

**Designing New Light Rail**  
*Taking Engineering Beyond Vanilla*

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As light rail transit (LRT) systems mature and expand, outlying passengers are faced with increasingly longer trip times to reach the urban core. Providing service to these customers by conventional means can be disproportionately expensive for the transit carrier in terms of operating and capital expense. Innovative operational practices to expedite train movements, however, are often confounded by current LRT design and deployment methods. This is partly attributable to design methods that follow a “stovepipe” approach to individual engineering disciplines and components, rather than directing focus on optimizing railway functionality and flexibility as a comprehensive entity. It is also attributable, in part, to a failure to address the ultimate potential of a railway at the definition/developmental stage and to subsequently articulate and document the operational requirements that are necessary to support the stated mission.

This paper provides a survey of the critical engineering “systems” that comprise a light electrified passenger railway, and suggests those that are most significant in affecting innovative operational practices. It illustrates the model relationship between operations and systems design by a case study based on the first implementation of express service on a modern LRT system.

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**INTRODUCTION**

As prospective light rail transit (LRT) systems undergo conceptual design and preliminary engineering, achieving implementation of the minimal operable system is a more pressing concern than any consideration of a future “maximal operable system” (MOS). Nevertheless, most light rail systems eventually expand as they mature, pushing increasingly farther and farther out from their original core.

System expansions can quickly reach a point of diminishing returns as new passengers at outlying stations face longer travel times to the urban centers—an experience punctuated by stops at each and every station enroute. Providing service to these customers by conventional means can be disproportionately expensive for the carrier in terms of operating and capital expense. Longer trip times translate into a less attractive service that is less capable of competing against travel by automobile, which result in a lower modal split and diminished ridership potential.

## EXPEDITED SERVICE

### The Interurban Era

The interurban railway industry—the functional progenitor of modern LRT—faced a similar challenge in attracting passengers for longer distance trips a century ago. In response, several midwestern interurbans augmented local train service with expresses that skipped intermediate stops outside of towns. A few lines went a step further, adopting limited service with stops only in major towns and destinations. A major period of interest in limited operations began in 1922 as interurbans faced increasing competition with automobiles. (1)

Interurbans that operated high-speed intercity service frequently handled heavy commuter service, which also required a large terminal population. A combination of the two represented a vital advantage that enabled many carriers to outlive the majority of the interurban industry. The most notable high-speed systems of yesterdays that successfully employed expresses and other forms of expedited train service to attract and keep commuters were:

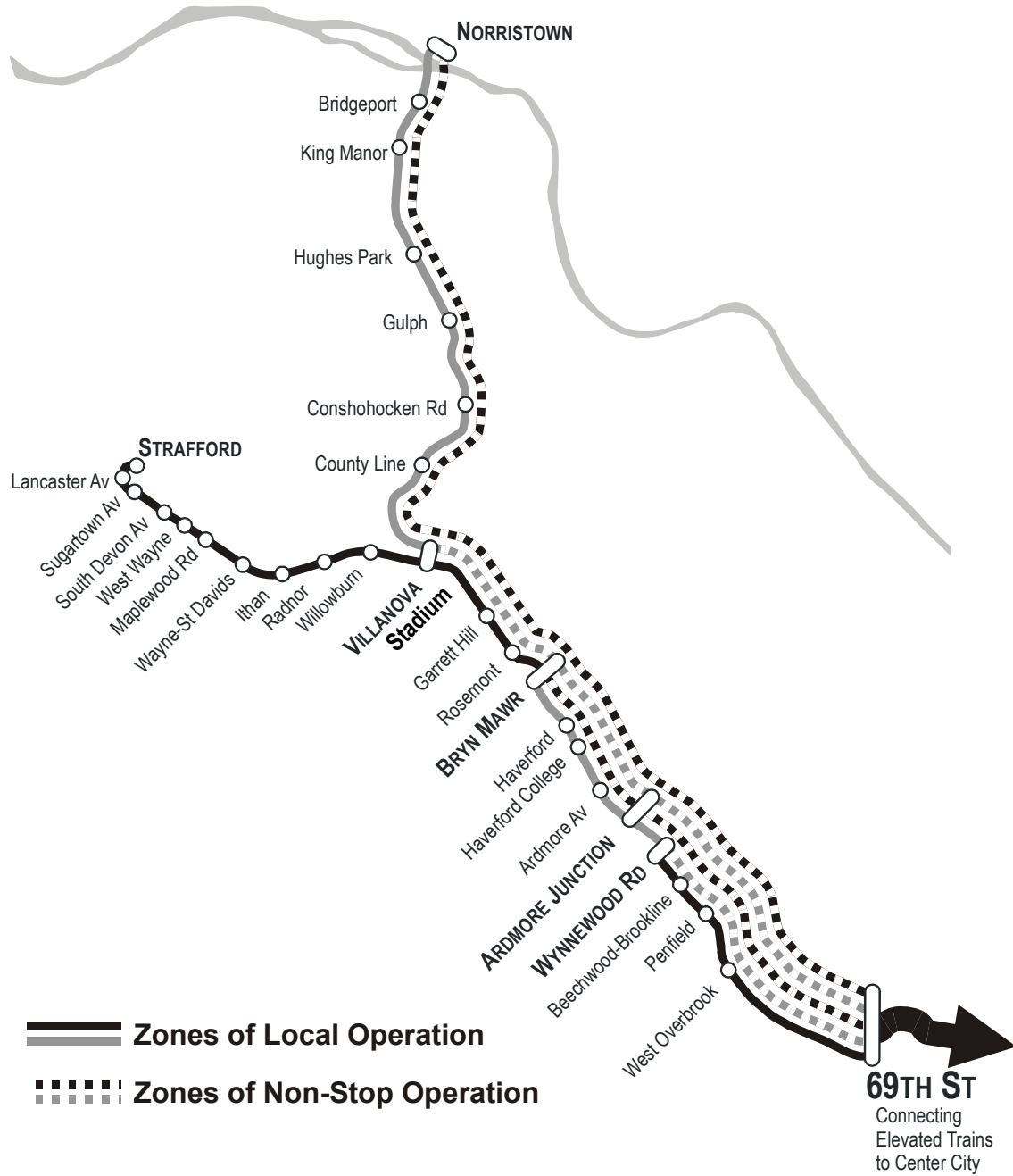
- Chicago, South Shore, and South Bend Railroad (South Shore Line)
- Chicago, North Shore, and Milwaukee Railroad (North Shore Line)
- Chicago, Aurora, and Elgin Railway
- Sacramento Northern Railway (Northern California)
- Bamberger Electric Railroad (Utah)
- Pacific Electric Railway (Southern California)
- Indiana Railroad
- Detroit United Railways
- Milwaukee Electric Railway & Light Company
- Lehigh Valley Transit Company (Eastern Pennsylvania)
- Philadelphia and Western Railway

