

PLANNING METHODS FOR INTEGRATING LRT OPERATIONS INTO AN URBAN STREET TRAFFIC CONTROL SYSTEM

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INTRODUCTION

Approximately 1.5 miles (2.4 kilometers) of the Hudson-Bergen Light Rail Transit System (HBLRTS) alignment passes through Jersey City's Central Business District (CBD). This is one of the most congested parts of the urban street network within the proposed LRT travel corridor. The HBLRTS ultimately will serve a 20.5 mile (33 kilometer) - mile long corridor along the New Jersey Hudson River Waterfront - prime area for commercial and residential development in recent years. The LRT system is expected to carry 100,000 weekday riders by



HBLRTS Station Stop

2010, and will incorporate 65 light rail vehicles, 5 major intermodal transfer sites (light rail, ferry, bus), 8 regional park-and-ride lots with 8,885 parking spaces and 33 stations. The system will link Jersey City, Hoboken, Bayonne, Weehawken and North Bergen, some of the most congested areas in the Northeast. As part of the preliminary engineering design, Parsons Brinckerhoff Quade and Douglas, Inc. (PB) was directed by New Jersey (NJ) Transit to integrate the vehicular and pedestrian traffic movements through the street network while simultaneously facilitating light rail vehicle (LRV) movements--two potentially conflicting/competing demands.

To accomplish this objective, PB used both standard traffic engineering software tools and a customized simulation model to develop an integrated

vehicular/pedestrian and LRT traffic control system that provides acceptable operations at the roadway/LRV interfaces. The LRT system was to give preferential treatment to the LRV and to create efficient traffic signal operations on the major arterial roadways serving Jersey City's CBD. The following sections describe the

methodology employed and the results.

METHODOLOGY

The following five steps describe the methodology employed to determine and evaluate the traffic signal operations required to facilitate light rail vehicle (LRV) movements through Jersey City's CBD while maintaining efficient traffic flow on

the surface streets.

STEP 1: REPRESENT VEHICULAR/LRT TRAFFIC NETWORK AND ASSOCIATED VOLUMES

The first step was to develop balanced peak hour traffic volumes for the CBD street network under a design year of 2010 conditions. The street network composed of 40 intersections was organized into five primary arterial systems, each separated into sections depending on the traffic flow pattern (one-way vs. two-way). For purposes of this paper, the critical P.M. peak hour was chosen for presentation of analysis and findings.

The LRT alignment in Jersey City's CBD is both semi-exclusive (by definition, a separate right-of-way or in a street or railroad right-of-way where motor vehicles, pedestrians, and bicycles cross at designated crossings

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only) and mixed traffic. Because LRVs stop at a station and likely will encounter variable dwell times, it was logical to separate the LRT route into unidirectional station-to-station segments. Closely spaced intersections (i.e., less than the LRV vehicle length) that should operate together to avoid potential LRV storage problems were grouped together. The proposed HBLRTS alignment that was the focus area of our study is presented in Figure 1. Along Essex Street, the alignment is in partially shared right-of-way; the westbound track shares the roadway area with Essex Street, which is one-way westbound. The LRT alignment continues in a generally northward direction paralleling Hudson Street, Christopher Columbus Drive and Greene Street within a semi-exclusive right-of-way. The LRT will operate concurrently with non-conflicting movements at most locations along these roadways. Beyond Greene Street, the alignment is in its exclusive right-of-way, intersecting other surface streets at mid-block locations. Figure 1 also depicts the street network configuration, proposed traffic control and street patterns.

STEP 2: SIMULATE LRV/VEHICLE TRAFFIC

The second step involved simulating the automobile and LRV traffic in the network using TRANSYT-7F to generate first-cut/suboptimal signal timing plans. To simulate the LRV flow, special TRANSYT-7F components (vehicle and link characteristics, speed and stop/dwell times, etc.) that are designed to model transit/bus operations were adjusted to emulate LRV operations. In addition, the LRV's unique performance characteristics, size, and location in the street right-of-way required that it was sometimes provided with a separate signal phase and phase timing so it would move safely and efficiently through signalized intersections.

