accumulation has important effects which it is unrealistic to ignore. This left me stymied, since I was unable to work out the mathematics that would take care of the additional complications.

Tanner developed the same formula independently. Since he was interested in pedestrians, who can cross in groups, the question of accumulation did not lead him into any special complications.

Still another application of this formula can be tested by the author's own data. In Figure 5 he shows a set of intervals which he calls "*blocks*".[1] They are the intervals which separate one acceptable gap from another. It can be proved mathematically (*3*) that the lengths of these blocks are distributed in exactly the same way as the waiting times, even though there is no connection between a particular block and a particular waiting time. The absence of such a relation is clear from Figure 5, which suggests a 9-percent probability of waiting more than 5 seconds as compared with zero probability that a block will be longer than 5 seconds.

Table A compares values computed from the formula with the author's data shown in the lower half of Figure 6. They are in close agreement.

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[1] These are not the same as the intervals called blocks in Reference 3, but they are closely related.

Traffic Operation at Vehicle Tunnels

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OVER the past few years traffic movement studies have been made by the Port of New York Authority in an effort to obtain better traffic operation and to increase peak-hour capacity of its vehicle tunnels. This paper is a report of some of these studies pertaining to the efficiency of toll collection in the toll-booth lanes, the manner of feeding traffic to the tunnel lanes, and the characteristics of flow through the tunnels.

Studies comparing the efficiency of right-hand and left-hand toll booths (a left-hand booth is one on the drivers' side of the vehicle) showed that from 1 to 1.5 seconds additional time is required for the toll time in right-hand lanes. For example, passenger cars required 3 seconds toll time in left-hand and 4 seconds in right-hand lanes. Total time for movement of a passenger car through a toll lane was found to require 8 and 9 seconds, respectively, for left-hand and right-hand lanes. Another study compared the effectiveness of left- and right-hand booths at various traffic volumes. It was found that motorists avoid right toll lanes when left-hand lanes are available. At low traffic volumes a right-hand lane was only 20 percent as effective as a left, and at heavy volumes 69 percent as effective.

Studies of the feeding of traffic into the tunnel lanes from a full storage plaza showed that self-merging of traffic lanes increases the peak-hour capacity of a tunnel. The old method was a straight officer feed of plaza lanes. Complete self-feed was first tried with up to four lanes of traffic being merged to a tunnel lane. This was later modified to have officer feed of two lanes simultaneously, because of the traffic-accident increase experienced. This change in the method of feed has increased the peak-hour capacity of the Lincoln Tunnel by an average of 50 vehicles per hour in the two-lane tunnel.

The flow of traffic through the tunnel was studied by simultaneously recording the speed and density of traffic at nine points. It was found that the slowest movement in the tunnel was at the entrance portal and at the foot of the tunnel downgrade. This latter slow point appeared to restrict the capacity of the tunnel. Slowing at this point appeared to result from: (1) the failure of motorists to provide more power to compensate for the force of the downgrade, when reaching the level section of the tunnel, and (2) braking which occurs in this area, because the downgrade momentum causes vehicles following one another to approach too closely the preceding vehicles.

● THE invitation to present a paper was willingly accepted by The Port of New York Authority as an opportunity to report the results of traffic studies conducted in 1952. These studies were aimed at particular traffic problems in an effort to obtain better traffic operation and to increase peak-hour capacity of our tunnels.

Figure 1 is a map of a portion of New York City and adjacent New Jersey across the Hudson River. The Holland Tunnel connects Canal Street in Manhattan with US 1 in Jersey City. It was opened to traffic in 1927 and has a two-lane tube in each direction.

The Lincoln Tunnel connects mid-Manhattan with New Jersey Route 3 in Weehawken, New Jersey. Like the Holland Tunnel, it has one two-lane tube in each direction. It was opened to traffic in two stages, one tube in 1937 and the second in 1945. At the present time a third tube for the Lincoln Tunnel is under construction.

Other major vehicle tunnels are the Queens Midtown Tunnel connecting Manhattan with Queens, and the Brooklyn Battery Tunnel connecting Manhattan with Brooklyn. Both of these tunnels are operated by the Triborough Bridge and Tunnel Authority, a New York City agency.

