River Crossing Travel Choice: The Hudson River Experience

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A set of models has been developed to allocate peak-period and off-peak-period trips for each of three modes—auto, bus, and rail—to facilities crossing the Hudson River. The set of allocation models is one of a series of models to be used to forecast trans-Hudson travel for alternative transportation systems within the framework of the New York region's changing demography and economy. Previous techniques were reviewed to determine the best one for developing the allocation or assignment process. Unlike most previous techniques, the method selected incorporated a number of determinants of route choice. Multiple regression analysis fed by a massive data bank and a large battery of programs was used. Times, costs, and number of transfers were compared on an origin-destination basis for each crossing facility within a mode; and their relative transportation parameters were ascertained to describe variations in facility usage. The results showed the great influence of time savings on the auto user, suggesting the general validity of the often-used all-or-nothing minimum-time-path approach to assigning auto traffic. The allocation models for the other modes suggest a lesser but still high value of time, with the differential number of transfers being an important determinant of the rail crossing choice. Dummy variables to test user biases toward particular facilities were tried but with no usable results. Families of curves of the models were prepared that greatly aided the analysis and understanding of the models. The allocation models were run for the base year 1964 to compare the results with the actual trip volumes. Results were generally good, but "fine tuning" was necessary for the auto mode. The models developed were deemed usable for forecasting purposes with full knowledge of the limitations of such empirically derived relationships. A continuing research effort with new data and improved techniques is being planned.

•THE PORT of New York Authority is engaged in the development of a series of traffic-demand forecasting models to aid in the planning of transportation facilities related to crossing the Hudson River. The goal of the model development is to efficiently forecast the trip demand by mode and facility of alternative transportation plans and policies within the framework of the changing demography and economy of the New York metropolitan area. Toward that end, a system of models was developed that is described schematically by the flow chart in Figure 1. There are three basic submodels in the in the system: a trip interchange model that forecasts the total number of trans-Hudson trips made between zonal pairs; a modal-split model that apportions these trips among the three major travel modes—automobile, bus, and railroad; and an allocation model that apportions the modal trips to each facility within the mode used to cross the river. It is this last model, the allocation or assignment model, that is the subject of this study.

Paper sponsored by Committee on Origin and Destination and presented at the 49th Annual Meeting.

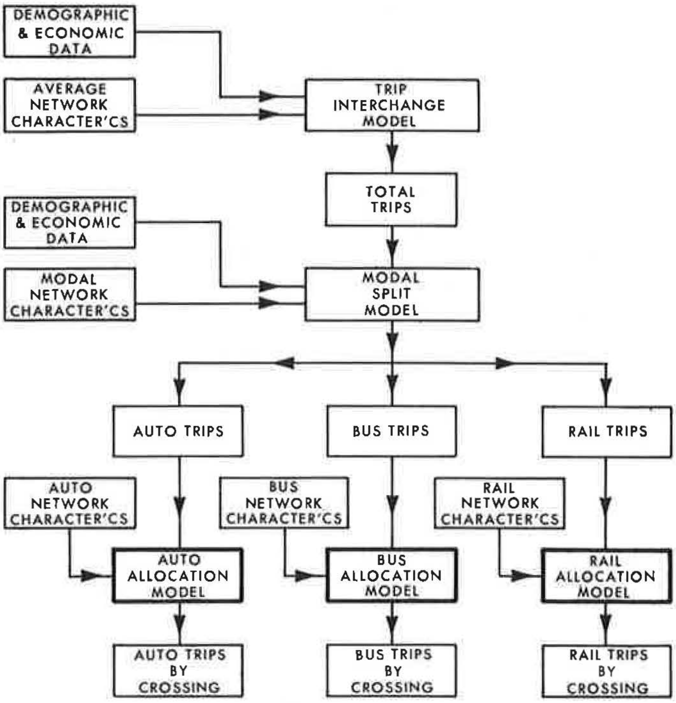

Figure 1. The model system—schematic flow chart.

DEVELOPMENT OF ASSIGNMENT TECHNIQUES

The techniques of forecasting the traffic assigned to a transportation network have evolved considerably in the last 15 years. In the early years of highway planning, "desire lines" were drawn between expected travel interchange points in proportion to the thickness of the volumes, and highway locations were then sketched in.

Later, traffic was assigned to expected routes of travel empirically derived with the aid of diversion curves. The relative time and/or distance and/or cost savings were calculated for the added facility, and the percent of automobile travelers that would switch over to the new facility was calculated for each origin-destination (O-D) zonal pair (1).

The increased availability and use of high-speed digital computers and the presentation of the Moore algorithm (2) in 1957 helped to improve the process of traffic assignment. It became possible to trace the route of least time, distance, or cost through a transportation network described in a computer and to assign each O-D trip volume to links in the network describing that route. Once accumulated, the trips on each link represented an estimate of the traffic that would be assigned.

There remained a number of serious shortcomings, however, with this assignment method. First, traffic was assigned on an all-or-nothing basis. All traffic was assigned to the minimum route over all other possible routes, no matter how small the margin. This was unrealistic because motorists will choose the next best route in significant numbers if the margin is small. This problem was overcome somewhat by the use of small traffic zones, thereby smoothing the lumpiness of the assignment. This solution, of course, added to the number of O-D pairs.