Baseline TRANSYT-7F Analysis. The specific operational policy applied to the baseline condition maximized traffic flow on the arterial systems while minimizing the disutility (i.e., delay, stop, etc), and not giving preferential treatment to any one arterial. The simulation model maximized progression, subject to maintaining sufficient green times for the minor street.

However, it is noted that from a traffic engineering point of view, it is desirable to favor one arterial or direction over another. In the baseline analysis, the LRVs were not given preferential treatment over the general vehicular traffic. Some of the underlying principles and assumptions used for traffic signal phasing, timing, and operating criteria input to TRANSYT-7F are described below.

Underlying Principles and Assumptions

1. Traffic Signal Phasing and Timing. An LRV phase can usually operate concurrently with selected non-conflicting automobile/pedestrian phases or phase combinations. However, it must be timed separately to efficiently implement the additional grade crossing clearance times required for the LRV. The clearance times were based on the assumptions of a service deceleration rate of approximately 4.4 feet (1.34 meters)/sec² and 2-car LRVs with an approximate length of 185 feet (56.4 meters).

At all signalized grade crossings along the LRT alignment, the LRVs will have a minimum of two signal faces in each direction. These signals will display a white bar in one of three aspects: vertical (proceed), slanting (prepare to stop), and horizontal (stop). These are analogous to the green, yellow, and red indications of typical vehicle traffic signals, and are similarly sequenced through the LRT phase. The LRV signal phases will have typical minimum "yellow" and default "red clearance" intervals of 5 seconds and 6 seconds, respectively, with the exception of a few locations where a longer default "red clearance" time is required.

The LRV phases will be actuated only when an LRV is approaching, unless that phase is the "rest" concurrent phase. Further, the LRV phase is timed independently of the concurrent vehicular phases and terminated before the concurrent vehicular phases because of different change and clearance times. Typical phasing schemes are presented in Figure 2 and representation of the phasing elements are depicted in Figure 3.