Our studies are chiefly concerned with the Lincoln Tunnel. Figure 2 shows the New Jersey plaza of the Lincoln Tunnel. The tolls collection for traffic in both directions is combined on this plaza. This is a desirable feature, because it simplifies tolls supervision and permits flexible use of toll lanes to meet directional demands. There are 12 toll lanes on this plaza and it is approximately 550 feet from the tunnel portal to the toll booths.

Figure 3 is a picture inside the Lincoln Tunnel showing the two-lane 21½-foot brick roadway and the so-called catwalk used by traffic officers posted throughout the length of the tunnel. The lane adjacent to the catwalk is referred to as the fast lane and the other lane the slow lane. The maximum grades

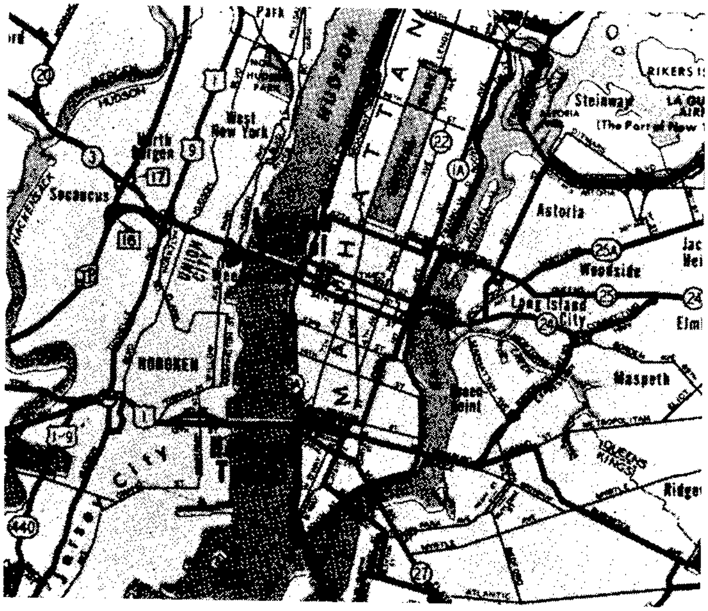

Figure 1.

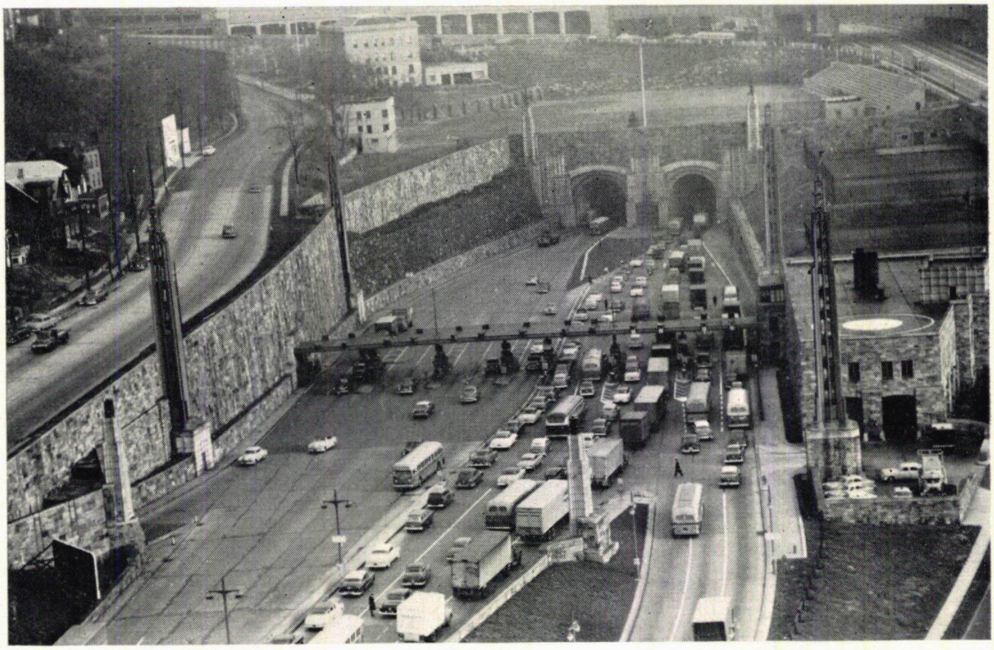

Figure 2.