The first four interurbans on the preceding list expedited service to city centers by running over grade-separated rapid transit rights-of-way (ROWs) belonging to other carriers with few or no stops. The last two systems on the list enjoyed a synergistic relationship in which the former ran in an expedited manner over the lines of the latter. All of these systems intertwined the operation of local, express, and often additional limited services on predominately two-track ROWs using train control and communications systems and dispatching techniques that appear primitive in comparison to modern day capabilities.

### Philadelphia and Western Railway

The level of complexity expedited operations of the interurban era achieved is best illustrated by the Philadelphia and Western Railway (P&W) in 1951. By this time, the Lehigh Valley Transit trains had ceased operation over the P&W. What remained was a two-branch railway consisting of two tracks except for pocket tracks at Wynnewood Road and Bryn Mawr where trains reversed direction clear of the main line. All switches were manually operated by motormen except for the junction at Villanova.

Every 15 min in the evening peak period, five trains were dispatched westward from 69th Street Terminal in Upper Darby in short order (Figure 1):



**FIGURE 1 Philadelphia and Western Railway peak service configuration (1951).**

1. Norristown Limited (non-stop to Norristown);
2. Norristown Express (express to Villanova with stops at Ardmore Junction and Bryn Mawr);
3. Strafford Express (express to Bryn Mawr with a stop at Ardmore Junction);
4. Bryn Mawr Express (express to Wynnewood Road); and
5. Wynnewood Road Local (2).

### Expedited Service Techniques

Following is a brief overview of the available techniques for expedited service:

- *Demand Stops.* Trains stop only upon demand at minor stations (“flag stops”) except at high-traffic stations (e.g., Central Business District, terminals, high volume, transfers). This requires that an on-board passenger signal to stop the train. Minor stations also must be equipped with a passenger signal to stop train, or train operators must observe where passengers are waiting as they approach each station. This can be a particularly efficient way to increase line schedule speed and reduce operating costs except at higher capacity levels when all trains will stop at all stations. Demand stops are rare on new North American light rail systems [e.g.: Southeastern Pennsylvania Transportation Authority (SEPTA) Route 100], even where there would clearly be benefit from bypassing low-volume stations in off-peak periods. (3)

- *Skip-Stop Express.* Lower trafficked intermediate stations are alternately designated as “A” or “B” stops, while high-traffic stations are designated as “all stop.” Alternate movements are designated as “A” or “B” trains that stop only at their respective stations and at “all stop” stations. This method is only applicable if headways are sufficiently short that the “up to two-headway wait” at minor stations will be acceptable to passengers. Skip stops provide faster travel times for the majority of passengers with less equipment and fewer staff but do not increase capacity as the constraint remains the dwell time at maximum load point stations at which, by definition, all trains must stop. In fact, capacity can be slightly reduced as the extra passengers transferring between A and B trains at common stations can sometimes increase dwell times. Skip-stop operation increases speed but not capacity. (3)

- *Zone Express.* Outlying stations are grouped into zones. Two or more different routes are overlaid with trains bypassing stations between the terminal and the start of their designated zone. The 1951 P&W operation illustrated in Figure 1 is a LRT example of a zone express operation. Zone express is capable of providing high schedule speeds and meeting a customer perception of true express service. However, because zone operation on a transit line essentially consists of zone expresses overtaking “ghost slots” (discussed later), this service is not suitable for lines running at or near capacity.

- *Skip-Zone Express.* This technique is a combination of skip-stop and zone expresses. Outlying stations are grouped into zones. Similar to simple skip-stop service, trains make all the stops in one zones, then skip the stops in the next zone. This makes service patterns that are easier for riders to understand and the longer stretches of non-stop service are perceived as faster by riders.

