definition of the strip to be surveyed and the receipt of unchecked tracings is only six months on our current project. This is considerably less than would be required if the twelve miles of location survey had been added to the other assignments of our personnel.

Costs of Photogrammetric Maps—Table 1 provides information on photogrammetric maps procured for use in Connecticut.

To date the total cost of these operations has not been compared with the cost of obtaining the necessary design data without photogrammetry. However, it is believed that photogrammetric methods permit improved designs to be developed at approximately equal total costs and in considerably less time than previous methods.

Concerning costs, it should be pointed out that the element which is all important is the cost of checking the maps as received from the photogrammetry contractor. The Connecticut specifications detail the information and accuracy required on the final maps. They are not concerned with methods of obtaining that accuracy. What is needed is a product which will stand the accuracy tests imposed by the surveyors and engineers who will use them, and who must be convinced that photogrammetric methods will produce maps equal to or better than those made by conventional methods. Pride in one's work is a creditable trait. Surveyors are reluctant to accept the inexpensive innovation produced by photogrammetric means. Since checking costs can run to extremes and tip the economic balance, the photogrammetric engineering profession must make sure that accuracy specifications are fulfilled on every test.

TRAFFIC REPORT BEFORE AND AFTER IMPROVEMENT AT INTERSECTION OF ROUTES 1 AND 25[1]

W. R. BELLIS, *Chief, Bureau of Traffic and Safety Research, New Jersey State Highway Department*

SYNOPSIS

An extremely severe traffic congestion problem at a right angle intersection was solved by a relatively inexpensive re-design. It is believed that this type of design, which might be termed "Directional Channelization", has not been employed before.

The principle of the design is to remove the left turning vehicles from the intersection proper by substituting a left turn off of the approach road before these vehicles reach the main intersection and then providing a left turn onto the exit road at a point beyond the main intersection with a roadway connecting the two. The locations of these points for left turns are selected at such distances that progressively synchronized traffic signals can be operated so that stops are not created in addition to those which would have been necessary without the improvement.

This "Before" and "After" study indicates that it is sometimes possible to increase the number of traffic signalized intersections and speed up traffic. It may be possible to expand this principle to the point where traffic signals combined with design may prove to be a means of temporarily deferring expensive grade separation construction for many years or may even prove to be satisfactory for an indefinite length of time.

At this intersection the re-design resulted in a saving of about one-half minute for the average car of the 45,000 cars per average day entering the intersection. This saving is the direct saving in travel time within the intersection area and does not include the time saved by increase in capacity and resultant elimination of long tie-ups.

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[1] A cooperative project between the Division of Planning, Traffic and Economics of the New Jersey State Highway Department and the Bureau of Public Roads.

In addition to the "Before" and "After" comparison, the study also provides comparisons of three types of traffic control:

Before Revision
After Revision
- No Traffic Signal Control
- Fixed Time Traffic Signal Control
- Fully Actuated Traffic Signal Control

Since the preparation of this report, new traffic counts have been taken, indicating that the intersection is being used by 64,650 cars per day instead of the 45,060 cars per day whereas the general traffic in this area increased only 10 to 20 percent. One explanation could be that drivers avoided this intersection during the "Before" period.

At the intersection of State Route 1 and State Route 25 (truck route) in Jersey City, New Jersey, there was for many years a very severe traffic congestion problem. The location is shown in Figure 1.

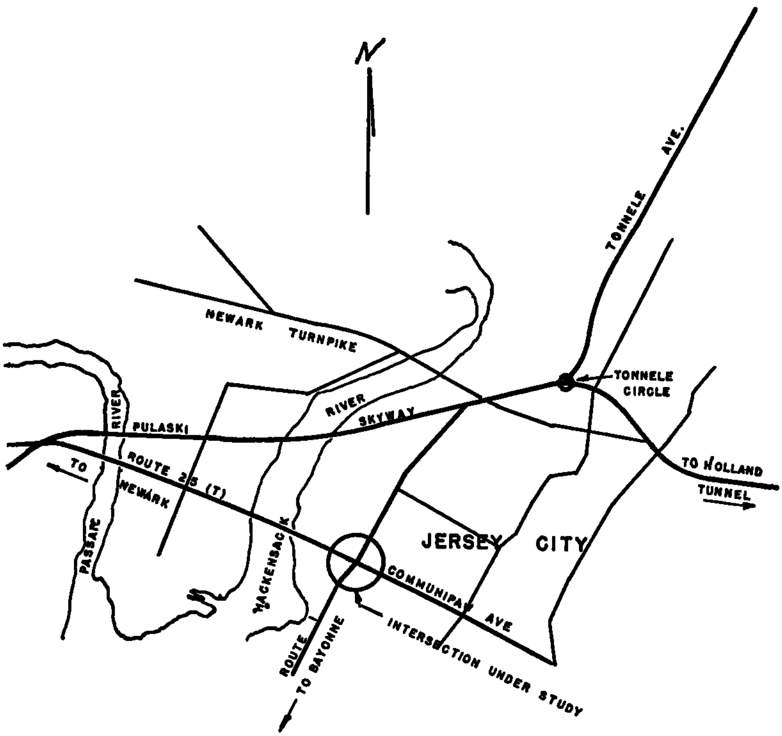


Figure 1

This was a simple right angle intersection at grade controlled by a traffic signal and traffic police. In order to improve this condition a novel design was adopted which provided two diagonal roads in addition to the existing roadways thereby creating three traffic signal controlled intersections in addition to the original one, making four signlaized intersections. As a result, congestion has been practically eliminated.

Design Suggested by Traffic Behavior—In studying traffic behavior throughout the State with the viewpoint that the existing road network is a full scale testing laboratory with artificial adjustments unnecessary and with the attitude that drivers are right rather than wrong, it was noticed that many drivers adjust their normal routes during periods of peak congestion in order to search for a means of avoiding the congestion. In an area where a grid system of roads is available and where a main signalized intersection becomes congested repeatedly, it can be observed that many drivers turn off their normal road upon reaching the backed-up traffic to use a parallel road and return to their route after passing the congestion. Figure 2 shows an example of this type of operation.

For cars intending to make a left turn at the main intersection much time can be saved by turning left at a street before reaching the rear of the congestion and at a time when there is a break in the opposite direction traffic, then proceeding to a parallel street, turning right and going to the street that would have been used after making the left turn normally and then turning left onto that street. With practice this can be done with a relatively continuous movement, slowing down only for the turns and without interfering with the movements of other vehicles.

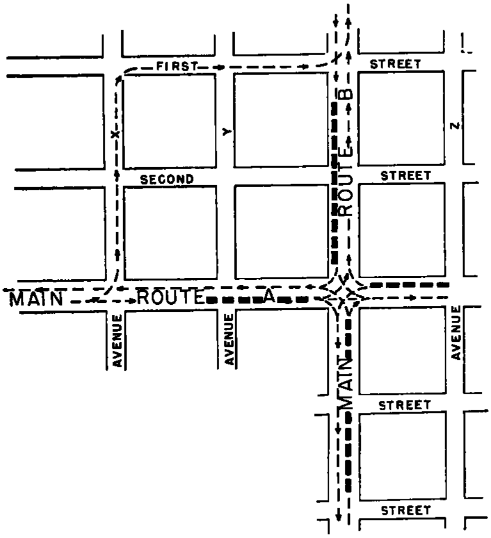


Figure 2. Typical Grid System of City Streets Showing Possible Alternate Route for Left-Turning Vehicles

This basic principle suggested the provision of specifically designed roads to best facilitate the left turn movement. Figure 3 shows the principle of such a design. Left turns are made by making a partial left turn into a diagonal connector prior to reaching the intersection and another partial left turn when the connector reaches the intersecting route.

Separate turning lanes are also provided for the right turns. One or more of these diagonal connector roads may be used at a given intersection as required.

Suitable Conditions for Testing of Design Principle—The problem at the intersection of Route 1 and Route 25 satisfied the requirements for testing such a design. Congestion was very extreme with traffic backed up almost daily for about ½ mi. on each approach road. Two of the left turns were significantly large requiring a four phase operation of the traffic signal which, during peak hours, was turned off and traffic alternated by traffic officers in the intersection. Modification by means of constructing a grade separation was considered but deferred because of the possibility of constructing a parallel route close by which probably would not utilize this grade separation. A traffic circle was also considered but discarded because traffic volumes would exceed the capacity immediately. Lands needed for the diagonal road type improvement were vacant, and therefore relatively inexpensive, favoring the decision to test the new design principle. Figure 3 shows the basic design developed.

Prevailing Traffic Data—As shown in Figure 4 the annual average daily traffic volume passing through the intersection is over 45,000 cars per day. Peak hour volumes reach 3,500 cars per hour through the intersection repeatedly. The road towards Newark, Route 25 (truck road), has an average of 30,000 cars per day with 45 percent trucks. Heavy trucks, classified as two axle trucks with dual tires and all extra axle trucks, amount to about 11,000 per average day. Classified by weight, 6,000 trucks per day exceed a weight of 10 tons and about 2,800 trucks exceed a weight of 20 tons.

Additional charts and tables showing traffic volumes at this location are appended to this report as Figures 9 to 15 and Tables 1 to 6.