Figure 3.

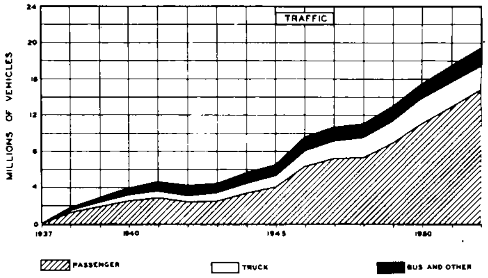

Figure 4. Lincoln Tunnel.

in the Lincoln Tunnel are 4.5 percent in the north tube and 3.5 percent in the south tube.

Figure 4 is a traffic chart showing the Lincoln Tunnel traffic composition and growth since the date of its opening. Both the Holland and Lincoln Tunnels have been operating at capacity during daily peak periods for several years. In fact, they now operate at capacity in both directions during evening peak hours.

This chart shows passenger-car volumes cross-hatched, truck volumes in white, and bus volumes in black. The composition of the 19½ million vehicles using the Lincoln Tunnel in 1952 was 76.2 percent cars, 9.6 percent buses, and 14.2 percent trucks. This represented an average daily traffic of 53,600 vehicles with approximately 25 percent commercial traffic. The usual peak-hour volume for each two-lane tunnel is 2,000 to 2,300 vehicles, dependent on traffic composition. A typical peak-hour composition might be 65 percent cars, 20 percent buses, and 15 percent trucks.

At the Holland Tunnel, morning counts in November of 1953 showed that eastbound traffic was 47 percent trucks. The slow lane of the tunnel carried 99 percent trucks and the fast lane 22 percent. In the slow lane, trucks with three axles or over constituted two thirds of the traffic. This tremendous truck load has reduced the normal peak-hour one-way capacity of the Holland Tunnel to 1,600 to 1,800 vehicles per hour.

A logical order to take up the traffic studies is to imagine a motorist proceeding through one of our tunnels. Normally he first encounters a toll lane. Our Operations Standards Division of the Department of Operations has studied toll-booth operation to devise the most-efficient method to man toll booths. Field studies were made and determined backup, rate of arrival, and occupancy of toll lanes with various combinations of right-hand and left-hand toll lanes. We term a left-hand toll lane one in which the toll transaction is conducted on the left-hand side or driver's side of the car. From this field information, analysis was made to determine desirable service standards for toll collection, accuracy of traffic prediction, efficiency of right- and left-hand toll booths, and the expected traffic volumes for each hour of the day and the consequent number of toll booths required to handle this volume at the established service standard. The analysis was of considerable scope and compared observed traffic volumes and backup with that indicated by Poisson and normal curve distribution.

Table 1 summarizes a separate study made to compare left- and right-hand booth operation with different types of vehicles. As used in this table, *holding time* is composed of two elements: *vehicle time*, which is the time required for a vehicle to advance to the collection location after the preceding vehicle de-

TABLE 1
BOOTH HOLDING TIMES DURING PEAK TRAFFIC

Type Vehicle	Type Toll Lane LH or RH	Vehicle Time	Toll Time	Total Time
		sec.	*sec.*	*sec.*
Passenger car	LH	5	3	8
Bus	LH	6.5	3	9.5
Truck	LH	6	5	11
Tractor trailer	LH	7.5	6.5	14
Passenger car	RH	5	4	9
Bus	RH	6.5	4	10.5
Truck	RH	6	6.5	12.5
Tractor trailer	RH	7.5	8	15.5

VEHICLE TIMES

Type Vehicle	Av. Length	Clearance	Tot. Distance
	ft.	*ft.*	*ft.*
Passenger car	17	5	22
Bus	35	5	40
Truck	25	5	30
Tractor trailer	45	5	50

Type Vehicle	Acceleration		Deceleration		Total	
	Dist.	Time	Dist.	Time	Dist.	Time
	ft.	*sec.*	*ft.*	*sec.*	*ft.*	*sec.*
Passenger car	11	2	11	3	22	5
Bus	21	3	19	3.5	40	6.5
Truck	16	2	14	4	30	6
Tractor trailer	27	3	23	4.5	50	7.5

parts; and *toll time*, the time required to complete the toll transaction while the vehicle stands opposite the booth. Vehicle times in this table are those determined by Greenshields, Schapiro, and Ericksen in Technical Report 1 of the Yale Highway Traffic Series and are identical for left-hand and right-hand lanes. Toll times were obtained by stopwatch timing over a 15-hour period. Except for tractor-trailer combinations, over 200 observations were made of each type passage. Ninety right-hand and 99 left-hand tractor-trailer observations were made.