- *Short Overtake Tracks or “Reverse” Shots.* Railroads traditionally utilized relatively short passing tracks, or have “reverse” run in order to permit faster trains (passenger or freight) to overtake and pass slower, inferior trains). Application of this technique in a short headway, transit environment requires both a detailed adaptation of the railway configuration (i.e., systems

design and integration) to a well conceived operating plan, and precise management of train operation so that trains arrive at their designated locations on schedule. Use of short overtake tracks was commonly used in Chicago, particularly for the Chicago, Aurora, and Elgin interurban trains operating over the Chicago Elevated to a terminal at the Loop. Recently, this practice was utilized on the Port Authority of New York and New Jersey's Port Authority Trans-Hudson system to operate non-stop express service in the morning peak between Newark and the World Trade Center Stations. The overtake was timed to occur at Journal Square Station utilizing a spare "running" track but the speed through the running track was not sufficient to accomplish the overtake without some delay to the local.

Expedited service may be provided on two-track rail lines by a variety of methods, each with merits and drawbacks. There is no singular "superior" method as the approach to service planning must be tailored to best reflect the operational configuration and the customer service requirements of each particular system. The only proper response to the question of "What works best?" is "It depends."

### **Contemporary Expedited Service**

The long heritage of expedited service applications in interurban operations has not translated to modern LRT operations. Contemporary examples are limited, for the most part, to commuter rail and rapid rail transit (RRT) operations. Virtually all modern LRT systems operate trains from one terminal to the other making all stops enroute. The two present-day LRT exceptions are the aforementioned P&W (now Route 100/Norristown High Speed Line of the SEPTA) and NJ Transit's new Hudson-Bergen LRT System (HBLR).

Attempts to introduce expedited service and other innovative operational practices in the modern LRT environment is often confounded by current design and deployment methods. This is partly attributable to design methods that follow a "stovepipe" approach to individual engineering disciplines and components, rather than directing focus on optimizing railway functionality and flexibility as a comprehensive entity. It is also attributable, in part, to a failure to address the ultimate potential of a railway during the definition/developmental stage and to subsequently articulate and document the operational requirements necessary to support the stated mission.

### **Vanilla Rail**

The result of these processes is labeled by the authors as "Vanilla Rail"—a cookie-cutter sameness in LRT operations pervading the North American transit industry with little or no regard of the site and situation of a specific application. There is nothing wrong per se with vanilla (it is, in fact, the preferred flavor of one of the author's daughters). "Vanilla Rail"—in the form an "Up-and-Back" railway making all stops, end to end—is often the appropriate operational approach in many LRT applications. The pejorative distinction of "Vanilla Rail" (in LRT operations as well as in the choice of ice cream) comes about when a decision is made in the absence of full consideration of the alternative "flavors."

At its worst, "Vanilla Rail" results in limited operating flexibility and growth potential at the same time individual systems are designed as high end. One such example (drawn from one recent anonymous LRT system but equally applicable to many) results in:

- Track constructed to 80 mph standards, comprised of all new continuous welded rail laid on concrete ties.
- Constant tension, compound catenary, also suitable for 80 mph operation.
- Full cab signaling with Automatic Train Protection/Automatic Train Control (ATP/ATC) with reverse-running signal capability.
- High-performance light rail vehicles (LRVs) with a 65-mph balancing speed.
- Maximum authorized speed on level, tangent track limited to 55 mph by signal block length and level crossing starts.
- Low speed crossovers at terminal stations and junctions.

Two casual factors may be suggested as contributing causes for “Vanilla Rail:”

1. Operational planning practice that fails to comprehensively and concisely establish Operating Requirement Documentation (ORD) at the commencement of systems design and to advocate for adherence with the ORD throughout the design evolution. This is particularly important with respect to Systems Integration (i.e.: How do individual systems intereract to support a defined mission for LRT?).

2. Engineering Practice which uses “bottoms-up” design, that is, each system (track, train control, traction power) is designed to standards which optimize individual systems. Integration is often limited to physical parameters (loads, dimensions), but does not sufficiently consider functionality of the entire railway or operational parameters.

### **Challenge of Moving Beyond Vanilla**

With its mix of ROW types and train control technologies, LRT offers the widest range of latitude in the areas of systems design, applications engineering, and operating practices. The challenge in design is to fully realize the potential of LRT in any given application while avoiding over-design that results in excessive capital investment beyond what would suffice for its intended mission. This issue can be expressed as building a rapid transit infrastructure in accordance with the LRT mission defined in the ORD.

A corollary challenge would be—given a particular level of capital investment—to utilize good applications engineering and systems integration practices to maximize the operational flexibility designed into an LRT system. This would provide capability to satisfy reasonable changes in the ORD beyond those originally baselined. Such flexibility is important to recognize at the earliest stages of design, acknowledging the inexorable tendency of most LRT systems to expand beyond the original extent of their MOS.

HBLR (Figure 2) provides one example of LRT that has evolved (and is continuing to evolve) beyond vanilla. This claim can be demonstrated in terms of its route structure and integrated service plan that optimizes use of core capacity with current zone express service and future consideration of making use of “overtake” opportunities. HBLR design processes borrows freely from the operating practices of interurban and regional/commuter railroads. A case study is presented pertaining to the HBLR express service.