Principle of Design at Route 1 & Communipaw Ave.—The principal factor in the design is to locate the diagonal roadways so that the distances between intersecting roadways are such that signal timing can be synchronized to permit progressive movements of traffic with reasonably normal speeds. The two right turns corresponding to the two heavy left turns are also heavy movements. One way roadways were provided for them so that the the traffic flows as they occur on the new layout.

While the intersection type was first proposed for use at Communipaw Avenue and

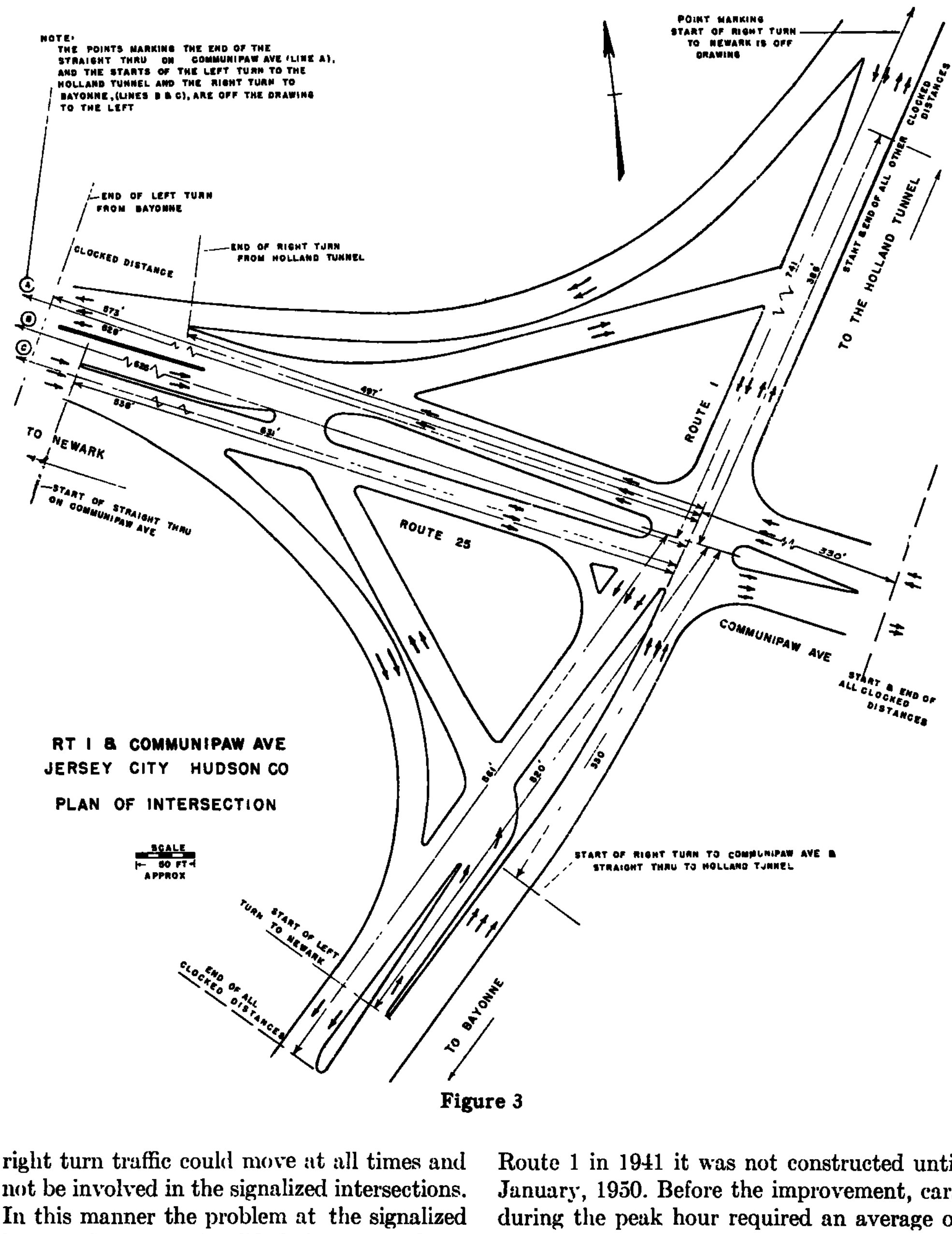


Figure 3

right turn traffic could move at all times and not be involved in the signalized intersections. In this manner the problem at the signalized intersections was simplified. Figure 5 shows Route 1 in 1941 it was not constructed until January, 1950. Before the improvement, cars during the peak hour required an average of 64 sec. to get through the intersection, whereas after the improvement they required an average of 33 sec. Constant users of the intersection were quick to realize the improvement, claiming savings up to 15 minutes. Some expressed their reaction by written comment.

Recorded Personal Impressions and Operational Data—When a condition of bad congestion is corrected, it is very easy to forget the previous condition and, therefore, the degree of improvement loses its significant impression. Without specific records, references to former conditions are very often doubted as exaggerations. Because of the possibility of wider use of the proposed principles, records were made of the "Before" and "After" conditions. These records included both personal impressions and detailed operational studies.

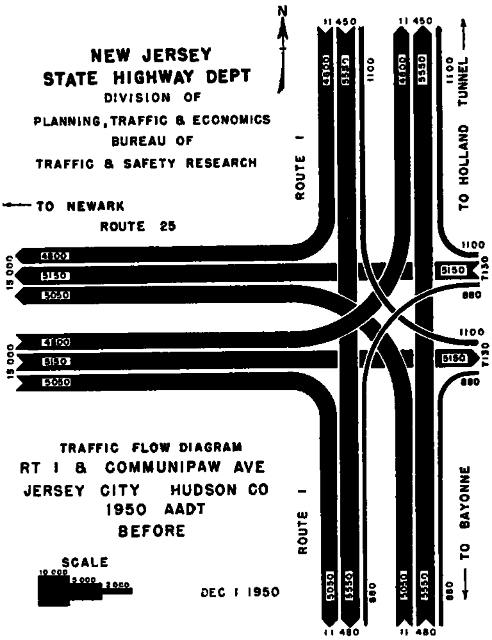


Figure 4

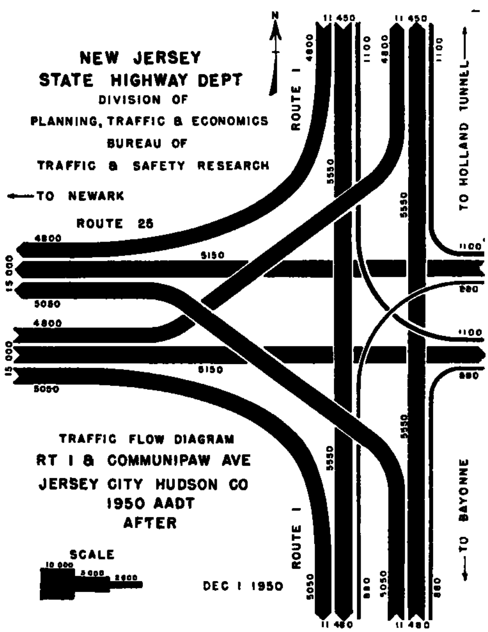


Figure 5

Mr. Robert Nolan, an Assistant Engineer with this Bureau, spent one day specifically observing "Before" traffic conditions and then recorded impressions. He lives in Trenton and, therefore, is not familiar with the intersection other than by this specific inspection. He was instructed as to normal conditions and what to look for so as to avoid some of the unnecessary details on which he might otherwise have concentrated his attention. It is intended that he will make an "After" observation and record his impression of the change. A similar report was made by Mr. R. Evensen, a Junior Engineer with the Bureau, who lives in Jersey City and therefore, somewhat familiar with the past reputation of the intersection. He has since left our employment but it may be possible to still obtain an "After" report from him. Other unsolicited comments are available from drivers who used the intersection daily, and more comments could undoubtedly be obtained if the desire was made known. (Comments of Mr. Nolan and Mr. Evensen are part of the complete report on file in the New Jersey State Highway Department.)

A traffic officer, who had been assigned to manual control at the intersection, stated that after redesign, traffic moved better with no control at all than with signals. He was very emphatic about it when questioned critically. This finding concurred with impressions made on the recorder, Mr. Downs, and later supported by preliminary summaries and analyses.

The analytical data was collected by Mr.

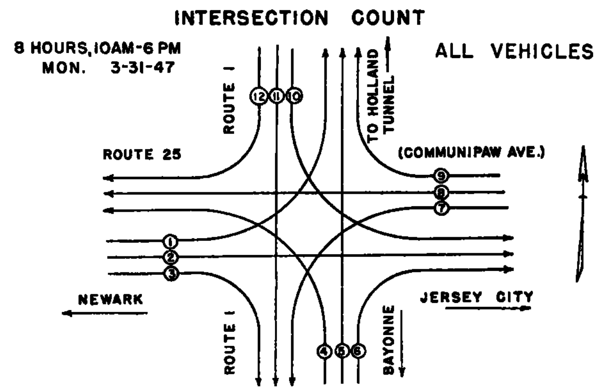
T. J. Downs, who is undoubtedly the best source of personal opinion concerning the degree of benefit of the change. He lives in Jersey City and has used the intersection often for many years. In recent years, before the improvement he was aware of the proposed change every time he passed through the intersection. He made the time studies of cars passing through the intersection before the change and after the change, with no control, with fully actuated traffic dispatcher type controllers and with fixed progressively synchronized signals. All of these tests covered a combined period of about one year. In addition to the conclusions drawn from the data he collected, the authentic record of his personal impressions are of utmost value especially in support of conclusions from recorded data.