As seen, toll time was found to be greater for right-hand booths for all types of vehicles. For example, cars required 3 seconds for the toll transaction in left-hand lanes compared to 4 seconds in right-hand lanes. With the total holding times shown in this table and knowing the percentage composition of traffic, it is possible to compute the capacity of a right-hand or left-hand lane. Assuming a composition of 64 percent cars, 15 percent buses, 14 percent trucks, and 7 percent tractor-trailer combinations, a left-hand booth is computed to carry 400 vehicles per hour compared to 350 for a right-hand booth. These capacities compare well with our operating experience. It should be noted that the toll time will vary with the complexity of a toll schedule. At the port authority, we have approximately 12 toll classifications.

Table 2 offers a comparison of the effectiveness of four left-hand lanes against three left-hand and one right-hand lane, and summarizes 4 hours of observations at the George Washington Bridge and the Lincoln Tunnel. The percent occupancy represents average occupancy of the toll lanes when recorded at 30-second intervals. The delay ratio equals the amount of time a vehicle is delayed beyond the average time required to stop and pay a toll, divided by this average toll collection time. In other words, where the delay ratio is shown as 2.00, vehicles were required to wait in line twice as long as was required for the toll time. So it is seen that delay was consistently greater with the three-left-one-right combination and that the increase in delay was about 50 percent. This 50-percent increase with one right-hand lane instead of one left-hand lane is obviously not solely due to the additional toll time required in the right-hand lane, but is due mainly to the fact that drivers avoid right-hand toll booths because of the inconvenience associated with them. The second half of the table confirms this, as for a given delay ratio, the percent occupancy of four left, and three left and one right-hand booths are compared and it is seen that the same delay ratio consistently occurs at a lower occupancy in the combination of three left and one right. The last column shows that as delay increases motorists will accept a right-hand booth more readily and its value approaches that of a left-hand booth. With a delay ratio of 0.40 the right-hand booth is only 20 per cent as effective as a left-hand, but at a 2.00 delay ratio, the right-hand booth is 69 per cent as effective.

An associated problem that we have encountered with right-hand booths is that in avoiding them, a line of vehicles backed up at a left-hand booth, will block the use of other booths.

Because of the above findings, the port authority is now installing only left-hand booths in new construction on main plazas and doing this even though fewer left-hand lanes can be fitted into a given width. For example, we are providing 16 left-hand lanes rather than 18 right-hand and left-hand lanes in revising the George Washington Bridge toll plaza. The left-hand lanes require more width because a toll-booth island is required for each lane. With left- and right-hand lanes one toll-booth island can be used for two lanes.

TABLE 2
DELAY RATIOS
Comparison of 4L with 3L-1R Booths

Percent Occupancy	Delay Ratio		Percent Increase in Delay
	4L	3L-1R	
			%
50	0.40	0.60	50
60	0.60	0.85	41
70	0.85	1.25	47
80	1.25	1.80	44
90	2.00	3.00	50

Delay Ratio	Percent Occupancy		Value of RH Booth Compared to LH
	4L	3L-1R	
			%
0.40	50	40	20
0.60	60	50	33
0.85	70	60	43
1.25	80	70	50
2.00	90	83	69

Once through the toll lanes the next problem a driver has is to merge with traffic from other toll lanes and enter one of the two tunnel lanes. Six or seven toll-booth lanes are required to feed two tunnel lanes, and it is necessary to have a traffic storage area beyond the toll booths to insure that sufficient traffic to fill the tunnel is continuously supplied. From this storage area, which can be seen in Figure 2, we formerly had been using officer control to feed the various lanes of traffic from a holding line to the tunnel lanes. Two officers worked at this line, one feeding traffic to the fast lane and one feeding traffic to the slow lane.

