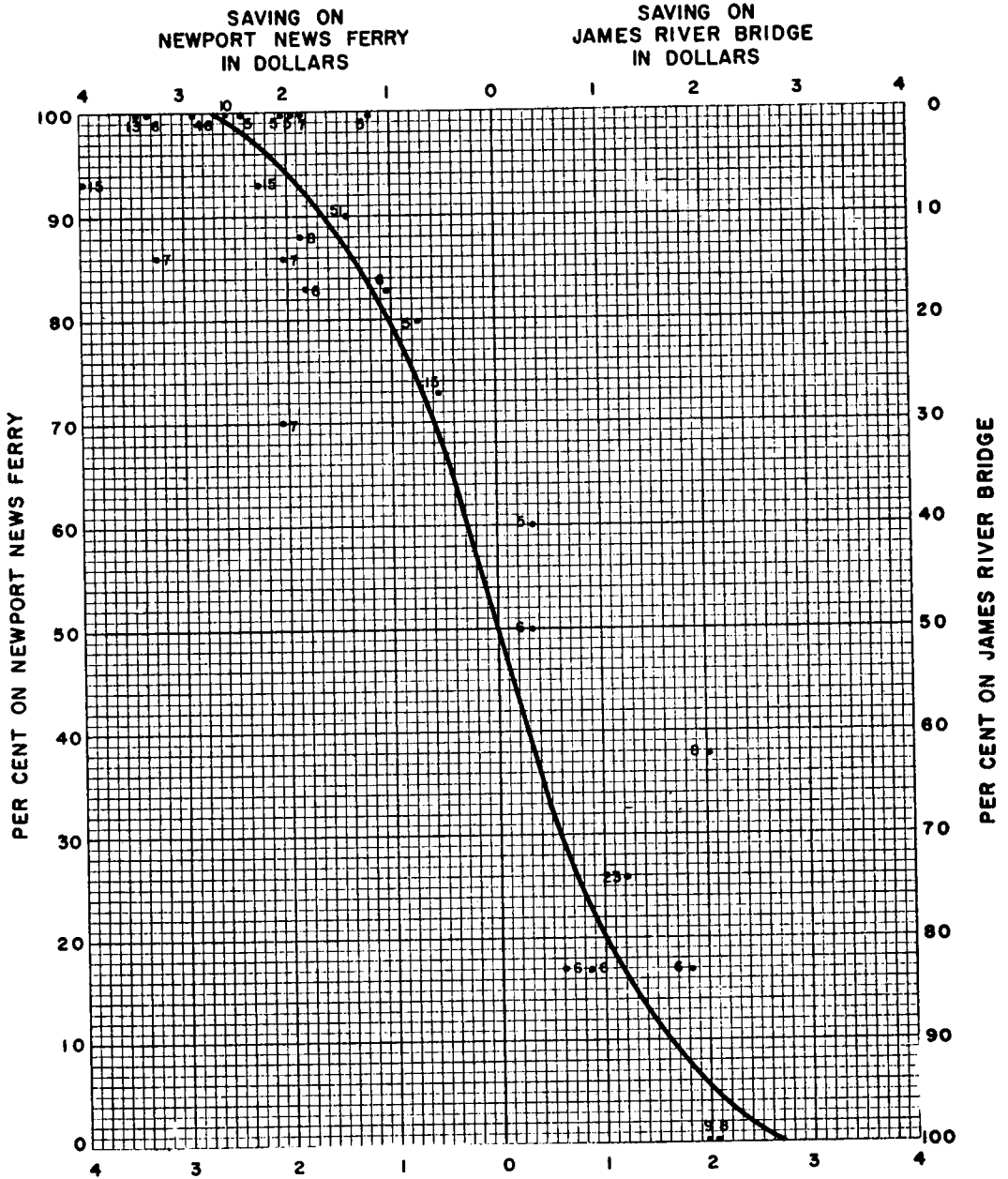


Figure 5. Newport News Ferry commercial vehicle trip costs and usage compared with James River Bridge commercial vehicle trip costs and usage. Based on time at 5½ cents per minute, distance at 9 cents per mile and average commercial vehicle toll of \$1.93 on the ferry and \$1.77 on the bridge. Number of trips shown beside points.

ing comparative costs for the various zone-to-zone movements. One hundred per cent of the trucks were found to be using the favored facility when savings were \$2.70 or greater. As was the case with automobiles, approximately 50 percent of the trucks went each way when costs were equal. The curve was found to be accurate within four percent when checked against present zone-to-zone movements.

It is our opinion that motorists will continue to place the same values on time and distance as they do at present when deciding whether to use the proposed Hampton Roads Bridge and Tunnel System or the James River Bridge System. The derived curves were used, therefore, to allocate traffic between these two facilities. Time, distance, and their monetary values were computed for the alternate routes for all zone-to-zone movements. Cost differentials were then computed, percentages determined, and individual allocations made. The allocations indicated that the proposed Bridge and Tunnel System would divert about 360 vehicles per day at 1954 traffic levels from the James River Bridge System while retaining all of the 3,720 vehicles per day now carried by the ferries. In the traffic assignments, toll schedules on the two facilities were assumed to remain approximately the same as the present schedules. (Trucks tolls on the ferries are based on length which would not be a desirable basis for tolls on the proposed Bridge and Tunnel System.)

Benefits for motorists using both U.S. 460 and Virginia 10 destined to the Norfolk metropolitan area were compared with the benefits for motorists traveling via the peninsula. See Figure 1 for the location of the alternate routes. Vehicles using the southern route cross the James River at Richmond. Vehicles using the peninsula route cross on the James River Bridge or Chesapeake Ferries. Since comparisons here were mainly between a route with

tolls and a toll fee road, the derived curves were similar, but not identical with curves used in comparing two toll facilities. It was possible, however, to analyze these potential trips in much the same manner as that used in comparing trips between the two systems having tolls.

Of the motorist now traveling southbound via the southern routes, U. S. Route 460 and Virginia Route 10, only those having a origin in Richmond or points north or west thereof are potential users of the proposed Bridge and Tunnel System. There are 1,610 of these potential daily trips at 1954 traffic levels now traveling via U. S. Route 460 or Virginia Route 10. There are 1,070 corresponding trips traveling via the peninsular routes, U. S. Route 60 or Virginia Route 168.

The proposed Bridge and Tunnel System would provide additional time and distance benefits over the present peninsular route. The value of these additional benefits would vary between \$0.26 and \$0.91 for automobiles, and between \$0.96 and \$2.28 for "average" trucks, depending upon the zone of destination in the Norfolk area. It has been estimated that the overall effect of these additional benefits would be to divert 220 automobiles and 70 trucks per average 1954 day from the routes south of the James River Bridge to the proposed Bridge and Tunnel System.

It has been the experience elsewhere that a new facility such as the one now under construction across Hampton Roads generates traffic volumes greater than can be accounted for by diverted traffic plus subsequent natural increases. The additional traffic is termed "induced traffic." The induced traffic for this new facility has been estimated at 25 percent of the diverted traffic. If the proposed Bridge and Tunnel System had been in operation for the year ended August 31, 1954, the average daily traffic would have been approximately 5,500 vehicles.