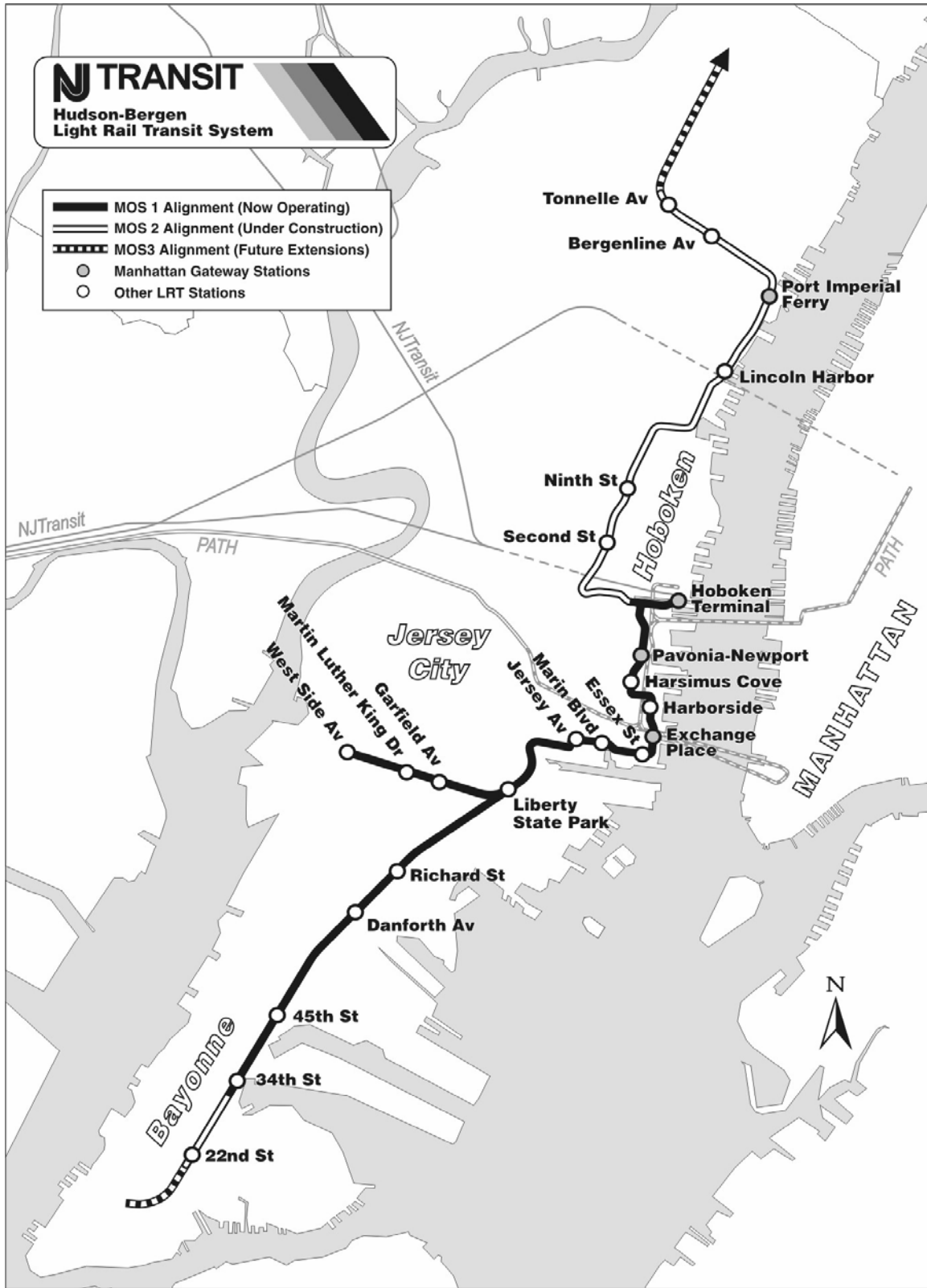


FIGURE 2 HBLR Transit System

## LIGHT RAIL: A SYSTEMS PERSPECTIVE

### Concept of a System

Complex engineering equipment is commonly categorized by “systems”, wherein each system provides a defined, stand-alone capability, and wherein each system—in conjunction with other systems—supports the stated mission of the equipment. Complex systems like an aircraft or spacecraft are developed and designed according to their component systems, such as air frame, navigation system, propulsion, and possibly weapons systems (4). Perusing the table of contents of an automotive shop manual for a 1950 Dodge demonstrates how even a relatively simple product is often organized around its component systems:

*Ignition, Electrical (differentiated from Ignition), Suspension, Chassis, Drive Train, Fuel System, etc. (5)*

An engineered product is developed by systems, with proper attention throughout the product development cycle to satisfying the mission of the product and the derivative operational requirements, and to systems integration/interface requirements. Systems are defined by their function, not by their engineering discipline. Systems are hierarchical in nature, with each system further broken down into sub-systems, and then typically into assemblies, parts, components, etc.

In developing the HBLR, particularly with respect to assuring ultimate satisfaction of the operating and systems integration requirements expressed in the Mandatory Design, Build, Operate, and Maintain Criteria, Washington Group developed a formal protocol for defining systems and sub-systems on an electrified railway. This protocol was presented to the industry as a recommended practice (6).

### HBLR Protocol

Table 1 summarizes the recommended protocol for systems and sub-systems. On HBLR this serves as a basis for design, railway commissioning, and of Safety Certification of revenue ready status. On operating segments it provides the basis for the maintenance organization (including a work breakdown structure for those craft positions covered by a collective bargaining agreement), for failure reporting and for the accumulation and analysis of reliability and availability data. The systems protocol has also served as the basis for operational planning wherein the contribution (or lack of contribution) of each system to a candidate operating scenario is evaluated based on the engineering performance designed into that system.