However, another vehicle tunnel in New York, the Queens Midtown Tunnel, had begun using what they termed a self-feed operation. In this scheme officer control was eliminated as well as a holding line, and traffic was simply merged from the toll lanes into the tunnel lanes. Stanchions and rubber traffic cones were used to converge three toll lanes into each of the tunnel lanes. This method appeared to feed traffic to the tunnel more continuously, so we made an hour study at the Lincoln Tunnel and Queens Midtown Tunnel to compare this self-feed method with officer control. A portion of the observations at the Lincoln Tunnel are shown in Table 3. Volumes were recorded at 1-minute intervals and gaps in traffic at the tunnel portal of 4 seconds or over were timed with stopwatches. The third column from the right lists individual gaps observed. These gaps existed despite a 350-foot distance between the holding line and the portal, in which platoons of traffic fed by the officers would be expected to catch up with a preceding platoon. In contrast to the gaps observed in traffic at the Lincoln Tunnel portal, the observations at the Queens Midtown Tunnel showed no gaps occurred under the self-feed method.

TABLE 3

TRAFFIC FEED STUDY

Lincoln Tunnel, Fast Lane, South Tube

Time	One Minute Volumes	Length in Seconds of Excessive Time Gaps	Total of Gap Lengths, Seconds
5:01	21	7	7
02	20	4, 7, 8	19
03	25	6	6
04	21	4, 6, 10	20
05	19	9, 4	13
06	25	8, 7	15
07	22	4, 13	17
08	11	—	—
09	24	—	—
10	12	13, 5, 14	32
11	19	—	—
12	26	7	7
13	21	8	8
14	22	—	—
5:15	8	—	—
Total	296		144

The fact that gaps did occur under the Lincoln Tunnel officer-feed operation did not prove it was affecting the capacity of the tunnel, because it could be argued that these large gaps were closed as the vehicles proceeded through the tunnel. A comparison of the volume of traffic in each tunnel during the 1-hour counts did show that the Queens Midtown Tunnel carried a much-higher volume. Table 4 summarizes the 1-hour counts and shows the classification of traffic by lane, for each tunnel. If the findings of the Highway Capacity Manual are applied to each tunnel with this composition, the Lincoln Tunnel with about 20 per cent of commercial traffic should carry 2,140 vehicles per hour, whereas the Queens Midtown Tunnel with 10 per cent commercial traffic should carry about 2,620 vehicles per hour. In these calculations a factor of 85 per cent was used for lane width plus edge clearance, and a factor of 63 per cent at the Lincoln Tunnel and 77 per cent at the Queens Midtown Tunnel for per cent of commercial traffic.

The self-feed system was installed at the Lincoln Tunnel and watched closely. A check of peak morning and evening traffic volumes by day of week for a 1-month period before and after showed that in all but one case volumes had increased after installation of the self-feed system. The hourly increase varied from 4 to 160 vehicles per hour.

A bad effect that quickly became apparent was a sharp increase in traffic accidents in the area where traffic merged to enter the tunnel. We had been experiencing 5 to 8 accidents here each 3 months. During the first 3 months of the self-feed operation, 33 accidents occurred in this same area. In addition to the accident rise, the public did not like the three-lane competitive merge to a single lane, especially when trucks and buses were included in the contest. The accident question had been raised with the Queens Midtown Tunnel before installation of self-feeding, but they had reported that they experienced no acci-

TABLE 4

LINCOLN TUNNEL-QUEENS MIDTOWN TUNNEL PEAK HOUR FLOW COMPARISON, JUNE, 1952

Legend: C—Cars, B—Buses, T—Trucks

	Lincoln Tunnel Eastbound 5:00–6:00 P.M., Tuesday, June 3, 1952				Queens Midtown Tunnel Westbound 8:30–9:30 A.M., Tuesday, June 17, 1952			
	C	B	T	Total	C	B	T	Total
Fast Lanes								
0–15	243	47	6	296	363	0	3	366
15–30	194	54	3	251	370	1	2	373
30–45	121	39	6	166	381	2	4	387
45–60	212	62	3	277	360	0	5	365
Tot.	770	202	18	990	1474	3	14	1491
	77.8%	20.4%	1.8%	100.0%	98.9%	0.2%	0.9%	100.0%
Slow Lanes								
0–15	187	—	44	231	262	0	39	301
15–30	218	—	26	244	254	5	64	323
30–45	172	—	34	206	304	2	144	350
45–60	232	—	48	280	242	1	67	310
Tot.	809		152	961	1062	8	214	1284
	84.2%	0.0%	15.8%	100.0%	82.8%	0.6%	16.6%	100.0%
Totals								
	1579 80.8%	202 10.3%	170 8.9%	1951 100.0%	2536 91.4%	11 0.4%	228 8.2%	2775 100.0%

dent problem. The difference in experience was apparently due to the greater number of large commercial vehicles at the Lincoln Tunnel.