A second problem occurred because the computer was unaware of the phenomenon of traffic congestion. Traffic was assigned to links in the network that exceeded the capacity of the links to carry them. Refinements were forthcoming with the advent of capacity restraint procedures. In one such procedure, overassigned traffic on a link caused the computer to raise the travel time on that link. This resulted in the selection of other routes and in a subsequent reduction in assigned traffic to a volume closer to the link's capacity (3). Another procedure involved loading the trips into the networks in an incremental fashion with diversion to other routes occurring when an increment produced overloading.

A third problem resulted from the difficulty of representing the travelers' preference for a route using only one form of impedance to travel. The choice of route is indeed a complex one, involving many conscious and subconscious decisions. Although travel time has been used most often, travel cost and travel distance have also been considered. The assignment to a toll road has made it useful to merge time and cost by using some equivalent. Distance has also been incorporated on occasion because of the problems of comparing a fast, long route with a short, slow one.

A sketch history of the evolution of traffic assignment techniques as of 1964 is found in the Bureau of Public Roads Traffic Assignment Manual (4).

A promising new technique, the direct traffic-estimation method (5), is a complete departure from the previous procedures described. It is based on the concept that traffic volume on a link is a result of the ability of nearby areas to generate trips plus the access to that link. The Tri-State Transportation Commission is currently calibrating this model and refining this technique (6).

Given the existing problems associated with traffic assignment techniques, a method was attempted that hopefully would avoid these difficulties.

THE ALLOCATION MODEL

Requirements and Restrictions of Model Development

The Port of New York Authority's approach to the problem of assignment or allocation (the latter term will be used hereafter) is governed by the unique nature of both its responsibilities and its data base. The Port Authority's concern is with the Hudson River crossings and the facilities that directly affect them. The allocation process to be devised must focus on these facilities and must be applicable to the three primary modes of trans-Hudson travel—auto, bus, and rail. The Port Authority has collected a great deal of O-D information on these trans-Hudson crossings and has coded them in some areas to what might be considered a gross zone base.

The more traditional approaches to assignment require the construction of extensive networks, a process which is rather wasteful if only a few links on the network (i.e., the Hudson River crossings) are of concern. In addition, with the data base, the traditional all-or-nothing approach would result in a great deal of lumpiness in the assignment, especially in the bus and rail systems where relatively few zones contribute a large portion of the trips.

It was also thought that the choice of a route across the river was based on more than just one variable, particularly in the bus and rail modes. For the bus mode, in a portion of the region west of the river, the trip-maker has a choice of two sets of bus lines, each to a different bus terminal on the east side of the river. These alternatives present a number of choices of trade-offs for the trip-maker involving travel time differences, travel cost differences, and a differential number of transfers. There can be four basic alternatives for traveling by rail from the zones on the west side of the river. They also involve many trade-offs for the trip-maker. Five different automobile

TABLE 1

HUDSON RIVER FACILITIES BY MODE

Mode	Facility
Auto	George Washington Bridge (GWB)
	Lincoln Tunnel (LT)
	Holland Tunnel (HT)
	Staten Island Bridges (SIB)
	(Bayonne Bridge, Goethals Bridge, Outerbridge Crossing)
	Tappan Zee Bridge (TZB)
Bus	George Washington Bridge Bus Station (GWBBS)
	Port Authority Bus Terminal (PABT)
Rail	Pennsylvania Railroad (PRR)
	Hudson Terminal (HT)
	Port Authority Trans-Hudson (PATH) Uptown (PUP)
	Central Railroad of New Jersey (CNJ)

crossings are also available. The 11 choices for the three modes are given in Table 1 and are shown in Figure 2.

Considering the difficulty of constructing huge networks in this situation, the lumpiness of all-or-nothing assignments, and the difficulty of using one variable to describe the travel impedance, it was decided to develop an allocation model designed to overcome these difficulties.

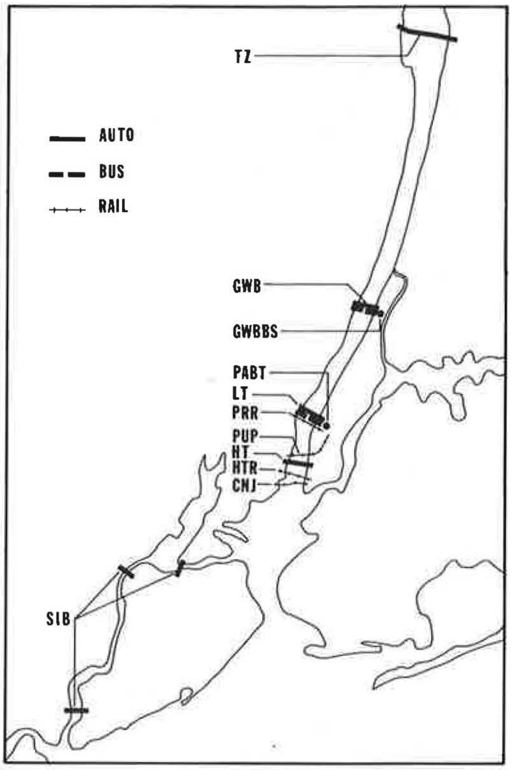

Figure 2. Hudson River crossings map.

The Model Concept

The allocation technique employed is based on the concept that each crossing facility within a mode of travel competes with all others for the trips made within that mode between each O-D pair. Although it is true that there is competition between modes as well as between facilities within a mode, a considerable amount of literature indicates that different factors govern modal choice. These factors might not be handled easily in an allocation method that does not specifically identify the mode. The technique considered for allocation within modes does not necessarily identify the facility per se in its concept.