A comment by Mr. Downs recording his personal impression after the collection of the field data is appended to the complete report.

Collection of Travel Time Data—It was planned to collect statistics as to the time required by vehicles to travel through the intersection in such a manner that direct comparisons could be made of corresponding movements for traffic density variations, for average day volumes, for peak hour volumes, for trucks, passenger cars or total vehicles. Field work for both the before and after studies was done by the same man so that personal equation factors would be constant and, therefore, compensating. Studies were made before reconstruction and after reconstruction with no control, traffic dispatcher control, and with fixed time control.

Method Used in Time Studies—All of the time checks were made manually by means of a

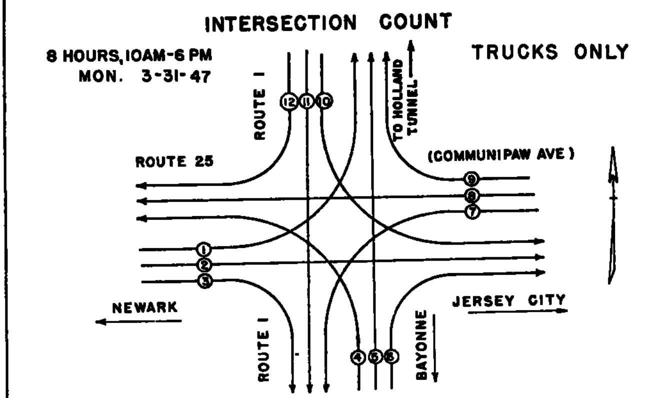
TABLE 1



FROM	NEWARK				BAYONNE				JERSEY CITY				HOLLAND TUNNEL				
TO	HT	JC	B	TOT.	N	HT	JC	TOT.	B	N	HT	TOT.	JC	B	N	TOT.	
	1	2	3		4	5	6		7	8	9		10	11	12		TOTALS
10AM 11 A	341	261	121	723	159	231	49	439	27	241	45	313	52	197	214	463	1938
11A 12N	364	246	127	737	162	215	57	434	30	230	38	298	36	256	230	522	1991
12N 1PM	330	284	178	792	165	244	47	456	24	258	42	324	49	145	196	390	1962
1 P 2 P	387	312	151	850	179	248	63	490	33	269	49	351	58	138	218	414	2105
2 P 3 P	330	229	143	702	219	213	59	491	53	210	33	296	48	284	206	538	2027
3 P 4 P	522	385	183	1090	297	491	49	837	22	352	112	486	65	319	312	696	3109
4 P 5 P	594	552	699	1845	463	532	118	1113	31	375	109	515	20	450	447	917	4390
5 P 6PM	678	556	862	2096	473	558	96	1127	42	350	128	520	14	774	505	1293	5036
TOTAL	3546	2825	2464	8835	2117	2732	538	5387	262	2285	556	3103	342	2563	2328	5233	22 558

stop watch. The clocked distances were different for each movement but each started at a point previous to entering the intersection and ended at a point beyond the intersection. It was attempted to select the beginning point far enough back of the intersection so that traffic was not slowed up or stopped by other traffic waiting for the signal to change to green. This was impossible for the "Before" period because of the long distances that vehicles backed-up. Another handicap during the "Before" period was the difficulty in seeing long distances for turning traffic from accessible vantage points because of trees and other obstructions to sight. For the "After" period many of these obstructions were removed. It was also recognized that it was desirable to have the beginning and ending points of clocked distances the same for the same movements for each test. In order to compensate for the lack of these in the "Before" period, it was necessary to add increments of time to the beginning and end for the corresponding distances with assumed average speeds through these added distances. The adjustment was made with assumed faster speeds than were probable so that the comparison of "Before" and "After" is on the conservative side, giving the "Before" period less time loss than was actual. This method was assumed to produce better accuracy than breaking the clocked distance into two sections for separate clockings, the average of which would be added to obtain the full distance.

TABLE 2



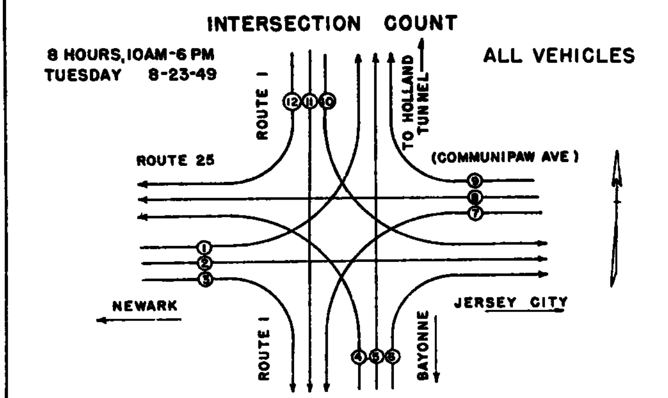
FROM	NEWARK				BAYONNE				JERSEY CITY				HOLLAND TUNNEL				
TO	HT	JC	B	TOT.	N	HT	JC	TOT.	B	N	HT	TOT	JC	B	N	TOT	
	1	2	3		4	5	6		7	8	9		10	11	12		TOTALS
10AM 11 A	262	59	33	354	78	102	8	188	9	68	21	98	11	93	198	302	942
11 A 12 N	267	53	29	349	70	85	5	160	6	60	18	84	14	112	204	330	923
12 N 1 PM	258	63	31	352	74	125	7	206	5	72	25	102	23	58	169	250	910
1 P 2 P	281	71	37	389	76	97	5	178	7	68	24	99	31	98	219	348	1014
2 P 3 P	289	89	48	426	56	82	18	156	14	70	17	101	19	79	147	245	928
3 P 4 P	317	137	64	518	66	108	12	186	11	75	23	109	17	107	222	346	1159
4 P 5 P	143	61	22	226	72	68	17	157	8	53	13	74	4	49	109	162	619
5 P 6 PM	135	92	17	244	53	49	17	119	9	83	21	113	11	38	252	301	777
TOTAL	1952	625	281	2858	545	716	89	1350	69	549	162	780	130	634	1520	2284	7272

There is a drawbridge on Communipaw Avenue, Route 25, Truck Road, about 2,000 ft. from the intersection which opens frequently backing traffic into the intersection. Clockings were not made when this interfered with the intersection movements. The tests were made without announcement so as to avoid abnormal behavior of traffic.

Clockings were made on week days during good weather and including morning peak hours, evening peak hours and the off hours in between. Cars were clocked from one of the four directions to each of the other three directions continually until significant samples were obtained for each unit of movement. In a few instances the unit of movement occurred so infrequently that a significant sample was not obtained because of the long time which would have been required to get a few more samples. A passenger car making a left turn from Bayonne affected by the second red signal, or a truck going straight through from Newark and stopped at the first signal, etc. was considered as a "unit of movement."

One vehicle was clocked at a time in a random selection as follows: After a vehicle was clocked through its movement and the reading recorded according to its direction and signal condition the next vehicle at the starting point was clocked through its movement and recorded in its proper classification and so on as fast as possible. Hourly recordings were made in order to permit correlation with hourly volumes. This procedure was assumed to give proportional representation for each of the various movements entering the intersection. The small deviation between maximum and minimum variations in times and the normal distribution within individual samples indicated that the assumption was reasonably sound.

TABLE 3



FROM	NEWARK				BAYONNE				JERSEY CITY				HOLLAND TUNNEL				
TO	HT	JC	B	TOT.	N	HT	JC	TOT	B	N	HT	TOT	JC	B	N	TOT	
	1	2	3		4	5	6		7	8	9		10	11	12		TOTALS
10AM 11A	270	247	213	730	232	261	39	532	23	238	64	325	45	317	305	667	2254
11A 12N	300	244	239	783	246	253	43	542	23	225	83	331	67	329	295	691	2347
12N 1PM	279	183	174	636	217	242	47	506	33	196	90	319	49	303	278	630	2091
1 P 2 P	285	196	235	716	225	285	53	563	38	269	76	383	45	294	309	648	2310
2 P 3 P	269	206	211	686	238	256	66	560	36	262	64	362	41	289	301	631	2239
3 P 4 P	293	353	503	1129	247	277	74	598	31	292	72	395	47	339	294	680	2802
4 P 5 P	250	361	580	1191	325	471	123	919	26	257	89	372	68	441	311	820	3302
5 P 6PM	205	386	663	1254	257	424	139	820	38	250	75	363	60	493	304	857	3294
TOTAL	2151	2156	2818	7125	1987	2469	584	5040	248	1989	613	2850	422	2805	2397	5624	20639

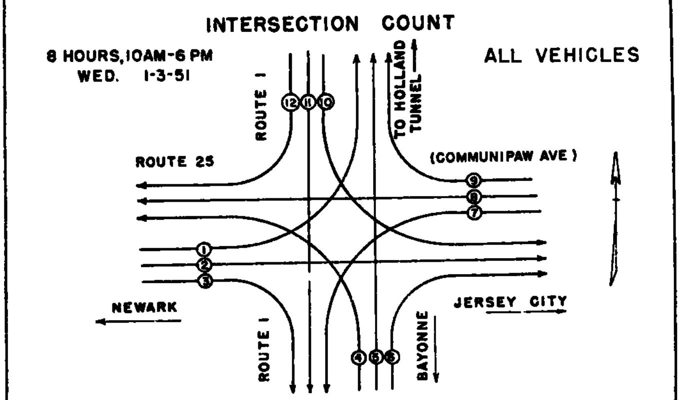
After completion of each series of tests and after the changes were made on the type of control, a period of at least one month was allowed before clocking the next series. This was to allow traffic to become familiar with the new system.