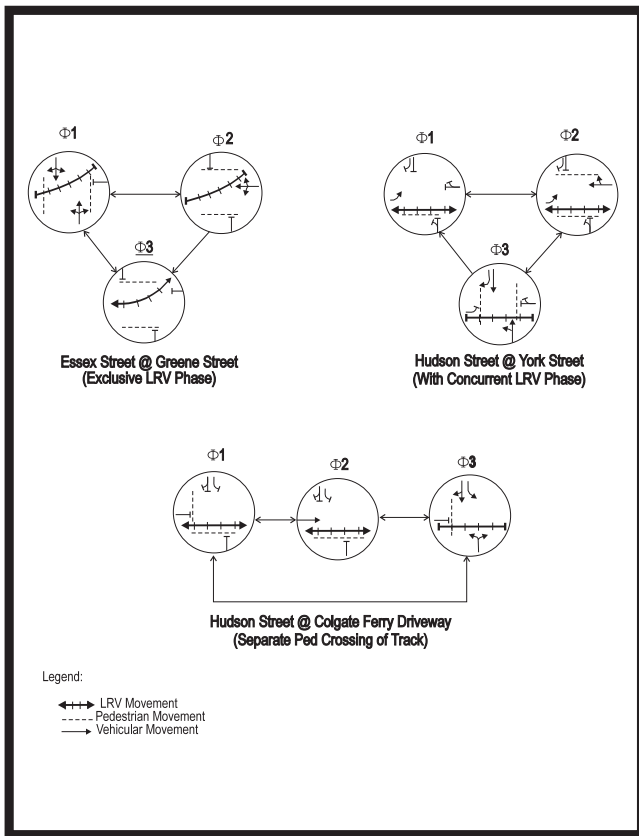


Figure 2 Typical Phasing Scheme

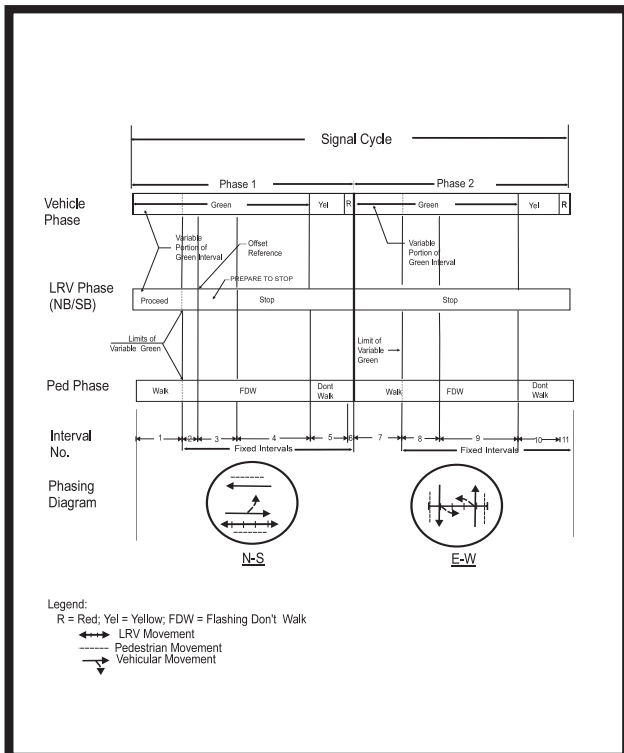


Figure 3 Phasing Time Elements

2. Flexible Intersection Operating Criteria. Typically, a system of three detectors will be provided to detect LRVs on each approach to a signalized grade crossing. The first detector (an antenna capable of reading a signal from a track-to-wayside transponder beneath each end of the LRV) will be placed upstream of the intersection to provide advance detection of an approaching LRV. The second detector will be placed a few feet in advance of the grade crossing at the LRV stopline. This will function as a check-in detector, sensing the arrival of the LRV by identifying a coded signal for the front of the LRV. The third detector will be placed a few feet beyond the grade crossing to function as a check-out detector. Identifying a coded signal for the rear of the LRV will indicate the LRV has completely cleared the grade crossing. The check-out detection will allow for early termination of the LRV phase, providing an opposing LRV is not approaching the crossing. The surplus LRV phase timing can be reallocated to the other phases. The side street approaches will also be detectorized to insure minimum green time allocation if vehicular demand is present.

This semi/fully actuated signal operation will allow flexible intersection operation within the limits of the sum of fixed intervals (i.e., W (walk), FDW (flashing don't walk), DW (don't walk)/Yellow and Red) as the minimum, and upper limits of the variable green interval (maximum) for a particular phase subject to a background signal cycle length typically set at 90 seconds, as shown in Figure 3. At intersections where traffic volumes are low, a background signal cycle length of 90 seconds may be unnecessary and too long, causing excessive delays. At the locations where such conditions prevail, implementation of double signal cycles is beneficial.

In addition, several side street phases may be subject to "green shortening" to extend the progression window for LRVs in either direction. The traffic signal controller may also be programmed to allow phases to be skipped. This provides partial LRV preferential treatment during coordinated signal operation, or full preferential treatment during free signal operation. Even though a vehicle green phase may be shortened or skipped entirely, the

associated pedestrian phases (if called) and background cycle will continue uninterrupted.

STEP 3: PROGRESSION BAND FOR LRV PREFERENTIAL TREATMENT

Subsequent to establishing the TRANSYT-7F baseline suboptimal timing plans, an arterial signal timing pattern was developed that gives preferential treatment to the LRT route, but minimizes adverse impacts on arterial and side street operations. The approach used Time-Space Diagram-Windows (TSD-WIN), a bandwidth enhancement tool, to achieve bi-directional coordinated green bands.