### Categorization by Systems

The systems protocol provides an excellent basis for categorizing light rail as a sub-mode within the rail transit mode. Following Vuchic (7) and others, the ability to operate on exclusive and semi-exclusive ROWs as well as in mixed-traffic with automobiles, and to gain the maximum benefit of the particular ROW, is seen as the primary differentiator between LRT and other rail transit modes (reflected in Table 1 as Systems 11.0).

Viewed from the system perspective, consideration of the ROW directly leads to two additional systems whose functionality and design differentiate LRT from RRT and streetcar

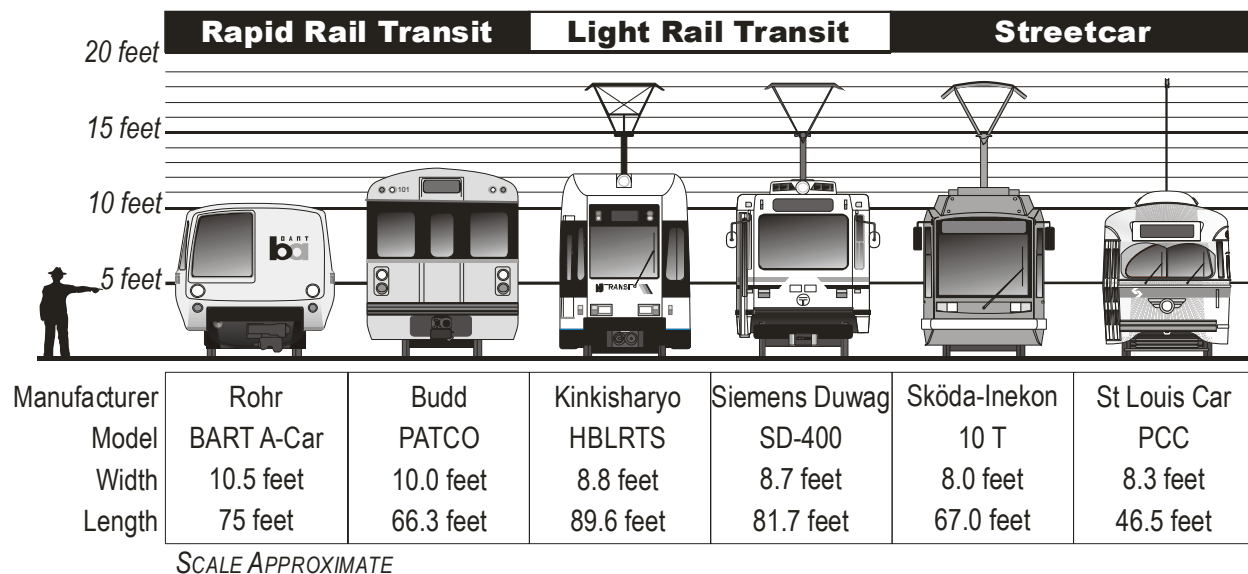


**TABLE 1 HBLR Engineering Systems and Subsystems**

System	Subsystem	System	Subsystem
1.0 Rolling stock	1.1 Light Rail Vehicles	7.0 Fare Collection	7.1 Ticket Vending Machines
	1.2 Non-Revenue Rail Equipment		7.2 Ticket Validators
	1.3 Track Cars/Hi-rail Equipment	7.3 Software	
2.0 Electrification	2.1 Substations	8.0 Administrative Systems	8.1 Maintenance Management System
	2.2 Overhead Contact System	9.0 Traffic Operating System	9.1 Traffic Signals
	2.3 Stray Current Mitigation		9.2 Light Rail Transit “Bar” Signals
3.0 Track	3.1 Ballasted Track	10.0 Stations	9.3 Area Controller
	3.2 Embedded Track		9.4 Local Controllers
	3.3 Direct Fixation Track		9.5 Local Network
4.0 Train Control	3.4 Special Track/Ballasted	11.0 Right-of-Way	10.1 Plaza
	3.5 Special Track/Direct Fixation		10.2 Platforms
	3.6 Miscellaneous Trackwork	10.3 Stairs & Structures	
	4.1 Interlockings	10.4 Parking	
	4.2 Train Separation-Automatic Train Protection	12.0 Tunnels	11.1 Drainage
	4.3 Signal Power		11.2 Fencing
	4.4 Wayside Equipment		11.3 Minor Structure
5.0 Communication	4.5 Intrusion Detection	13.0 Guideway	11.4 Slabs
	4.6 On-Board Equipment		11.5 Line Equipment
	4.7 Grade Crossing Protection	14.0 Shop	12.1 Ventilation
	5.1 Telephone		12.2 Fire Protection
	5.2 Passenger Information Subsystem		12.3 Egress Facilities
	5.3 Security Subsystem		12.4 Structure
5.4 Communication Backbone	12.5 Electrical		
5.5 Radio	12.6 Drainage Subsystem		
6.0 Integrated Control System	5.6 Systems Control and Data Acquisition	15.0 Yard	13.2 Viaduct
	6.1 Workstations		13.3 Major Bridges
	6.2 Software/Hardware	14.1 Electrical	14.2 Mechanical
6.3 Traffic Operations Interface	14.3 Electronics		
		14.4 Local Communications	14.5 Special Equipment
		14.6 Structure	15.1 Ladders & Leads
			15.2 Car Storage Building

(SCR). These are “Rolling Stock” and “Train Control” (System 1.0 and System 4.0, respectively, in Table 1).