We next tried to eliminate our accident problem by using stanchions and cones to create two merging movements of two lanes to a single lane rather than one merging movement of four lanes to a single lane. This was not found successful, because it increased the number of merging movements and tended to favor toll lanes which had the most-direct alignment with the tunnel lanes.

Our next change was to establish a new holding line about 5 car-lengths from the booths, with traffic officers at this line feeding two lanes of traffic simultaneously to each tunnel lane. We thereby were able to take advantage of the continuous self-merging of two lanes of traffic and still retain an orderly and equal flow from the toll lanes. Accidents have dropped to about 15 for 3 months, and these are generally of a minor type, which do not result in sufficient damage to even require reporting to the state motor-vehicle department.

TABLE 5

LINCOLN TUNNEL EASTBOUND PEAK HOURS

Sat., Sun., Holiday Excluded, Average for Respective Day of Week Before and After Self Feed System

Before, March–June 1952		After Sept.-Dec. 1952		Increase	
Days	Average	Days	Average	Vehicles	%
A.M. Peak Hour					
18 Mon.	2,095	16 Mon.	2,137	42	2.00
18 Tues.	2,065	16 Tues.	2,119	54	2.62
18 Wed.	2,103	18 Wed.	2,155	52	2.48
18 Thurs.	2,112	15 Thurs.	2,154	42	1.99
16 Fri.	2,121	17 Fri.	2,166	45	2.12
88	2,099	82	2,146	47	2.24
P.M. Peak Hour					
18 Mon.	2,147	16 Mon.	2,191	44	2.05
18 Tues.	2,167	16 Tues.	2,219	52	2.40
18 Wed.	2,148	18 Wed.	2,186	38	1.77
18 Thurs.	2,184	15 Thurs.	2,269	85	3.89
16 Fri.	2,218	17 Fri.	2,269	51	2.30
88	2,172	82	2,226	54	2.49

Table 5 presents a 4-month before-and-after study of the effect of the self-feed system on peak-hour traffic volumes. Peak traffic hours were listed for morning and evening peaks each weekday, and these were averaged for the 15 to 18 such weekdays in the 4-month periods. As seen in the next-to-last column, the increase varied from 38 to 85 vehicles per hour and the overall average was about 50 vehicles per hour.

A comparison of the volume and composition of traffic during the 8 months studied was made to determine if a change in the composition of traffic might have been responsible for the higher peak hours in the after period. This was found not to be the case, as commercial vehicle use of the tunnel during the after period was slightly greater than during the before period and tractor-trailer usage increased 11 per cent.

Our last consideration after passing the toll booths is the manner in which traffic flows through the tunnel. This study was an extension of our comparison study of the traffic flow at the Lincoln Tunnel and the Queens Midtown Tunnel. Figure 5 summarizes the data obtained at the Lincoln Tunnel. What we wanted to explore was the variation in speed and density of traffic at points through the tunnel. The field work was done by a group of nine trainees, so it was possible to simultaneously cover nine stations in the tunnel. At each station a 100-foot course was laid out in the fast lane, so that speeds could be measured by the stopwatch method. It was also possible to obtain a measure of the density of traffic by noting how many vehicles were within the 100-foot course after each speed observation. A vehicle was considered within the course if its front wheels had entered the course. The stations were selected to fall at points of grade change, in addition to the entrance and exit portals. During the 1-hour period of the study, the number of speed observations varied from 113 to 234 at the various stations with an average of 185 per station. In the similar study at the Queens Midtown Tunnel, 204 to 353 observations were made at the various stations with an average of 270 per station.

The survey technique in measuring the density of traffic was admittedly not precise, and the speed observations were subject to human error common to stopwatch timing. However, the survey personnel were all college graduates who were interested in the work, and the summarization of the data obtained indicates that their work was accurate.