The TSD-WIN easily enables the micro-adjustment of signal timing and offsets to improve bi-directional coordination. The timing may be manipulated on-screen using a mouse, and the resulting green bands displayed instantly.

About this time in the analysis, LRV speed profiles had become available from the Operations Design group on the HBLRTS project team. These profiles describe the performance of an LRV as it travels along the LRT alignment.

Physical features of the alignment which would impact LRV performance were built into the performance profile model. These features included: block lengths; locations, lengths, and radii of curved sections; grades; station locations and anticipated dwell times; speed restrictions, etc. Performance features of the LRV, such as braking distances and acceleration rates from various speeds to terminal speed, were also placed in the model. The output of this model provided many statistics describing the LRV operating performance at all points along the alignment. These statistics included: locations of brake applications, and beginning and end of acceleration; crossing speeds; segment travel times; and total elapsed travel time.

The splits and offsets developed for the LRV route under the TRANSYT-7F baseline condition were imported into TSD-WIN. Also imported were the link speeds from the speed performance profile model. Minor split and offset adjustments were made to minimize blockages at specific intersections along the route in both directions. There were two significant factors considered that allowed for a micro-scale adjustment. First, since the speeds are not necessarily uniformed within the links, consideration was given that the green bands shown on the screen must include the time acquired to accelerate or decelerate. Second, it is desired to have a “proceed” indication displayed to the operator of an approaching LRV in advance of its arrival at the crossing. This is to avoid the situation of brake application immediately followed by either an acceleration, or a short stop. Thus, the lower border of the progression band would intersect the green interval a few seconds into the interval, and the upper border would be allowed to intersect the clearance interval by the same length. In the network sections where parallel traffic travels in the same progression with the LRV, the governing offsets were based on the LRV route. The output of the TSD-WIN signal timing plans (splits and offsets) was then entered into the TRANSYT-7F baseline model. The model was rerun to determine vehicular network performance. The important aspect of this procedure is that the timing pattern that accomplished the maximum signal progression band for the LRV route was locked in the reevaluation process so that LRVs receive preferential treatment.

Table 1 presents the estimated system level of performance indicators showing the comparison between the baseline condition (no preferential treatment for LRVs) and final optimization (with preferential treatment for LRVs). With LRV priority treatment, the results of the analysis reveal that along the LRT route, total delay, passenger delay and stops improved. The slight reduction in system speed is attributed to the small increase in delay on the side streets as a result of the priority given to the LRT movement. It is also noted that the vehicular traffic traveling along the arterial sections of Hudson and Greene Streets will benefit significantly with the LRV

progression band. Nonetheless, Washington Street and Christopher Columbus Drive as well as other parts the vehicular network show a reduction in performance. A check of the TRANSYT-7F output indicates the degree-of-saturation in most cases remains within an acceptable range. There are exceptions of a few locations where congestion persists even without the LRT priority treatment.

STEP 4: VISUAL EVALUATION OF NETWORK OPERATIONS WITH CUSTOMIZED DYNAMIC SIMULATION MODEL

Once the phasing patterns, timing splits and offsets were set by TRANSYT-7F, these signal operation parameters were programmed into a three (3) dimensional simulation model developed specifically for the project. The simulation model was created in an “AutoMod” platform which is a simulation system that uses CAD-like drawing tools to create the physical elements of a system, a spreadsheet interface product process details, and an engineering-oriented language to model complex control logic and material flow. The simulator’s powerful graphics accurately capture the physical constraints of

The simulation model was utilized not only to visually verify the proposed traffic control strategies. It was also used to view passenger alightings and boardings at the Exchange Place Station stop (a major transfer station to the Port Authority of NY & NJ PATH system), and interaction of pedestrian flows. Minor adjustments to signal timings and offsets, LRV headway’s and different traffic volume conditions (i.e., a.m. peak vs. p.m. peak hours) were conducted to test the impacts of these factors on system operations.