Clocking points were set up and foresights selected from the vantage point using the same foresights and vantage point each day when clocking corresponding distances.

At first it was assumed that the clocked distances should include the extreme distance where cars were first affected by the backed up traffic. In this manner the total time saving advantage of the improvement could best be measured. Time checks were not made beyond generous limits of the "After" design principally because of lack of time available. It so happened that such checks proved to be unnecessary to establish the justification of the improvement. If they should still be considered desirable, conservative estimates can be made as adjustments.

The true value of this study is for possible future application at other locations, and for this purpose the assumed limits of the intersections are reasonably selected for application to other problems. The extent of the additional time loss is a function of the capacity of the intersection and the approaching traffic volume in excess of this capacity. This can be added for each particular case.

TABLE 4



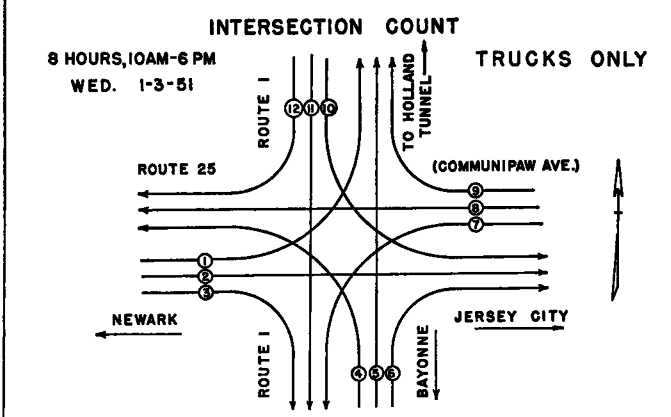
FROM	NEWARK				BAYONNE				JERSEY CITY				HOLLAND TUNNEL				
TO	HT	JC	B	TOT.	N	HT	JC	TOT.	B	N	HT	TOT	JC	B	N	TOT.	
	1	2	3		4	5	6		7	8	9		10	11	12		TOTALS
10AM 11A	537	295	215	1047	267	348	66	681	85	298	78	461	135	366	420	921	3110
11A 12N	584	358	253	1195	299	286	67	652	59	347	52	458	127	352	491	970	3275
12N 1PM	431	274	203	908	271	347	42	660	71	298	89	458	99	342	345	786	2812
1 P 2 P	459	200	191	850	268	294	35	597	54	326	84	464	108	344	404	856	2767
2 P 3 P	541	253	244	1038	494	302	36	832	27	435	75	537	76	457	534	1067	3474
3 P 4 P	444	599	735	1778	393	301	36	730	54	421	79	554	112	508	436	1056	4118
4 P 5 P	614	721	774	2109	564	402	82	1048	82	487	111	680	72	499	468	1039	4876
5 P 6 PM	430	474	415	1319	608	264	86	958	66	459	56	581	85	412	484	981	3839
TOTAL	4040	3174	3030	10244	3164	2544	450	6158	498	3071	624	4193	814	3280	3582	7676	28 271

Preliminary Summary—Data have been summarized and average times applied to average volumes for comparison of the time saving advantages of each type of control. There is no question about the advantage of the new design over the old design because of the large reduction in time for the average car to pass through the intersection.

The preliminary summary of the data indicates that the average car passes through the redesigned intersection with the least time loss when there is no control at all. This is true during the peak hours as well as during off hours. The fixed time progressively synchronized signals results in a slightly greater time loss, the fully actuated dispatcher type controller results in a still greater time loss and the original simple intersection with traffic signals proved to be the slowest for the corresponding limits of the intersection for the average car is shown as follows:

	All Hours	*Peak Hour Only*
No Control............	28	27
Fixed Time............	35	33
Fully Actuated........	38	38
Original Intersection...	60	64

TABLE 5



FROM	NEWARK				BAYONNE				JERSEY CITY				HOLLAND TUNNEL				
TO	HT	JC	B	TOT	N	HT	JC	TOT	B	N	HT	TOT	JC	B	N	TOT.	
	1	2	3		4	5	6		7	8	9		10	11	12		TOTALS
10AM 11 A	460	191	101	752	155	97	27	279	32	121	47	200	53	139	341	533	1764
11A 12N	501	229	119	849	175	113	13	301	21	150	28	199	57	148	402	607	1956
12N 1PM	381	174	104	659	157	131	11	299	24	129	41	194	48	146	278	472	1624
1 P 2 P	363	126	111	600	133	101	10	244	17	124	36	177	41	136	290	467	1488
2 P 3 P	462	159	127	748	155	88	15	258	6	221	31	258	32	121	442	595	1859
3 P 4 P	376	114	152	642	148	79	9	236	11	194	27	232	58	148	350	556	1666
4P 5P	513	116	123	752	210	75	21	306	21	246	29	296	39	159	401	599	1953
5P 6PM	356	100	100	556	209	51	19	279	16	198	17	231	44	111	422	577	1643
TOTAL	3412	1209	937	5558	1342	735	125	2202	148	1383	256	1787	372	1108	2926	4406	13 953

average vehicle. The study included the clocking of 14,557 vehicles.

Indicated Results—Based on the study there appears to be good justification for removing the signals and having no control at all. With fixed time and dispatcher control, traffic requires about 25 percent more time to pass through the corresponding limits of the intersection than it does with no control.

Time, in seconds, to pass through corres-

Summaries of travel time data are appended as Tables 7 to 12.

The objection to the no-control system is the possible hazard to the cross traffic. Because of the lack of high speeds and because of the small percentage of strangers, it is quite improbable that no control would result in more accidents than would signalized control. Nevertheless, because there is a lack of sufficient evidence supporting this fact, it is quite certain that stop street signs would be installed and enforced if light control were eliminated. This would slow up the average vehicle to the extent that the time advantage would be lost.

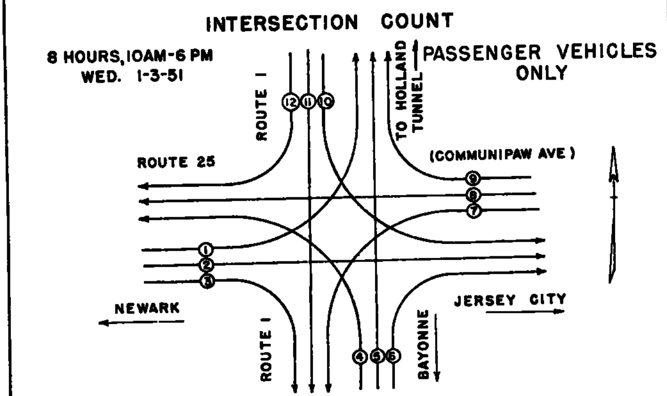
The choice then must be between the fixed-time and the traffic-dispatcher controls. In this particular case the fixed-time control is the less expensive and is also more efficient, and, therefore, should be the recommended type for such designs.

Figure 6 shows diagramatically the traffic signal offsets. For instance, Communipaw Avenue westbound traffic would get a red signal at the westerly intersection 15 sec. after getting the red signal at the intersection of Route 1 and Communipaw Avenue. Eastbound traffic would receive a red signal at Route 1 fifteen seconds after receiving it at the westerly intersection (with a 60-sec. cycle).

Figures 7 and 8 show graphically the capacity of the intersection. Figure 7 represents the satisfactory capacity and Figure 8 the absolute capacity. In this manner the bottlenecks are shown. Comparisons of prevailing traffic volumes and the capacity volumes will show where congestion will probably begin as traffic volumes increase in the future.