The allocation model is based on a rating system first introduced by Cherniack (7). The concept assumes that the traveler compares the travel time, travel cost, and (in the case of bus and rail) the number of transfers for the various available facilities. In evaluating the alternatives, the traveler perceives the fastest facility and compares that time to the times of the other facilities; he perceives the least expensive facility and compares that cost to the costs of the other facilities; he perceives the most convenient alternative and compares it to the others; or, more realistically, he perceives some combination of all factors. He then rates the alternate facilities and gives the highest rating to the one that he decides has the best combination of time, cost, and convenience and a lesser rating to those he believes lack these advantages. Conversely, if the use of each facility is based on the cumulative rating of all users, then each facility could be given a rating based on its traffic volume compared with the traffic volume of all other competing facilities. The facility with the highest volume gets the highest rating; and others, comparatively lower ratings.

Using multiple regression techniques, the relationship between these three factors and the comparative usage of the facilities was explored for each mode. The rating of facility 1 can be expressed as follows:

$$R_1 = \frac{T_1}{T_H} = f\left(t_1 - t_s,\ c_1 - c_c,\ F_1 - F_f\right)$$

where

T_1 = trips via facility 1,
T_H = trips via facility most heavily used,
t_1 = door-to-door travel time via facility 1,
t_s = door-to-door travel time via the fastest facility,
c_1 = travel cost via facility 1,

c_c = travel cost via the least expensive facility,
F_1 = number of transfers via facility 1, and
F_f = number of transfers via the facility with the fewest transfers.

The R value or rating will equal 1.0 if the facility in question is the most heavily used and will be less than 1.0 for all lesser-used facilities. Also, the differences will equal zero if the facility in question is the best for the particular transportation variable. The ratings and the differences (Δt, Δc, and ΔF for times, costs, and transfer differences respectively) are calculated for each facility within each O-D pair for each mode. Thus, for the automobile allocation model with five available crossings, each O-D pair can theoretically contribute five data points. In this study, each O-D pair contributed fewer points because only those facilities that were within 20 minutes of the fastest were deemed worth considering. Needless to say, few if any trips were found in that excluded category.

When using the model to forecast facility usage, it is not necessary to find the most heavily used facility. The rating for each facility, being the dependent variable, is determined by the time, cost, and transfer differences. The share of the total traffic for each facility is the ratio of its rating to the sum of all the ratings.

Input Data Development

A few words are in order concerning the problems of data collection and handling. The Port Authority analysis zones (Fig. 3) were used. On the west side of the Hudson River, 92 zones were considered; on the east side, 69 zones. Included, then, were 6,348 O-D pairs. The entire model system was designed to consider only average weekday travel. The calibration process was based on 1964 data. The peak period (7 a.m. to 10 a.m.) was considered separately from the off-peak period. Travel times and travel costs had to be found for each of the O-D pairs for each time period for each of the 11 crossing facilities considered. In addition, six facilities required transfer values. To be added to this were the trip volumes for each cell, for each time period, and for each facility. The items of data totaled 494, 544, and therefore a high-speed digital computer was employed with a data bank and a battery of supporting programs having great flexibility.

The determination of the proper values to be placed in the data bank merits some attention. Auto trip data were taken from the continuous-sample O-D surveys taken at the Port Authority facilities and at the Tappan Zee Bridge. Bus trip data were based on O-D surveys taken at the two bus terminals. Rail trip data, including the PATH system, were synthesized from a PATH O-D survey, from O-D surveys of those rail lines involved in the Aldene Plan (Central Railroad of New Jersey; Pennsylvania Railroad, Shore Branch), from various conductor counts, and from the Manhattan Journey-to-Work Surveys taken in 1961-1962.

For auto times and costs, it was necessary to build peak and off-peak link-and-node networks. Travel time for each facility was calculated along the minimum-time path with all of the other trans-Hudson facilities removed from the system. Costs were found by skimming over those paths and were based on over-the-road costs of 2.8 cents per passenger-mile plus tolls and average parking costs.

The bus and rail time, cost, and transfer matrices were developed by adding rows and columns for what might be called a common-point network. Travel times were determined from each zone west of the Hudson to a Manhattan terminal (Penn Station, for example). Travel times then were determined from that terminal to each zone east of the Hudson. The same was done for costs and transfers. This depicted quite naturally how a bus or rail trip is made; and it was necessary only to add the rows and columns to determine the full i to j matrix of all time, cost, and transfer data.

The theory that travelers would show a preference toward a particular route, even if it was not superior according to our measures, was also set up for testing. By using a dummy variable for each facility, it was possible to determine if there was a significant bias toward a particular facility. It was theorized, for example, that bridges were preferred to tunnels, irrespective of small time and cost differences.