The lower graph in Figure 5 shows the vertical alignment of the tunnel with the entrance portal at the zero point and the exit portal at the 8,250-foot point. The south tube of the Lincoln Tunnel has a 3.5 percent downgrade and a 2.8 to 3.5 percent upgrade. In between the lower and upper graphs the horizontal alignment of the tunnel is shown. For example, beginning at the entrance portal there is a 650-foot-radius right curve approximately 1,000 feet long, as indicated by the horizontal scale. In the upper graph, speed curves show

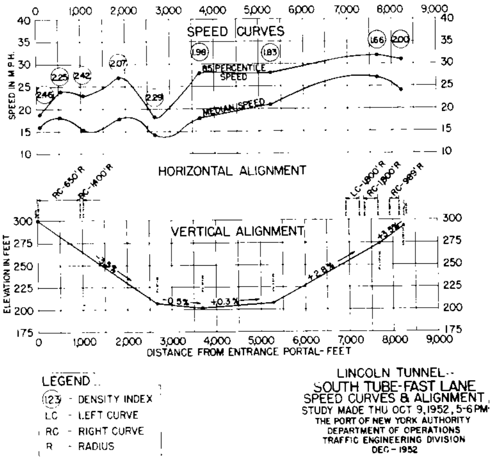

Figure 5.

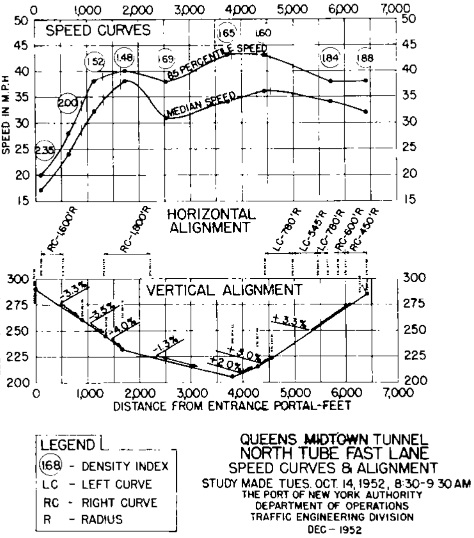

Figure 6.

the 85-percentile and median speeds at the survey stations. Also shown at each station in a circled figure is the density index. This index is simply the average number of cars observed in the 100-foot course. It was assumed that a bus was equivalent to two cars in computing this average.

The survey was made during capacity operation and traffic to the tunnel was being fed by the self-feed method. Traffic entered the tunnel at its maximum density and at a slow speed. Traffic speeds then increased and the density decreased on the tunnel downgrade. Our problem then appears near the foot of the 3.5-per cent downgrade, where speeds dropped to their minimum and density increased. From this point on, speed increased through the remainder of the tunnel, except for a slight decrease at the exit portal of the tunnel. This increase in speed occurred despite a volume of 20 percent buses, the 3.5-percent upgrade, and a 4-percent grade on the exit plaza outside of the tunnel. The top speeds in the tunnel were recorded at the station about 1,000 feet inside of the exit portal where the 85-percentile speed was 32 mph. and the median 27 mph. The minimum speeds were an 85-percentile speed of 18 mph. and a median speed of 14 mph, which occurred at the foot of the downgrade. This 85-percentile speed was about 10 mph. less than at the stations on each side of the foot of the downgrade and is a measure of the severe slowing at that point.

Figure 6 presents the identical information for the fast lane of the Queens Midtown Tunnel. Remember that traffic in this lane is almost 100 percent passenger cars, and note the series of comparatively sharp horizontal curves approaching the exit. Traffic enters the Queens Midtown Tunnel at much the same speed and density as it does at the Lincoln Tunnel. Then it shows a sharp rise in speed and decrease in density which is not nearly as adversely affected at the foot of the principal downgrade as was noted in the Lincoln Tunnel. Speed then increased to a maximum at about 2,000 feet from the exit portal, after which the series of sharp curves caused a decrease in speed. The maximum speeds in the Queens Midtown Tunnel were an 85-percentile of 43 mph. and a median of 38 mph., which oddly did not occur at the same station. The minimum speeds in the Queens Midtown Tunnel occurred at the entrance portal where the 85-percentile speed was 20 mph. and the median speed 17 mph.