It should also be noted that the average annual daily traffic referred to for Route 25 (Truck Road) of 30,000 vehicles per average day may be incorrect by a greater degree than is desirable because of the difficulty in arriving at the A.A.D.T. On this road there is a very high percentage of traffic which is industrial and subject to wide fluctuations from labor strikes. The controls used for expanding short counts are on other roads less affected by strikes. There were estimates from different controls and by different methods which varied from 25,000 to 38,000 vehi-

TABLE 6



FROM	NEWARK				BAYONNE				JERSEY CITY				HOLLAND TUNNEL				
TO	HT	JC	B	TOT.	N	HT	JC	TOT	B	N	HT	TOT.	JC	B	N	TOT.	
	1	2	3		4	5	6		7	8	9		10	11	12		TOTALS
10AM 11 A	77	104	114	295	112	251	39	402	53	177	31	261	82	227	79	388	1346
11A 12N	83	129	134	346	124	173	54	351	38	197	24	259	70	204	89	363	1319
12N 1PM	50	100	99	249	114	216	31	361	47	169	48	264	51	196	67	314	1188
1 P 2 P	96	74	80	250	135	193	25	353	37	202	48	287	67	208	114	389	1279
2 P 3 P	79	94	117	290	339	214	21	574	21	214	44	279	44	336	92	472	1615
3 P 4 P	68	485	583	1136	245	222	27	494	43	227	52	322	54	360	86	500	2452
4P 5P	101	605	651	1357	354	327	61	742	61	241	82	384	33	340	67	440	2923
5P 6PM	74	374	315	763	399	213	67	679	50	261	39	350	41	301	62	404	2196
TOTAL	628	1965	2093	4686	1822	1809	325	3956	350	1688	368	2406	442	2172	656	3270	14 318

cles per day. The 30,000 figure was selected arbitrarily. Other traffic volumes are related to this volume and, therefore, subject to the same possible error. A traffic profile for two points is attached as Figure 9.

From the summaries it is noted that for the condition of no control and fixed time, the speed of the average vehicle was faster during peak hours than during off hours. This phenomenon has been noticed in other samples of speed checks and is probably acceptable. That is, for increases of traffic density the average speeds increase up to a certain critical density above which the average speeds decrease with further increases in traffic density. This should probably be studied individually.

TABLE 7

Summary of actual counts showing comparison of the average times required, during all hours, in minutes, for vehicles to make all movements before re-construction, after construction with no control, after construction with traffic dispatcher lights and after construction with fixed traffic lights. All distances were adjusted to conform to the traffic dispatcher lights.

	Av. Time Before Const.	Av. Time After Const. No Control	Av. Time After Const. Dispatcher	Av. Time After Const. Fixed Time
Trucks				
From Newark				
R.T.	.551	.295	.357	.336
S.T.	1.650	.532	.733	.630
L.T.	1.602	.693	1 102	.713
From Bayonne				
R.T.	.406	.378	.402	.570
S.T.	1.119	.491	.625	.675
L.T.	1.581	.654	.820	.730
From Jersey City				
R.T.	.546	.449	563	.744
S.T.	1.575	.530	813	.674
L.T.	1.355	.568	.759	.827
From Holland Tunnel				
R.T.	.607	.381	.395	.388
S.T.	1.196	.507	.825	.890
L.T.	1.168	.536	.772	.761
Passenger Cars				
From Newark				
R.T.	.495	.262	.304	.302
S.T.	1.231	.483	.655	.563
L.T.	1.277	.554	.945	.626
From Bayonne				
R.T.	.414	.356	.356	.443
S.T.	.847	.404	.558	.542
L.T.	1.279	.589	.739	.660
From Jersey City				
R.T.	.420	.398	.505	.623
S.T.	1.161	492	743	.597
L.T.	1.172	.583	.769	830
From Holland Tunnel				
R.T.	.577	.357	347	.328
S.T.	.970	.429	.727	667
L.T.	.917	.455	.700	.649

The following notes are for the purpose of clarifying the locations of the traffic profile graphs shown as Figure 9.

TABLE 8

Summary of actual counts showing comparison of the average times required, during all hours, in minutes, for vehicles to make all movements before reconstruction, after construction with no control, after construction with traffic dispatcher lights, and after construction with fixed traffic lights. All distances were adjusted to conform to the traffic dispatcher lights.

	Av. Time Before Const.	Av. Time After [Const. No Control	Av. Time After Const. Dis-patcher	Av. Time After Const. Fixed Time
All Vehicles				
From Newark				
R.T.	.514	.270	.321	.313
S.T.	1 378	.509	.684	.592
L.T.	1.501	.659	1.046	.685
From Bayonne				
R.T.	.413	.360	.362	.471
S.T	.935	.431	.575	.595
L.T.	1.399	.604	.763	.686
From Jersey City				
R.T.	.466	.413	.521	.671
S.T.	1 333	.505	.769	.634
L.T.	1 234	.578	.768	.829
From Holland Tunnel				
R.T.	.596	.378	.385	.374
S.T.	1.059	.449	.756	.760
L.T	1 016	.482	.720	.686
Total No. of Vehicles in Sample	1,612	3,528	4,996	4,332
Total Time for all Vehicles	1,598.539	1,623.838	3,170.013	2,508.134
Av. Time for all Vehicles	.992	.460	.635	.579
Av. Time in Seconds	59.5	27.6	38.1	34.7

14,557 Total Vehicles Clocked

Profile Graph: Route 25, Westbound:

This traffic count was made on a continuation of the west leg of the intersection of Route 1 and 25 (Communipaw Avenue) approximately 1.8 miles west of the intersection. There is one major intersection and several large industrial plants situated between Routes 1 and 25 (Communipaw Avenue) intersection and the location of this traffic count.

Profile Graph: Route 1, Southbound:

This traffic count was made on a continuation of the south leg of the intersection of Routes 1 and 25 (Communipaw Avenue) approximately 0.5 mile south of this intersection. There is one minor intersection and several small industrial plants situated between Routes 1 and 25 (Communipaw Avenue) intersection and the location of this traffic count.

Comparison of Directional Channelization with Conventional Design—Mr. H. W. Giffin, Chief of the Division of Construction and Design of the New Jersey State Highway Department, after reading through the report, asked how a cloverleaf grade separation would have differed from the existing directional channelization in the efficiency to move traffic through the intersection.

This type of a comparison is very valuable in order to assist in making decisions for future improvements at other intersections. As time permits, studies are being made so that we will be able to measure the behavior at cloverleafs for such a comparison but at present usable data is very insignificant.

Nevertheless, an estimate of the comparison is of value even if it does no better than stimulate interest in a more reliable measure of advantages of the two designs.

TABLE 9

Comparison of the average times at the peak hour of the day, 5 P.M. to 6 P.M., required in minutes for vehicles to make all movements before reconstruction, after construction with no control, after construction with traffic dispatcher lights, and after construction with fixed traffic lights.

	Av. Time Before Const.	Av. Time After Const. No Control	Av. Time After Const. Dispatcher	Av. Time After Const. Fixed Time
Trucks				
From Newark				
R.T.	.625	.314	.375	.328
S.T.	2.081	.613	.992	.618
L.T.	2.586	.710	1.222	.703
From Bayonne				
R.T.	.399		.398	.631
S.T.	1.319	.406	.681	.647
L.T	1.592	.672	.865	.743
From Jersey City				
R.T.	.493	.429	.502	.939
S.T.	1.083	.590	.942	.627
L.T.	1.731	.474		.977
From Holland Tunnel				
R.T.	.658	.379	.383	.372
S.T.	1.308	.551	.911	.792
L.T.	1.177	.505	.780	.754
Passenger Cars				
From Newark				
R.T.	.506	.267	.312	.323
S.T.	1.277	.483	.761	.559
L.T.	1 525	.550	.923	.531
From Bayonne				
R.T	.442	366	.369	.495
S.T.	1 105	.400	.533	.567
L.T.	1 251	.583	.762	.600
From Jersey City				
R.T.	.418	.370	.460	.709
S.T.	1.169	.393	.706	.649
L.T.	1 085	.557	.712	.808
From Holland Tunnel				
R.T.	.600	.375	.339	.319
S T.	.894	.423	.724	.657
L.T.	1.029	.487	.697	.652

TABLE 10

Comparison of the average times at the peak hour of the day, 5 P.M. to 6 P.M, required in minutes for vehicles to make all movements before reconstruction, after construction with no control, after construction with traffic dispatcher lights, and after construction with fixed traffic lights.

	Av. Time Before Const.	Av. Time After Const. No Control	Av. Time After Const. Dispatcher	Av. Time After Const. Fixed Time
All Vehicles				
From Newark				
R.T.	.540	.274	.325	.324
S.T.	1.491	.510	.830	.583
L.T.	2.200	.668	1.093	.627
From Bayonne				
R.T.	.430	.366	.371	.534
S.T.	1.197	.401	.559	.603
L.T.	1.397	.588	.782	.686
From Jersey City				
R.T.	.444	.379	.467	.758
S.T.	1.139	.434	.777	.640
L.T.	1.408	.536	.712	.871
From Holland Tunnel				
R.T.	.632	.379	.376	.362
S.T.	1.092	.440	.778	.716
L.T.	1.086	.493	.713	.676
Total No. of Vehicles in Sample	188	340	505	265
Total Time for all Vehicles	199 034	150.755	320.709	147.640
Average Time for all Vehicles	1.059	.443	.635	.557
Average Time in Seconds	63.5	26.6	38.1	33.4

At the Woodbridge Cloverleaf, at the intersection of Routes 25 and 4, there were 66,000 cars per average day in 1950 which is just about the same as the 64,650 cars per day at the Communipaw Avenue Intersection. The Woodbridge Cloverleaf has reached its capacity as evidenced by the backing up of traffic because of its one heavy left turn. (The Communipaw Avenue Intersection has 2 heavy left turns.) The cloverleaf at Routes 4 and 17 in Paramus had 45,500 cars per 1950 average day and was backing up traffic with one heavy left turn. At the intersection of Routes 4 and 35 in South Amboy there were 38,000 cars per average day in 1950 and it had shown very serious congestion with one heavy left turn on its cloverleaf type ramp.