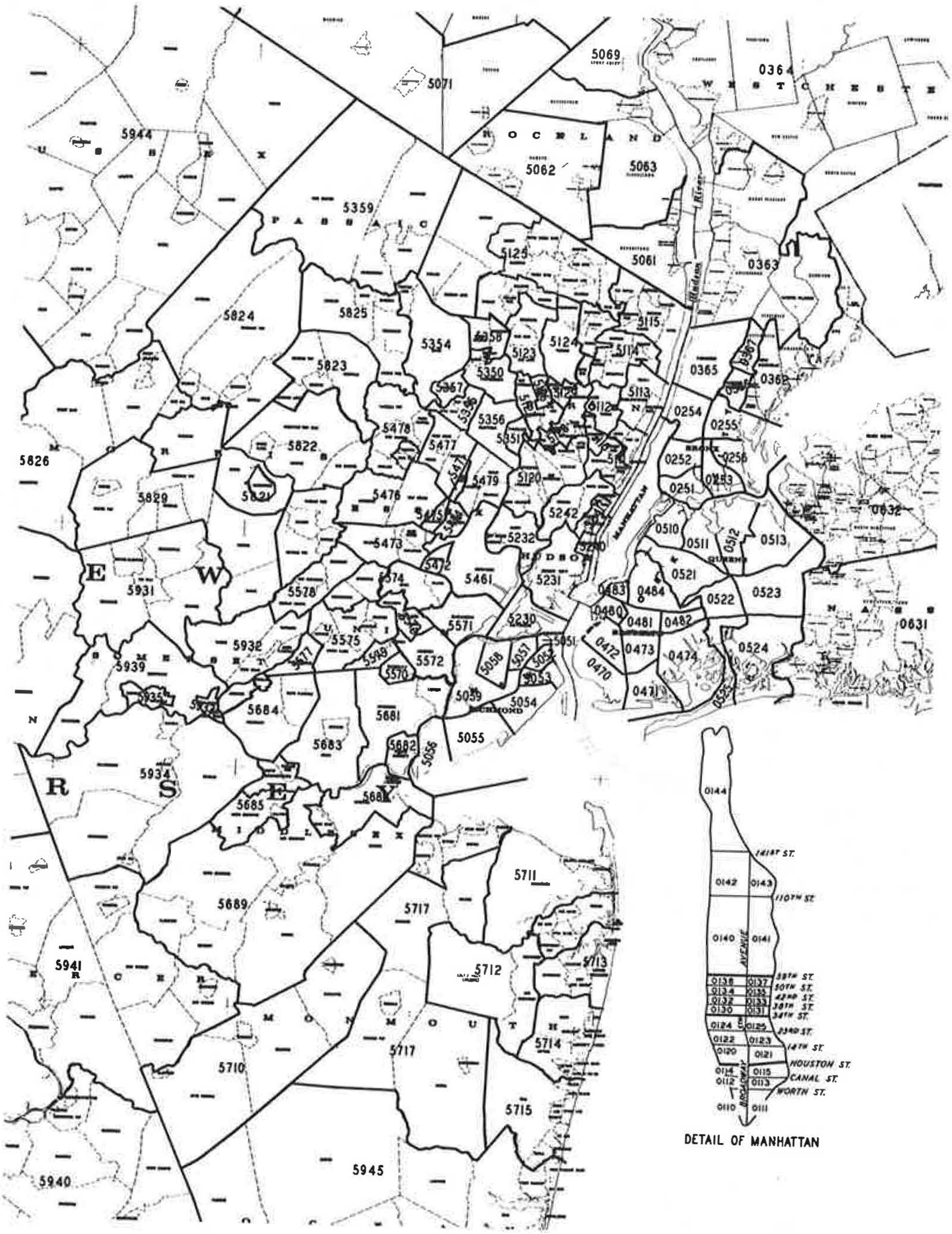

Figure 3. Port Authority analysis zones.

Model Development and Results

Many multiple-regression trials were run for each of the three travel modes. Data points were weighted in proportion to the modal trips in the O-D pairs, so that the less statistically reliable low-volume points were not heavily influential. The trials involved (a) testing linear and curvilinear forms, (b) the inclusion and the exclusion of the facility dummy variables, and (c) a further stratification of the data into trips oriented toward the central business district (CBD) and non-CBD-oriented trips. The resultant regression equations were studied for reasonable size and correct sign of coefficients. The final tests involved the application of the most promising equations to the total modal base-year trips and a subsequent analysis of the resulting differences from the sample O-D trip pattern to determine whether they reproduced the base year reasonably.

The chief findings of these regression trials were as follows:

1. The best form of the equations for the multiple correlation coefficient was $R = \exp[b1\Delta t + b2\Delta c + b3\Delta F + K]$;
2. Time differences were clearly the most significant determinant of route choice, particularly for the auto mode;
3. Cost differences were consistently the second most significant determinant;
4. Transfer differences were only significant for the rail model;
5. The CBD equations were significantly different from the non-CBD equations, with the exception of peak-period auto mode;
6. The auto allocation equations reproduced the assignment to the auto crossings fairly well but required small amounts of "fine tuning";
7. The bus allocation equations for the peak period did well in total assignment but were the result of large errors in isolated zones canceling one another out; those for off-peak period assigned very well; and
8. The rail equations assigned fairly well.

The vital statistics for the equations finally selected are given in Table 2. They are all of the exponential form just described. One equation was satisfactory for both the peak CBD and the peak non-CBD. When tried separately, the results were almost identical. Otherwise, the stratifications tried for each mode were significantly different from one another.

The facility dummy variables either indicated no biases that fit the possible theories previously set down or else did not improve the accuracy of the forecasting process. The authors had decided beforehand that for the auto mode there might exist a built-in preference for bridges rather than for tunnels. The results, however, were a crazy-quilt pattern of relatively insignificant coefficients of the dummy variables that neither confirmed this theory nor suggested a new one. For the rail mode, it was theorized that biases would favor the commuter railroads over the PATH facilities. Again, no