LRVs are distinguished from RRT rolling stock by their capability for operation in mixed traffic, generally resulting in a narrower car body and articulation in order to operate in a mixed-traffic street environment (Figure 3). Conversely, LRVs generally outperform SCR vehicles in terms of capacity and top end speed, and almost all modern LRVs are capable of multiple-unit operation. Particularly on exclusive ROW, the LRV can provide much higher “production” (i.e.: capacity multiplied by scheduled speed) than a SCR. Thus a 45-mph SCR operating on exclusive ROW cannot be considered as “light rail”. The latest generation of LRVs is significantly larger and faster than their predecessor, typically of length of 90 ft with maximum speeds of 60 to 70 mph.



**FIGURE 3 Comparative size of rail transit rolling stock.**

Partial low-floor; high-performance cars offering good ride quality, as typified by the HBLR car, represent the coming generation of LRVs.

LRT train control practice differs from RRT [where Automatic Train Operation (ATO) is the present day norm] and from SCR [where line-of-sight operation (LOS) is the norm, augmented perhaps by limited signaling at turnouts, stations, or other critical locations]. Train control practice for light rail is currently evolving (that represents an area requiring attention from the operational community) and can currently be categorized by two factors. They are:

- “High end” technologies are typically limited to cab signal application with ATP, with many LRT operations employing only Automatic Block Signaling (ABS) on exclusive right-of-way route segments.
- LRT will generally utilize multiple types of train control over a given route. This is also a function of the variety of ROW types.

A derivative of LRT is light rail rapid transit (LRRT), also referred to as “Light Metro.” Such railways are characterized by fully exclusive ROWs, “high end” train control systems with short headway capability, and floor level boarding. The HBLR fits this category, as does Los Angeles Metropolitan Transportation Authority Green Line and SEPTA Route 100.

The final “system” crucial to LRT is the train operator. Unlike modern RRT operating with ATO/ATP, the operator is a key element in a safe, high-quality LRT operation; a “train attendant” concept will not suffice. A LRT operator must be trained, qualified, observed, and periodically re-qualified. While this imposes responsibilities upon operational supervision, it also pays dividends when considering innovative operating practices. In many respects the operator of a light rail train more closely resembles the engineer on a commuter train than a “train attendant” on an ATO System.

## CASE STUDY: HBLR BAYONNE FLYER

### Role of Systems Engineering

While a large body of literature exists regarding the techniques and customer service implications of expedited service [e.g.: Vuchic (7) and Eisele (8)], little exists that analytically relates the design of engineering systems to a particular technique of expedited operations. This case study addresses zone express operation and delineates specific engineering design requirements that were critical to supporting this capability. The systems with the most significance to these operations are:

- Train control (block layout, reverse running);
- Track (turnouts, sidings);
- Integrated Control Systems (ICS);
- Vehicle (performance, configuration);
- Stations (signage, walkways); and
- ROW (high-speed operations, high confidence control of schedule performance).

HBLR presently provides revenue service between Hoboken Terminal and 34th Street, Bayonne, and between Hoboken Terminal and West Side Avenue (see MOS-1 in Figure 2). Extensions to 21st Street in Bayonne and to the north of Hoboken (see MOS-2 in Figure 2) are scheduled to open in November 2003 and March 2004, respectively. HBLR is a complex system with an intermediate terminal located on a branch (Hoboken) accessed through a half grand union junction.

- The line to Bayonne was constructed on the former four-track mainline of the Central Railroad of New Jersey (CNJ), providing an exclusive, high-speed ROW free of grade crossings (one active freight track remains, paralleling the two LRT tracks).
- The West Side Line is built on the exclusive ROW of the former CNJ Newark Branch. It consists of two LRT tracks with one street intersection and two gated grade crossings.
- Between Yard North (the junction between the Bayonne and West Side Lines, near Liberty State Park) and Marin Boulevard, HBLR consists of two tracks built on former CNJ railroad yards. While on exclusive ROW, speeds are generally limited from 15 to 25 mph due to track geometry and a number of street intersections.
- The tracks enter mixed traffic north of Marin Boulevard while the tracks enter mixed traffic. Cab signals are “latch” out and trains continue the approximately 1.5 mi on LOS operation (full train control cab signal with ATP/ATC exists elsewhere on HBLR).

HBLR initially opened on April 15, 2000, with service between 34th Street/West Side Avenue and Exchange Place. Service was extended a year later to Newport, then to Hoboken Terminal on September 29, 2002. A simple (“vanilla”) operating plan was originally envisioned that did not anticipate any form of expedited service.

## Bayonne Flyer-Morning Peak

Following a relatively short shakedown period after the April 2000 opening, a 12-min peak hour headway was established on both branches. The individual branch services combined to provide a 6-min headway on the trunk between Yard North and Exchange Place.