Intersection	*1950 Average Day*
Routes 1 and 25, Jersey City.....	64,650
Routes 4 and 25, Woodbridge....	66,000
Routes 4 and 17, Paramus.......	45,500
Routes 4 and 35, South Amboy...	38,000

A preliminary estimate of the time to travel through the Communipaw Avenue intersection on the assumption that a cloverleaf had been built and that the traffic volumes and distribution would be unaltered indicates that the cloverleaf would be 5 seconds faster per average car than the existing intersection. Although this estimate measures the time through the existing intersection accurately, it probably is in error on the unit time assumption for the cloverleaf to the extent that the 5 seconds would probably be found to be less

TABLE 11

Total elapsed time for all vehicles to travel through the above intersection on an average day with 45,060 vehicles entering the intersection adjusted to unit movements.

	Before Const.	After Construction		
		No Control	Dis-patcher	Fixed Time
	min.	*min.*	*min.*	*min.*
From Newark				
R.T.	2595.7	1363.5	1621.1	1580.7
S.T.	7096.7	2621.4	3522.6	3048.8
L.T. ..	7204.8	3163.2	5020.8	3288.0
Total	16897.2	7148.1	10164.5	7917.5
From Bayonne				
R.T.	363.4	316.8	318.6	414.5
S.T.	5189.3	2392.1	3191.3	3302.3
L.T..	7065 0	3050.2	3853.2	3464.3
Total	12617.7	5759.1	7363.1	7181.1
From Jersey City				
R.T.......... ..	512.6	454.3	573.1	738.1
S.T......... .. .	6865.0	2600.8	3960.4	3265.1
L.T.	1085.9	508.6	675.8	729.5
Total	8463.5	3563.7	5209.3	4732.7
From Holland Tunnel				
R.T.	2860.8	1814.4	1848.0	1795.2
S.T.	5877.5	2492.0	4195.8	4218.0
L.T.	1117.6	530.2	792.0	754.6
Total . . .	9855.9	4836.6	6835.8	6767.8
Grand Total Minutes	47834.3	21307.5	29572.7	26599.1
Vehicle Hours for Average Day ...	797.2	355.1	492.9	443.3
Average Minutes per Vehicle	1.062	.473	.656	.590
Average Time in Seconds.........	63.7	28.7	39.4	35.4

TABLE 12

Total elapsed time for all vehicles to travel through the above intersection on an average day with 64,650 vehicles entering the intersection adjusted to unit movements.

	Before Const.	After Construction		
		No Control	Dis-patcher	Fixed Time
	min.	*min.*	*min.*	*min.*
From Newark				
R.T.	3586.2	1883.8	2239.6	2183.8
S.T.	10357.0	3825.6	5140.9	4449.5
L T.	12887.6	5658.2	8081.0	5881.4
Totals	26830.8	11367.6	16361.5	12541.7
From Bayonne				
R.T..	440.7	384.1	386.3	502.6
S.T...	6133.6	2827.4	3772.0	3903.2
L.T.	9760.8	4214.1	5323.5	4786.2
Totals	16335.1	7425.6	9481.8	9192.0
From Jersey City				
R.T.	754.4	668.6	843.5	1086.3
S.T.	10018.8	3795.6	5779.8	4765.1
L.T. ...	1316.7	616.7	819.5	884.5
Totals	12089.9	5080.9	7442.8	6735.9
From Holland Tunnel				
R.T. . .	5117.3	3245.5	3305.6	3211.2
S.T.	6947.0	2945.4	4959.4	4985.6
L.T.	1644.9	780.4	1165.7	1110.6
Totals . . .	13709.2	6971.3	9430.7	9307.4
Grand Total Time	68965.0	30845.4	42716.8	37750.0
Vehicle Hours per Average Day..	1149.4	514.1	711.9	629.2
Average Minutes per Vehicle	1.067	.477	.661	.584
Average Time in Seconds........	64.0	28.6	39.7	35.0

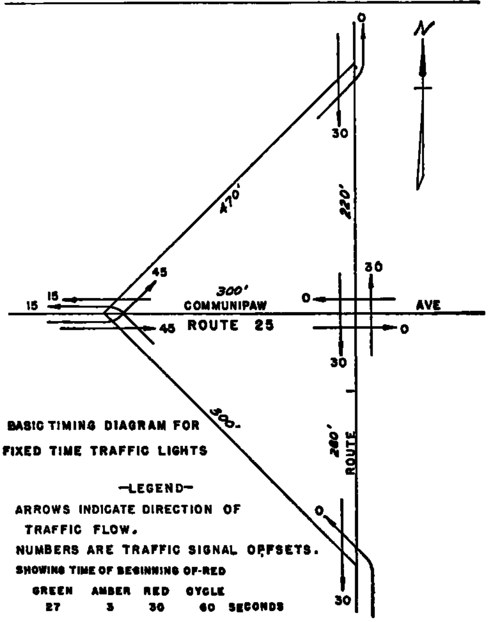


Figure 6

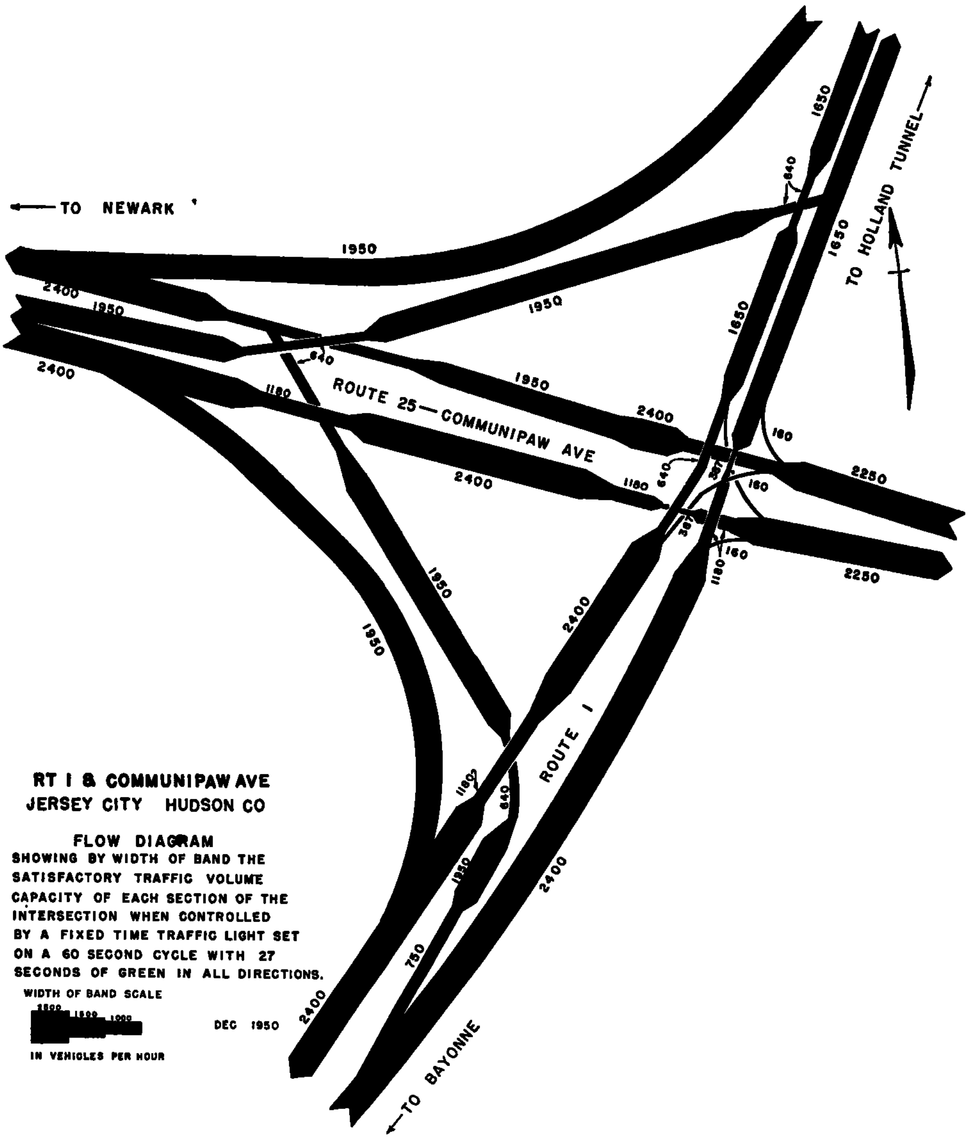

TO NEWARK
TO HOLLAND TUNNEL
TO BAYONNE
ROUTE 25—COMMUNIPAW AVE
ROUTE 1
1950
2400
1650
2250
1180
640
160
750
RT 1 & COMMUNIPAW AVE
JERSEY CITY HUDSON CO
FLOW DIAGRAM
SHOWING BY WIDTH OF BAND THE SATISFACTORY TRAFFIC VOLUME CAPACITY OF EACH SECTION OF THE INTERSECTION WHEN CONTROLLED BY A FIXED TIME TRAFFIC LIGHT SET ON A 60 SECOND CYCLE WITH 27 SECONDS OF GREEN IN ALL DIRECTIONS.
WIDTH OF BAND SCALE
IN VEHICLES PER HOUR
DEC 1950