TABLE 2
ALLOCATION MODEL DATA

Mode	Time	Orientation	Weighted N (degrees of freedom)	Coefficients			K (constant)	R
				Δ Time (min)	Δ Cost (cents)	Δ Transfers		
Auto	Peak	CBD + non-CBD	9,267	-0.536	-0.073	—	-1.915	0.660
	Off-peak	CBD	5,367	-0.695	-0.038	—	-2.052	0.712
	Off-peak	Non-CBD	7,080	-0.624	-0.050	—	-1.277	0.688
Bus	Peak	CBD	4,817	-0.249	-0.063	—	+0.085	0.525
	Peak	Non-CBD	615	-0.386	-0.227	—	-0.781	0.481
	Off-peak	CBD	1,978	-0.324	-0.091	—	-0.275	0.450
	Off-peak	Non-CBD	1,099	-0.427	-0.160	—	-0.534	0.539
Rail	Peak	CBD	8,353	-0.360	-0.081	-1.399	-0.030	0.659
	Peak	Non-CBD	767	-0.557	—	—	-2.821	0.521
	Off-peak	CBD	2,843	-0.306	-0.077	-0.470	-0.642	0.469
	Off-peak	Non-CBD	1,510	-0.438	-0.162	—	-1.297	0.477

TABLE 3
VARIABLE EQUIVALENCES

Mode	Time	Orientation	Value of Time (cents/min)	Value of Transfer (cents)	Time Value of Transfer (min)
Auto	Peak	CBD + non-CBD	7.3	—	—
	Off-peak	CBD	18.3	—	—
	Off-peak	Non-CBD	12.5	—	—
Bus	Peak	CBD	4.0	—	—
	Peak	Non-CBD	1.5	—	—
	Off-peak	CBD	3.6	—	—
	Off-peak	Non-CBD	2.7	—	—
Rail	Peak	CBD	4.4	19.7	3.9
	Peak	Non-CBD	No equivalences, only time considered		
	Off-peak	CBD	4.0	—	—
	Off-peak	Non-CBD	2.7	6.1	1.5

clear pattern emerged. Only for the bus mode, where it was theorized that riders would prefer the PABT over the GWBBS, did some semblance of expected preferences hold. For the peak CBD bus model, a dummy variable showing such a preference entered the equation. When this equation, however, was used in an attempt to reproduce the base-year trips, it did not perform as well as the equation without the dummy variable.

Interpretation of Model Results

The variable equivalents given in Table 3 must be interpreted with great caution. Because of the nature of the exponential decay form of the models, these equivalencies are only applicable at the lower ranges of the independent variables. They do not apply at the higher ranges where the curves approach the ratings asymptotically. Table 3 does give some interesting information, however. It indicates that the automobile user places a greater value on time than does the public transportation user. This appears to be logical because his choice of the auto mode in the first place generally reflects his interest in time savings and his lack of concern for high costs. The lower value of time exhibited by the peak auto users as compared to the off-peak users also seems reasonable. This might reflect the user's perception of the accumulation of costs over five round trips each week that are common to the peak auto user. Presumably, saving a few cents each day is important enough to be acted upon. The off-peak auto user is more likely to be the occasional trans-Hudson traveler. In such cases, the most direct and fastest route is apparently considered first, and the occasional extra toll is not paid often enough to be weighed heavily in route selection.

The significance of transfers for the rail mode is worthy of note. For rail trips made to the CBD in the peak period, the equation states that when various routes present roughly equivalent choices, the elimination of one transfer will attract as much traffic as the decrease in time of about 4 minutes or the lowering of the fare by about 20 cents.

The series of models are shown as graphs in Figures 4, 5, and 6. The series of curves on the left column of graphs show rating versus Δc for a family of curves of Δt. The other graphs show the same data in the form of rating versus Δt for a family of curves of Δc. The rating scales for the curves were normalized to make the rating equal to 1.0 where Δt, Δc, and ΔF all equaled zero in order to simplify description of the meaning and use of the curves. The meaning of these curves can best be described by examples.

Consider a case where three auto facilities are available for a peak-period trip from i to j. Facility 1 requires a travel time of 45 minutes at a cost of 1 dollar; facility 2, 47 minutes and 90 cents; facility 3, 50 minutes and 80 cents. Time and cost differences would be calculated from the least time and the lowest cost, and the rating would be read from the graph as shown in Figure 7. The percentage of total traffic from i to j that

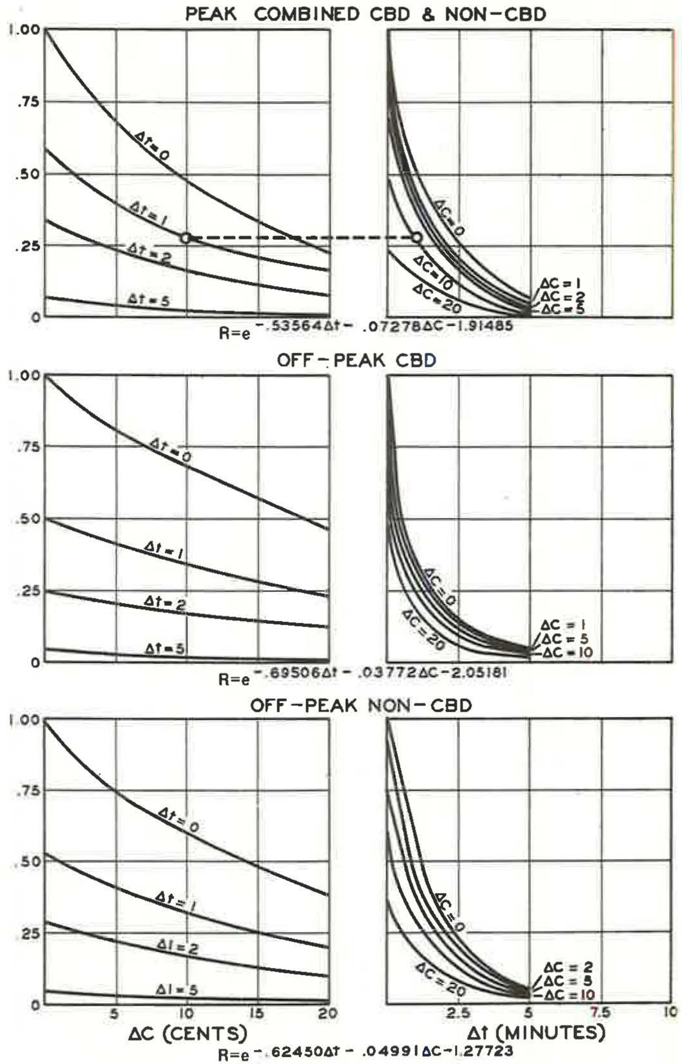

Figure 4. Auto allocation models.