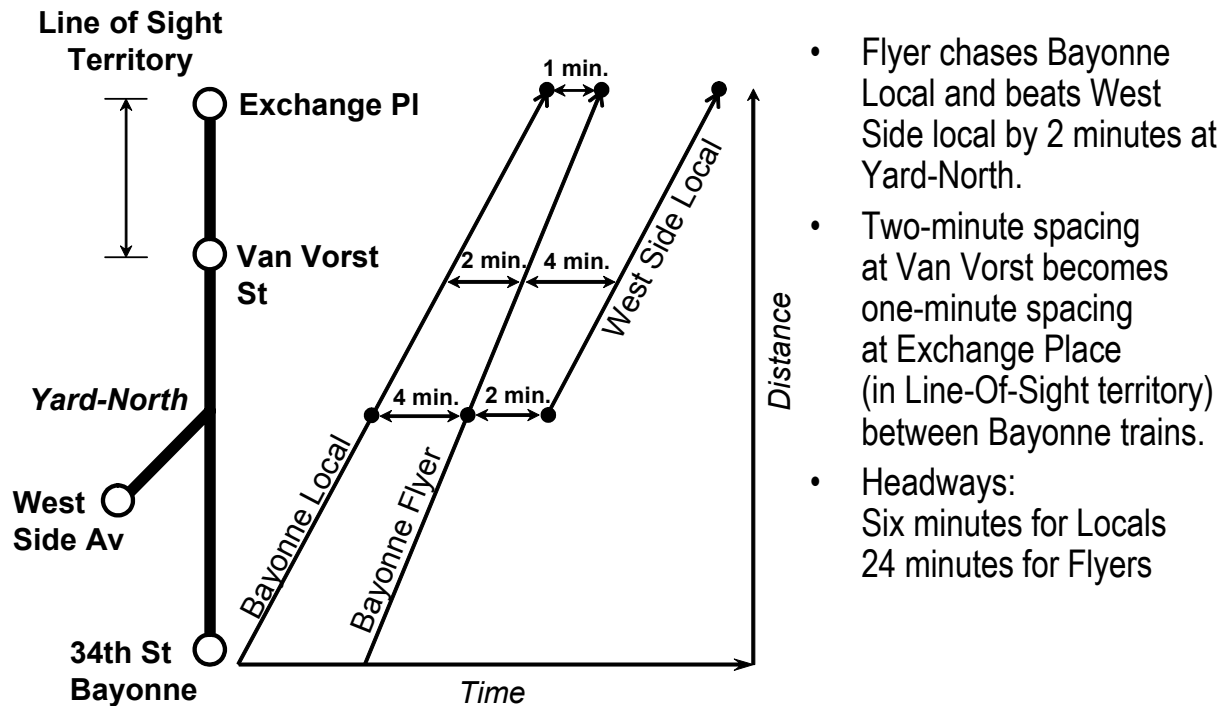
Ridership on West Side trains was light south of Liberty State Park. While Bayonne trains were not at crush loads, high ridership was observed at 45th and 34th Street Stations, each of which have large park-and-ride lots. Selected trains in the peak period had large numbers of standees when they arrived at Liberty State Park. Options for providing extra capacity at these stations included:

- *Use of two-car trains on Bayonne Line.* This was rejected as inefficient with respect to rolling stock utilization. Interline operation of trains provides optimal usage of LRVs, use of two-car trains on Bayonne would require alteration of this practice or else cause wasteful interline operation of these two-car trains over the lightly patronized West Side Branch.
- *Reduced headways on Bayonne.* This was rejected since the ridership during the three-hour peak did not justify establishing shorter peak period headways, and ridership at stations other than 34th, 45th, and Liberty State Park did not justify such action.
- *Use of extra trains.* Based on a detailed, train specific ridership survey a total of three additional departures were scheduled at maximum load times. Ridership at other stations served by Bayonne trains was light, with the exception of Liberty State Park. Therefore, it was decided to operate these trains as zone expresses—named “Bayonne Flyers”—originating at 34th Street and stopping only at 45th Street and Liberty State Park enroute to Exchange Place. This would provide a premier, high-speed service for commuters.

Flyers were scheduled to operate the 5.1 mi to Exchange Place in 14 min, resulting in a commercial speed of about 21.5 mph (which includes a mile of in-street running). This represents a 5-min improvement on the local schedule between these points. It should be noted that the Bayonne Flyers originated as a means of providing additional capacity. An improved product stimulates demand and there are currently six morning Flyers are operated on 24-min headways.

While the Flyers operate as a zone express, they must be scheduled without interference or delay to any local trains. [Figure 4](#) illustrates the morning Flyer operation using a simplified stringline. Of relevance from the perspective of engineering systems is:

- *Train Control.* HBLR is equipped with a cab signal system with ATP/ATC providing theoretical headway design for train separation of 90 to 120 s. The Flyer can close to within 90 s of its “leader” without being penalized by a “cab signal” downgrade.
- *Interlockings.* Headway capability at Yard North interlocking for alternating movements is 120 to 150 s. This headway degradation below “fleeting” capacity is due to the length (which includes a yard lead) of this interlocking.
- *Stations.* Bayonne Line stations are island platforms and all pedestrian walkways are located across the southbound track. The entire northbound track is clear of pedestrian walkways.



**FIGURE 4 Time–distance diagram for northbound morning flyer.**

- Flyer chases Bayonne Local and beats West Side local by 2 minutes at Yard-North.
- Two-minute spacing at Van Vorst becomes one-minute spacing at Exchange Place (in Line-Of-Sight territory) between Bayonne trains.
- Headways:  
Six minutes for Locals  
24 minutes for Flyers

- *Traction Power & Track.* These systems were constructed to be capable of supporting 80 mph operation, well above a maximum authorized speed of 57 mph; all curvature to accommodate widening of track centers is on southbound track.

Figure 4 shows that the “schedule point” for Flyers is at Yard North. Schedules for all trains were built from this point with Flyers scheduled to arrive at this interlocking 2 min ahead of trains from West Side Avenue. This placed Flyers 4 min behind their “leader” (a local from Bayonne). Since Flyers traverse the Bayonne Branch 2 min faster than locals, the Flyer departure time from Bayonne was set at 6 min after the Local, positioning it to address “peak of the peak” demand.