Figure 7

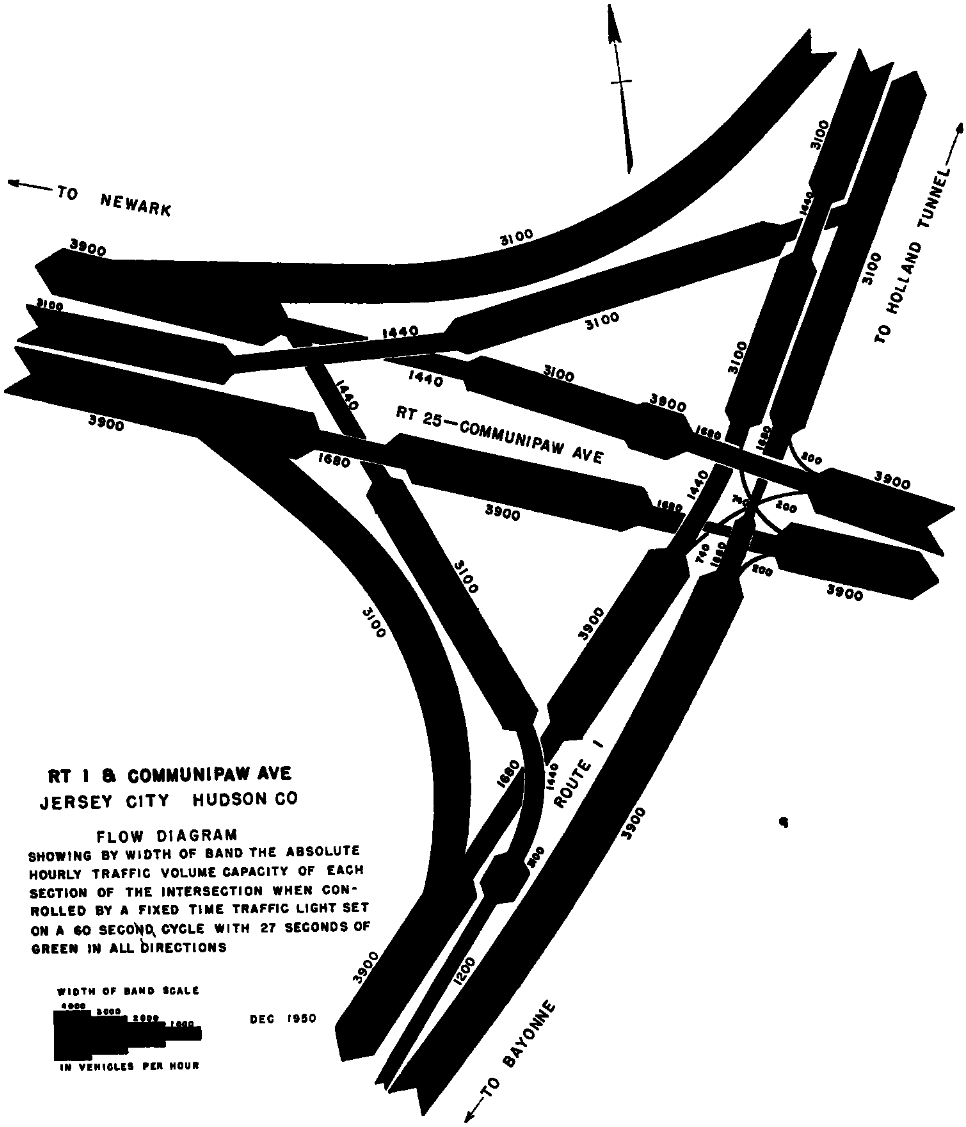

TO NEWARK
TO HOLLAND TUNNEL
TO BAYONNE
RT 25—COMMUNIPAW AVE
ROUTE 1
RT 1 & COMMUNIPAW AVE
JERSEY CITY HUDSON CO
FLOW DIAGRAM
SHOWING BY WIDTH OF BAND THE ABSOLUTE HOURLY TRAFFIC VOLUME CAPACITY OF EACH SECTION OF THE INTERSECTION WHEN CONTROLLED BY A FIXED TIME TRAFFIC LIGHT SET ON A 60 SECOND CYCLE WITH 27 SECONDS OF GREEN IN ALL DIRECTIONS
WIDTH OF BAND SCALE
IN VEHICLES PER HOUR
DEC 1950

Figure 8

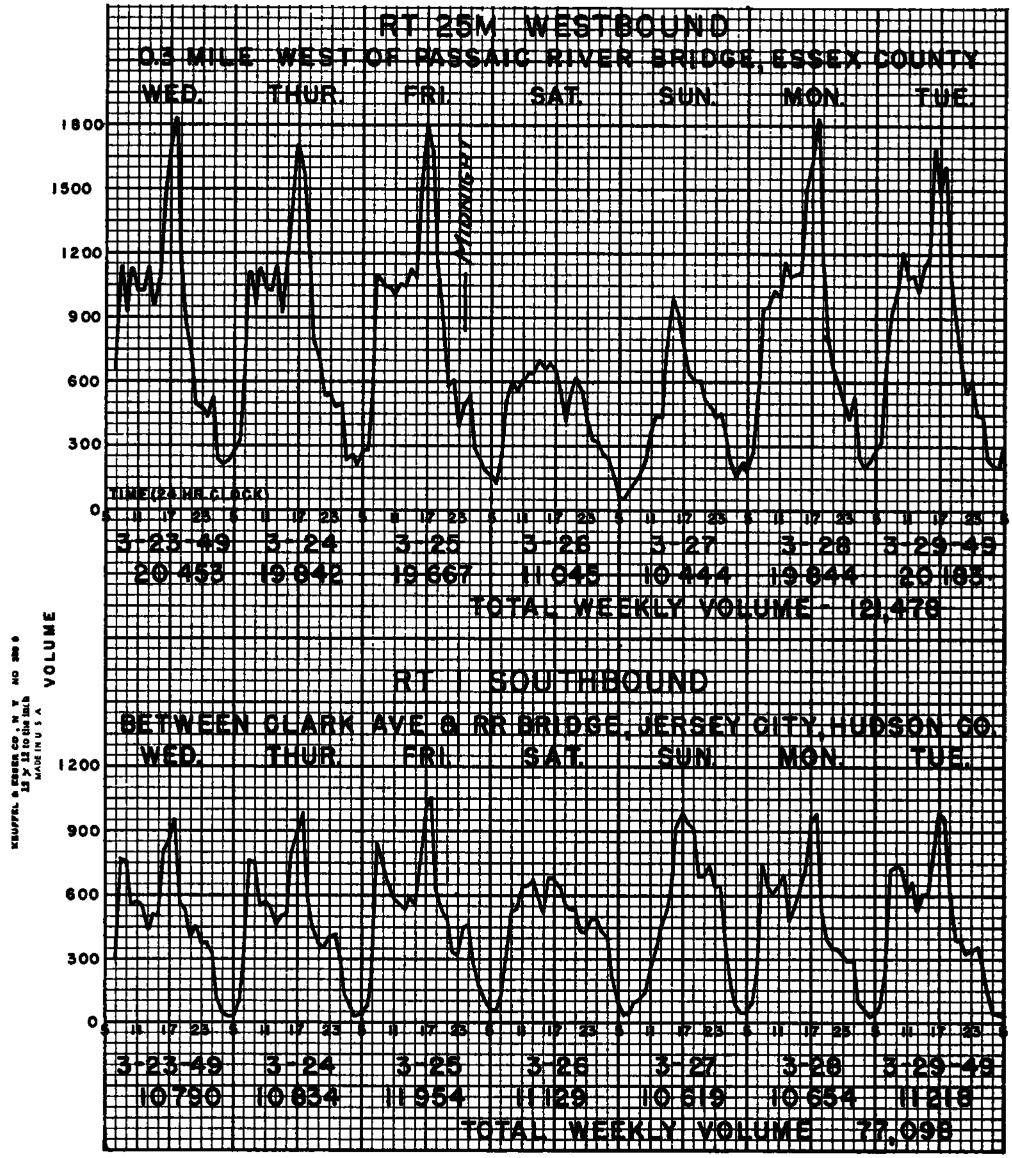


Figure 9. Traffic Volume Profile Graphs

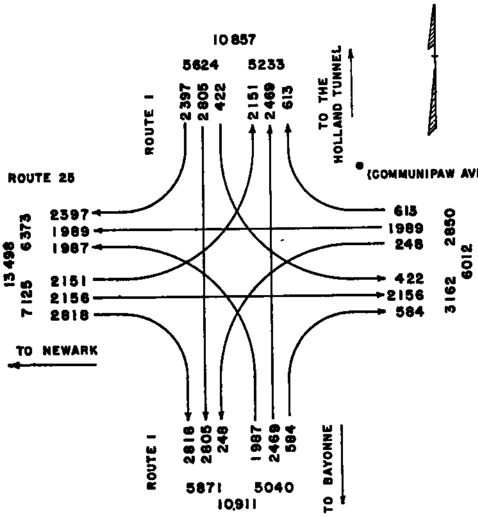


Figure 10. Traffic Flow Diagram—Before Revision—8-Hr. Count—10 AM-6 PM—8-23-49.