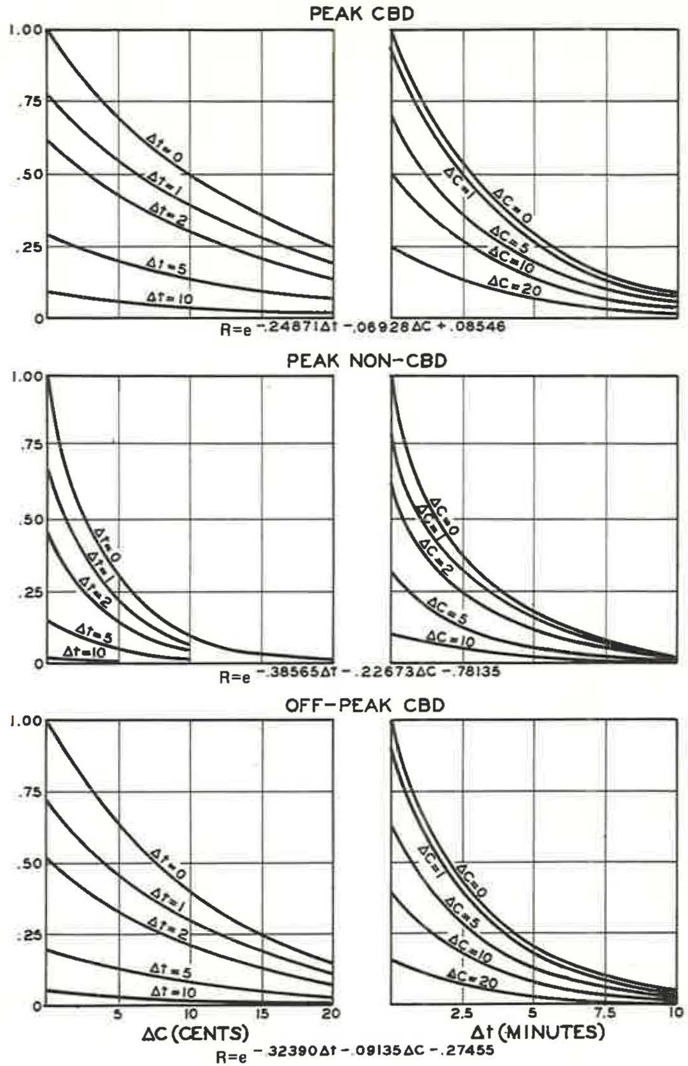

Figure 5. Bus allocation models.

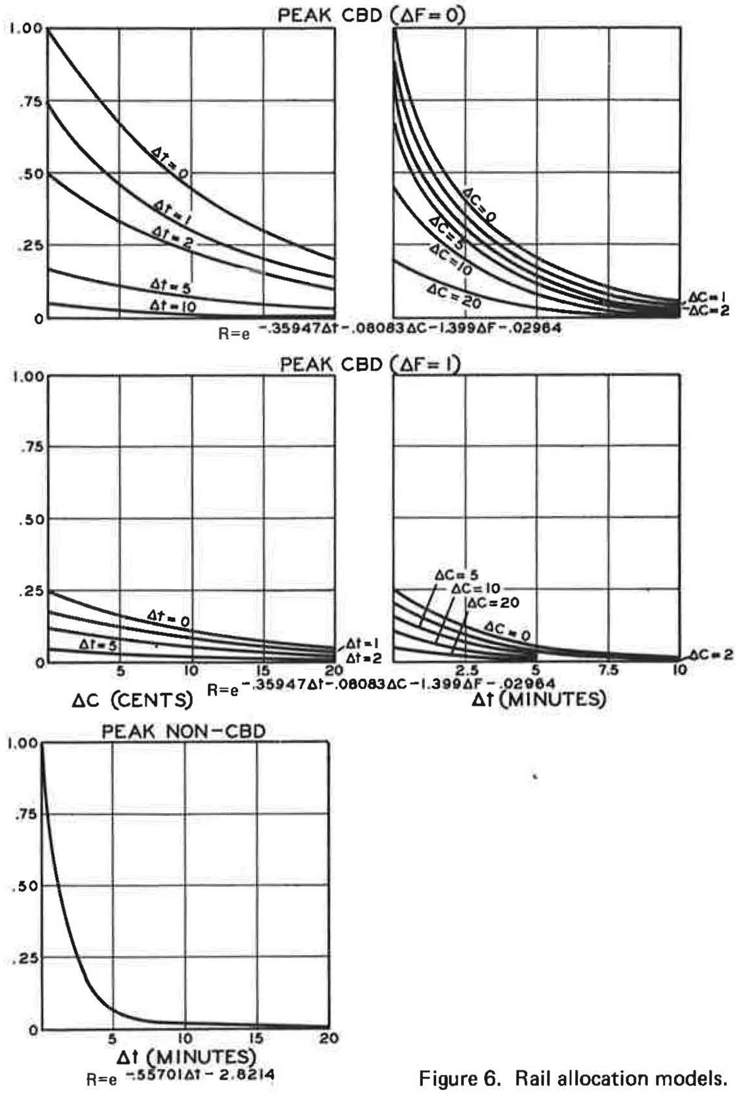

Figure 6. Rail allocation models.