At this time, the simulation model is still under development. In its current state, it permits one to view a simulation of traffic operations in Jersey City’s CBD. If a more detailed view is desired, one may “zoom-in” to view the location and also rotate the view to gain an infinite number of perspectives. Although the numerical outputs from the model are currently limited, it provides summary system and link delay measures, and number of passengers and vehicles processed.

Once the model is fully developed, a wealth of measures of effectiveness data will be available. This would include link and system speeds, degrees of saturation, and

Performance Measures	Units	NB/SB LRT Route		NB/SB Greene Street		NB/SB Hudson Street		NB/SB Wash. Street		EB/WB Columbus Drive	
		W/O	W	W/O	W	W/O	W	W/O	W	W/O	W
Total Travel	Veh-mi/Hr	48	48	265	265	19	19	174	174	265	265
Total Travel Time	Veh-hr/hr	5	5	34	22	3	2	8	10	164	495
Total Delay	Veh-hr/hr	2	1	12	11	2	2	2	3	154	180
Stops											
Total	Veh/hr	306	197	1695	2266	219	189	472	661	2463	3003
Percentage	%	35	23	40	53	55	48	15	21	61	74
System Speed ⁽¹⁾	mph	10.2	9.2	11.8	12.3	7.8	8.8	22.2	17.7	1.6	1.4

Table 1: 2010 PM Peak Hour Route Performance Without (W/O) & With (W) LRT Preferential Treatment

(1) System speed is an indication of the overall quality of flow in the network. It is simply the ratio of total travel (TT) and total travel time (TTT) and is thus expressed as veh-mi/veh-hr = mph.

distance, size, and space in 3-D. Since the actual geometric and physical roadway conditions were built into the simulation model by AutoMod, the traffic and LRT flows can be viewed as they “travel” through Jersey City’s CBD.

delays. There will also be the option of connecting the simulated displays to an enhanced view on video tape. The 3-D video image is expected to be a useful tool in addressing the concerns raised by interested parties regarding the impacts of the HBLRTS on Jersey City’s CBD.

**STEP 5: REEVALUATE CONTROL STRATEGY
WITH JURISDICTIONAL AGENCY
COORDINATION**

From the project's inception, governmental agencies, local politicians, community groups, and other interested parties have played a key role in the design and evaluation of the traffic control strategies of the at grade LRV/roadway interfaces. These parties have participated through a series of Traffic Group Workshops which has been an ongoing process.

The City of Jersey City Traffic Engineering Division currently maintains a closed loop traffic control system of approximately 150 intersections. The HBLRTS will add to this total through the creation of approximately 30 new signalized mid-block or intersection LRT grade crossings. The LRT alignment will traverse through several different traffic control sub-systems. Fortunately, a large section of the LRT alignment within the CBD traverses on the city boundaries where no traffic control system currently exists. Thus, the LRT traffic control system will create a new sub-system. The few adjacent signalized intersections will be adjusted to provide coordination with the new sub-system.

CONCLUSION

This traffic signal coordination study demonstrated that given the vehicular/LRV network configuration and traffic forecast in Jersey City's CBD by the year 2010, a traffic signal system that balances the needs for LRV priority treatment with conflicting vehicular and pedestrian flow is achievable. Traffic signal controllers can accommodate LRV phases that are timed independently of concurrent automobile phases. Each direction of LRV travel can have its own phase or can run concurrently with vehicular phase, and this can be actuated and terminated through a system of check-in and check-out detectors. LRV station-to-station priority treatment can be accomplished by the provision of green band through a series of signalized intersections.

The signal timing intervals/splits developed in this study provided phase minimums (i.e., sum of fixed clearance intervals) and maximums (i.e., the upper limits of the variable portion of the green interval) at specific intersections. The calculated offsets which are typically referenced to the beginning of the yellow/change interval ensures a fixed relationship among adjacent intersections. The study also provided the basis for operational strategies to be fine tuned in the field and altered over time as conditions and priorities change.