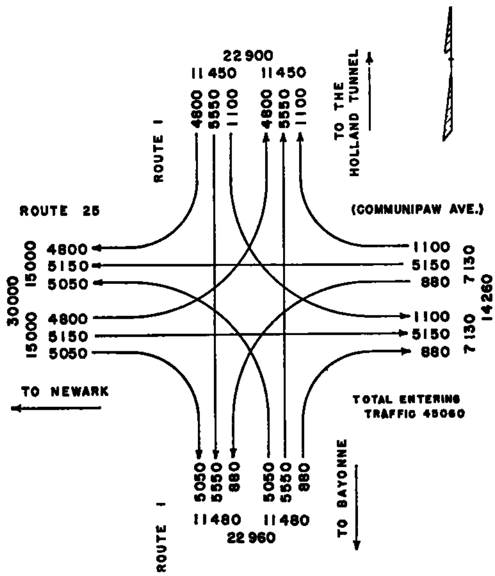


Figure 12. Before Revision—Average Annual Daily Traffic for Year Ending July 1, 1950.

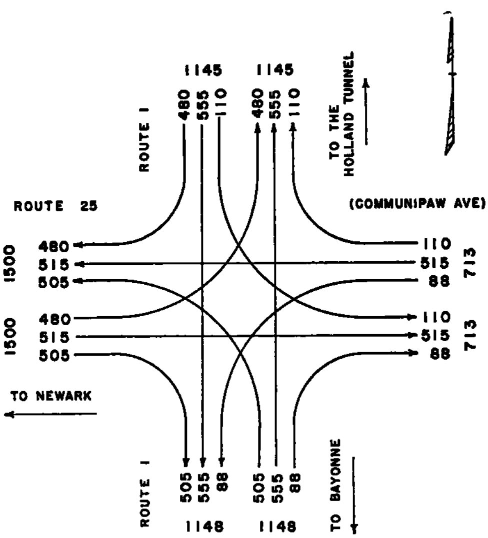


Figure 11. Before Revision—30th Peak Hour for Year Ending July 1, 1950.

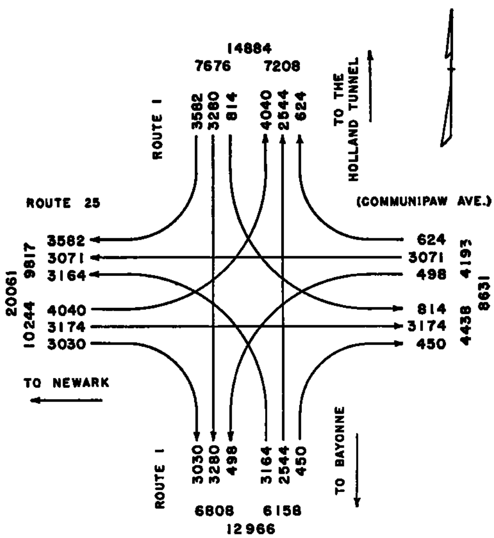


Figure 13. After Revision—8-Hr. Count—10 AM-6 PM—1-3-51.

by actual values. The preliminary estimate did not correct for the jamming that would result with a cloverleaf because of the over capacity condition that would exist; nor did it provide a correction for the heavy truck volume included in the heavy left turn movements.

If a cloverleaf had been built, its absolute capacity would be reached when traffic had increased 50 percent. The existing intersection will reach its absolute capacity when traffic has increased 70 percent.

In any case the "Directional Channelization" as employed at this intersection challenges the reputation of the "cloverleaf" as an ideal design and should be included in the classification of high type intersections. There are undoubtedly conditions under which directional channelization is more desirable than the cloverleaf and in which case the directional channelization is outclassed only by the directional interchange.

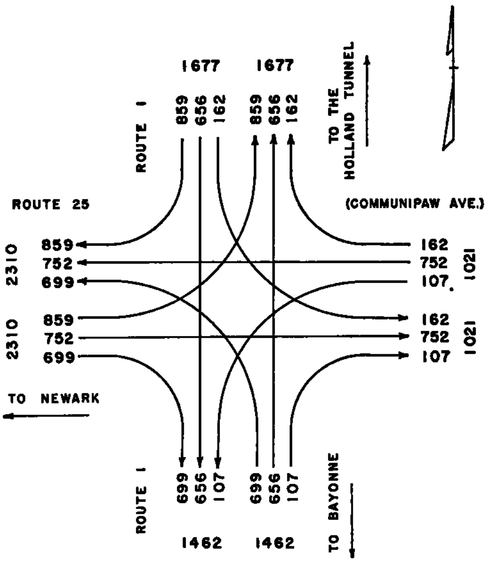


Figure 14. After Revision—30th Peak Hour for Year Ending Jan. 1, 1951.

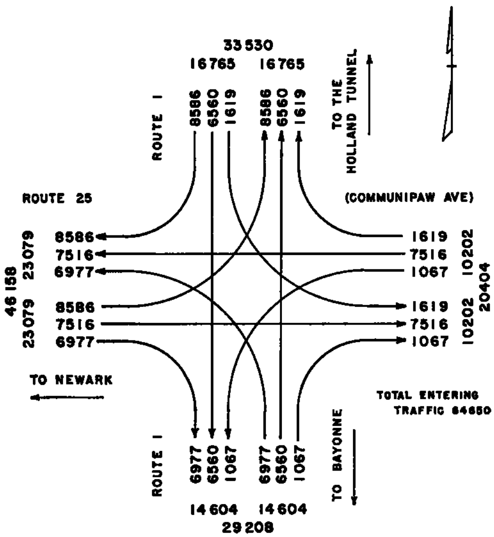


Figure 15. After Revision—Average Annual Daily Traffic for Year Ending Jan. 1, 1951.

DISCUSSION

MORTON S. RAFF, *Bureau of Public Roads:* Mr. Bellis has given a vivid demonstration of the benefits which can be achieved by channelizing a congested intersection. The redesign which he has described shows both imagination and intelligence, and its principles should be useful at many other locations where heavy left turns create a serious congestion problem.

The use of progressive signal timing is positively brilliant. Its success can be seen in the fact that even the most modern type of traffic-actuated controller is unable to reduce the average travel time below what is attained with fixed-time equipment.

Now that the improvement is plain for all to see, some will say that the result was obvious all the time. Yet I dare say there were many who scoffed at the idea that a congested intersection might be improved by creating three new signalized intersections. I take off my hat to the men who refused to be deterred by such criticisms.

DEPARTMENT OF SOILS

Harold Allen, *Chairman*

STRESS DISTRIBUTION BELOW PAVEMENTS UNDER TROLLEY BUS LOADINGS

Robert M. Hardy, *Dean and Professor of Civil Engineering* and P. J. Rivard, *Instructor, University of Alberta*

SYNOPSIS

Incidental to an investigation of the causes of rapid deterioration of pavements under Trolley Bus Loadings in the City of Edmonton a comprehensive series of stress measurements in the sub-soil was undertaken. The project was commenced in 1948 in cooperation with the National Research Council of Canada and the City Engineer's Department.

The stress distribution below both rigid and flexible pavements under normal traffic loadings was investigated. The effect of dynamic forces was also assessed. Stresses were measured with U. S. Waterways Experiment Station pressure cells using automatic recording equipment.

The data indicate that the pressure distribution below the flexible pavement was in close agreement with that computed by the Boussinesq equations of the elastic theory. This is also true of the pressure distribution below the rigid pavement if the thickness of concrete pavement is replaced by an equivalent thickness of soil obtained by multiplying the concrete slab thickness by a constant factor. The effects of impact, braking and acceleration forces were small compared to the stresses produced by static loads.

Many cities have experienced rapid deterioration of pavements on arterial streets following loading by trolley bus traffic. The experience, since 1945, of the City of Edmonton, Alberta, Canada, is typical of a number of cities in Western Canada. Both rigid and flexible type pavements developed extensive failures within a few months, and frequently within only a few weeks, after being subjected to trolley bus traffic for the first time. In some cases the road surface was old but had given satisfactory service for many years, in others the surface was practically new.

Failures, in general, have been of the type indicative of inadequate pavement support, although some instability of the asphalt surface was noted, particularly at the bus stop points. In Edmonton, where the sub-soil is a clay, the initial failures invariably developed at the bus stop points.

An investigation of such failures was undertaken in 1948 in the City of Edmonton by the Civil Engineering Department of the University of Alberta with funds provided by the National Research Council of Canada and the City Engineer's Department of Edmonton.

Soil Characteristics—Soil characteristics were surveyed over a stretch of some thirty-five blocks on the most heavily travelled bus line. Subgrade strength determinations were made and the load carrying capacity of the pavement was checked with CBR design curves. Table 1 shows a summary of the soil properties. A comprehensive series of stress measurements in the subgrade at two route stop points was also undertaken. This paper deals primarily with the results of the stress measurements as these are somewhat more general in significance than the results derived from the study of the local soil properties and moisture conditions.