each facility would be assigned would be calculated by dividing its rating by the sum of all ratings as given in Table 4. Note that the fastest but most expensive facility received the largest share of the traffic. Should travel via facility 1 then be slowed by only 2 minutes, the redistribution of traffic as in the second group of data would result. In this case, facility 2 captures the largest share of the traffic. This example indicates that the auto user will prefer the fastest facility even if it is more expensive. Only when times are nearly identical will cost become the determining factor.

Another example can be shown using the peak CBD rail curves (Fig. 8). Assuming three competing facilities with travel times of 60 minutes, travel costs of 60, 80, and 70 cents respectively, and with one additional transfer required for travel via the third facility, we obtain the distribution given in Table 5. If travel via facility 3 were made direct, without a transfer, the second group of results in Table 5 would be obtained. The removal of that transfer has enabled facility 3 to more than triple its share of the traffic. It also can be seen that facility 1 retains the majority of the traffic on the basis of its lower cost alone.

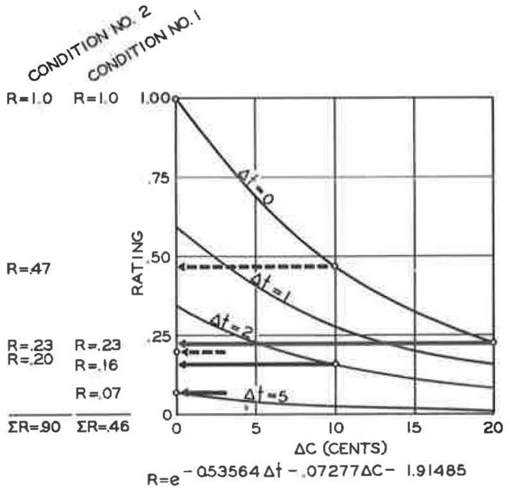

Figure 7. Peak auto model (combined CBD and non-CBD) example of use.

TABLE 4

CURVE APPLICATION: EXAMPLE 1

Facility	t	c	Δt	Δc	R	Share (percent) (R/ΣR)
1	45	$1.00	0	20	0.23	50
2	47	0.90	2	10	0.16	35
3	50	0.80	5	0	0.07	15
					ΣR 0.46	
1	47	1.00	0	20	0.23	26
2	47	0.90	0	10	0.47	52
3	50	0.80	3	0	0.20	22
					ΣR 0.90	

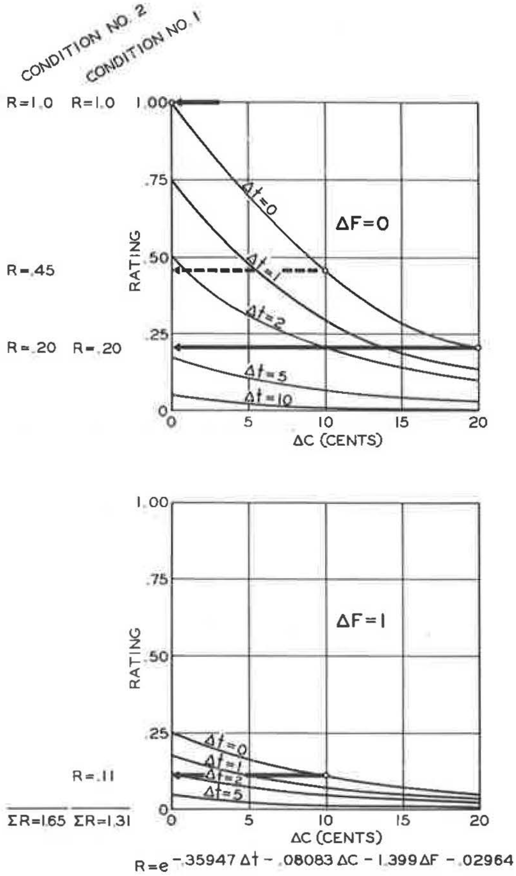

Figure 8. Peak rail model (CBD) example of use.

Trial Runs of the Models

Before it is possible to accept the model as a forecasting tool, it is necessary to see how well it predicts the base-year trips. This was done for a series of models; the end result was the acceptance of the models described but with some adjustments. In analyzing the results of the predictions, the volumes assigned to each facility were compared

TABLE 5

CURVE APPLICATION: EXAMPLE 2

Facility	t	c	F	Δt	Δc	ΔF	R	Share (percent) (R/ΣR)
1	60	60	1	0	0	0	1.00	77
2	60	80	1	0	20	0	0.20	15
3	60	70	2	0	10	1	0.11	8
							ΣR 1.31	
1	60	60	1	0	0	0	1.00	61
2	60	80	1	0	20	0	0.20	12
3	60	70	1	0	10	0	0.45	27
							ΣR 1.65	