What in brief does this comparison study show us? It shows that a steep downgrade causes a restriction to capacity in the vicinity of the foot of the tunnel downgrade. This was clearly apparent in the Lincoln Tunnel, and we believe can be explained by two happenings: First, in traveling through a tunnel it is difficult to tell whether you are on a grade or not and drivers do not provide the extra gas when reaching the level section of the tunnel to make up for the forward component of the gravitational force of the downgrade. Consequently, they slow up after passing the downgrade. Secondly, the downgrade causes vehicles to attain greater speeds than they naturally would, and drivers are forced to brake to maintain a safe distance from traffic ahead. This braking is magnified by succeeding vehicles so that traffic frequently comes to a dead stop despite fluid movement through the remainder of the tunnel.

Although the severe slowing of traffic was not apparent in the Queens Midtown Tunnel, there is a critical point in the tunnel about the same location as in the Lincoln Tunnel. Speeds after increasing steadily on the tunnel downgrade dropped at this point, the median dropping 7 mph. The apparently important factor causing the difference in flow of traffic through the two tunnels is the greater length of the steep downgrade in the Lincoln Tunnel. The 3.5-percent grade in the Lincoln Tunnel is 2,700 feet long as compared to a 1,700-foot 3.3-to-4.0-percent downgrade in the Queens Midtown Tunnel.

What can be done about this flow condition? That is our problem at the present time. We have existing signs in the tunnel reading UPGRADE MAINTAIN 30 MPH and KEEP 75 FT. APART. The UPGRADE MAINTAIN 30 MPH signs are located at the bottom of the tunnel downgrade in an attempt to overcome the tendency of vehicles to slow down after leaving the downgrade. The KEEP 75 FT. APART signs are mounted on the downgrade. We are now proposing to erect disc signs on the catwalk railing on the tunnel downgrade which would read 75 FT. and be mounted at that spacing. It is hoped these signs will promote better spacing of vehicles on the downgrade and thus reduce the slowing effect from the braking which is now occurring. This will be our first step and its success will determine our later action.

Walking Distances in Parking

R. H. BURRAGE, *Highway Engineer*
Bureau of Public Roads

FROM comprehensive parking studies made in 32 cities in six population groups, data are presented showing the walking distances of illegal parkers, free-curb parkers, and those parking at free and pay off-street facilities. The patrons of pay lots and garages walk much further than do any of the other classes. It is evident that walking distances increase as the population increases but that the rate of increase falls off after the 500,000-population mark is reached, and it appears that there is a relationship between this fact and the increase in the proportion of illegal parking, which thus becomes a rough index of toleration.

Data are given on median distances walked by off-street pay parkers, together with the average and the range, and it is suggested that these be used as tentative criteria in the location of new pay facilities, subject to adjustment for various other factors which may affect acceptance of a location.

The basic assumption is made that, in each population group, added facilities must be so located as to improve the parking conditions, which can best be done by reducing the current distances walked.

● IN any city where parking is a problem and where more parking spaces are needed, two questions of primary importance are: How many additional spaces are needed? Where should new spaces be located?

The Bureau of Public Roads has summarized certain of the results of the comprehensive parking studies[1] made in nearly a hundred cities by state highway departments in cooperation with the cities. These studies serve very well in showing, for each block in the central business district, the number of spaces available for parking, the demand for spaces, and the deficiency. However, since blocks deficient in parking space frequently are adjacent or very close to blocks having surplus spaces, balances must be made before net deficiencies may be determined. In the decision as to how much of the surplus space may be considered available, the factor of walking distance between those spaces and the ultimate destination is of course introduced. One of the bureau's summaries relates to walking distances.

The availability of existing surplus space is not the only reason for the importance of walking distance. The area of space deficiency is nearly always concentrated in the core or center of the business district, just where valuations are highest. Since it usually is economically impracticable to install parking facilities exactly where they are needed, the question arises as to how far away new facilities may be located. Also, in many cities, zoning ordinances, referring to parking generators, require that appropriate parking space be provided within a specified distance. Indeed, if walking distance is not considered to be a factor, then there is no parking problem in any city. The reason for this paper is the question: How far is too far for parkers to walk?

The comprehensive studies referred to have provided data upon which an approach may

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[1] Described in 1945 PROCEEDINGS of Highway Research Board.