TABLE 6

COMPARISON OF ASSIGNMENTS: AUTO

Method	Number of Trips					
	GWB	LT	HT	SIB	TZB	Total
Peak:						
Actual	23,560	11,159	3,214	2,770	5,205	45,909
Minimum time	24,868	11,106	2,679	2,424	4,834	45,909
Model	24,993	10,612	3,179	2,535	4,590	45,909
Model "tuned"	23,675	11,677	3,269	2,540	4,749	45,909
Off-peak:						
Actual	62,301	33,045	25,013	14,808	8,916	144,083
Minimum time	76,626	28,270	19,195	13,809	6,595	144,493
Model	72,892	29,087	22,124	14,175	6,259	144,489
Model "tuned"	63,883	34,766	24,067	14,235	7,259	144,214

to the actual volumes. However, this was not sufficient. It was also necessary to compare the results at a finer grain to determine whether the county-to-county or even zone-to-zone volumes compared well. It is at this level that problems were uncovered. Tables 6 to 8 give the total volume comparisons. In each case, the actual trips are shown on the first line and the trips assigned via the minimum-time-path method are shown on the second line. The latter was tried in order to examine the results that would be obtained by the more standard all-or-nothing method. Subsequent lines show the results of the key runs of the models.

For the auto assignments (Table 6), the model produced assigned volumes similar to the minimum-time-path assignment for the peak and performed somewhat better in the off-peak. This indicated what we had already come to know. The auto user is so heavily influenced by time that the minimum-time path is not all that bad. Nevertheless, having cost in the model does play some part in the assignment and makes the model available for testing cost or price changes. "Fine tuning" of the auto models involved an addition of an arbitrary time delay at one facility that was consistently overpredicted. Although this might have been considered a network correction, we could, in all honesty, find no justification from the observed field data to make this change.

The bus assignments are given in Table 7. As described earlier, the peak bus model had been tried with a dummy variable to explain the preference for the PABT. The data in Table 7 show that both

TABLE 7

COMPARISON OF ASSIGNMENTS: BUS

Method	Number of Trips		
	GWBBS	PABT	Total
Peak:			
Actual	11,268	47,577	58,845
Minimum time	8,972	49,873	58,845
Model with dummy	9,776	49,068	58,845
Model without dummy	10,651	48,194	58,845
Off-peak:			
Actual	10,706	32,366	43,072
Minimum time	9,222	33,850	43,072
Model	10,548	32,510	43,058

TABLE 8

COMPARISON OF ASSIGNMENTS: RAIL

Method	Number of Trips				
	PRR	HT	PUP	CNJ	Total
Peak:					
Actual	7,593	26,060	13,153	7,878	54,684
Minimum time	8,050	24,864	12,548	9,196	54,658
Model	7,442	25,962	12,532	8,722	54,658
Off-peak:					
Actual	2,648	9,854	5,998	390	18,890
Minimum time	1,341	10,136	6,616	798	18,890
Model	2,842	9,669	5,218	988	18,729

the use of this dummy variable and the use of the minimum-time path did not yield as close an agreement with the actual volumes as did the model selected. The data are deceiving, however. The close agreement of the model in total masks some large zones that fit very poorly but cancel one another out. It was concluded that the differential frequency of service is probably the factor missing from the allocation model. The off-peak bus model results fit very well in total as well as at the zonal level.

The rail assignments are given in Table 8. The minimum-time path assignment, which looks good in total, particularly for the peak, was very poor when individual zones were observed. This is no surprise because the model has shown that cost and transfers can play a significant role. The model assigned extremely well with only small difficulties related to the CNJ. These were in large zones or in zones where parallel competing services existed. In both instances, it was impossible to accurately describe the differences in service with the variables used. Because the CNJ system has been drastically revamped since the base year, the inaccuracy was of minor concern.

MODEL IMPLICATIONS

The modeling effort just described has provided us with a forecasting tool and with some knowledge concerning the relation of transportation network variables and trip route choice. Recognizing the imperfectness of fit in these relationships, however, can also be considered as knowledge gained.

The fact that auto assignment from the model differed only slightly from an all-or-nothing minimum-time assignment indicates that minimum time might be a reasonable method of allocating auto trips. It also shows that the model developed is highly reactive to time changes and is much less so to cost changes. Although this corroborates the results of other investigations on this subject, the exact value of the cost coefficient and the relation of the cost and time variables should be treated very carefully.

The bus allocation models showed that both time and cost differences proved significant, with the latter having far greater effect than they did in the auto model. Some index of convenience, however, such as frequency of service might have added to the quality of these models. Unfortunately, the data base that governed the zone description made it impractical to accurately describe a frequency variable.

The rail allocation models suggest a relation between time and cost similar to that of the bus allocation models. They further suggest a relatively strong reaction to the number of transfers. Because the transportation system from which the models were derived frequently requires at least one transfer (to the New York City subway system) and because this transfer involves additional cost, it is suggested that cost and transfers might be closely associated. Nevertheless, based on the rail system in this area, the model suggests that a rider might be more willing to pay an additional cost than to add time to his trip to avoid a transfer; and this appears to be reasonable.

The reader should remember that the models described herein are route-choice models, not modal-choice models.

In using any of the relationships, the modeler must be aware of the assumption implicit in all such efforts. There is no guarantee that the relationships derived for the base year are necessarily valid for forecast years. In recognition of this limitation, the Port Authority is engaged in a continued effort to update both the data input to the series of models sketched earlier and the modeling procedures themselves. Data for base year 1968 are now in the early stages of preparation.

ACKNOWLEDGMENT

The work described in this paper was developed jointly by The Port of New York Authority and the Traffic Research Group of Peat, Marwick, Livingston and Company, where Mr. Zupan was employed at the time of this work.

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