From Liberty State Park to Exchange Place Flyers bypass three stations, two of which are within train control territory. In this section the Flyers gain an additional 90 to 120 s on their leader as they cross Van Vorst Avenue. At that point, they have used up all of the spare capacity provided by the train control system and are about to “catch” their leader (i.e., begin to experience cab-downgrades), when they enter street running territory. North of this location, train separation is maintained by LOS operating rules and in bypassing Essex Street the Flyer closes to within 60 s of its leader.

Figure 5 shows signal control lines for clear capacity and “ghost” slots overlaid on the stringline. The “slot” for the Flyer is scheduled for clear capacity and overtakes “ghost slots”. If the line were operating at capacity, a real train would occupy each ghost slot and it would not be possible to schedule the Flyer as a zone express. In such a case, a “skip-stop” service might be implemented as an alternate to a zone service.

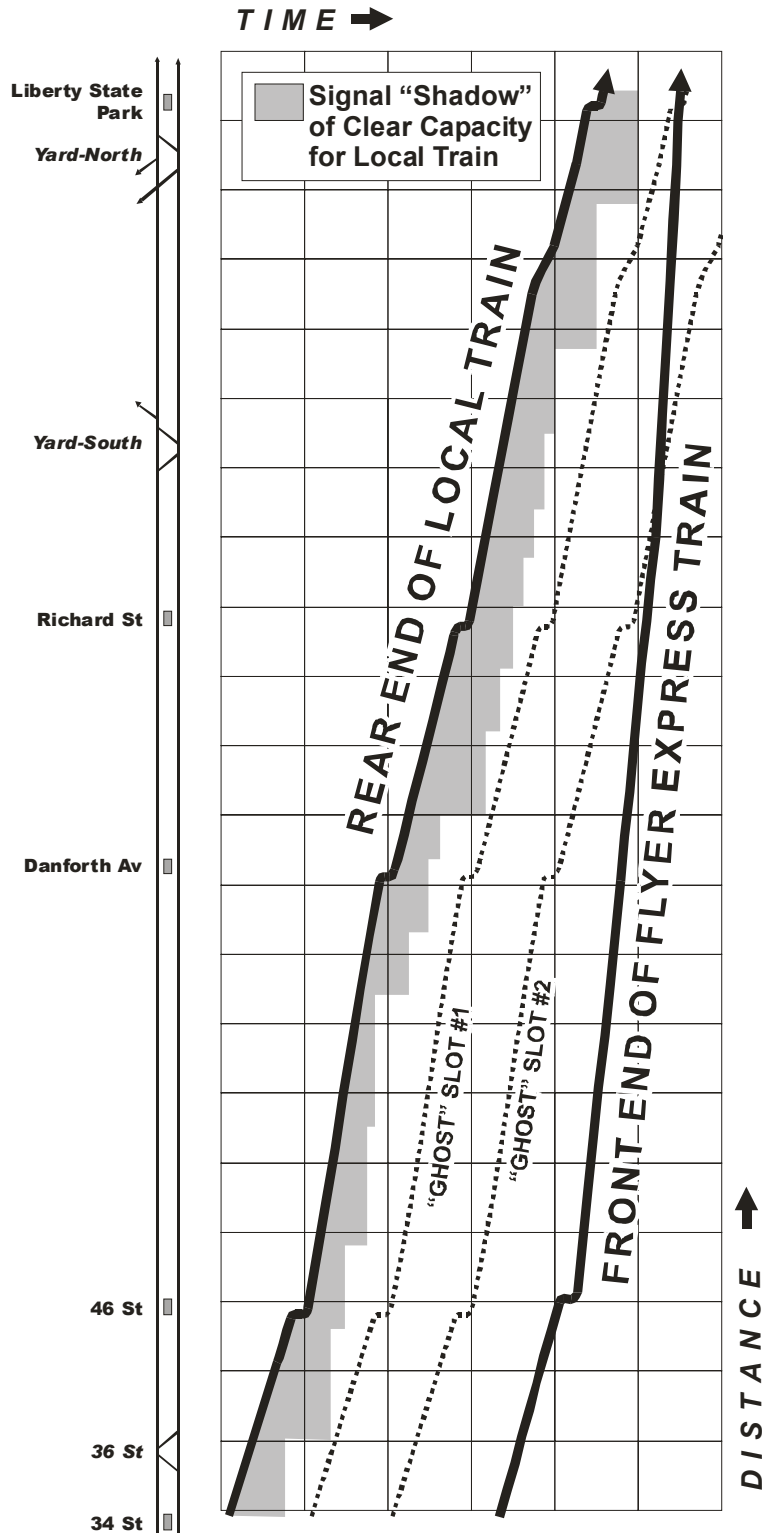


FIGURE 5 Time–distance/signal control diagram for northbound morning Flyer

Prior to implementation of Flyer operation, a system safety review was conducted; as a result the following measures were implemented:

- All Flyers are marked with special signage and operate with flashers on.
- Maximum speed of station by-pass is at 45 mph; this causes the train operator to take positive action to control the train.
- Horns or bells are utilized when bypassing stations.
- Operation of the Flyers is given specific surveillance by train controllers.

### **The Evening Bayonne Flyer**

With the success of the morning Flyers, customer demand arose for an evening peak express. The configuration of the Bayonne Line stations, with unprotected pedestrian crossings (except for static signage) across the southbound track, presented special challenges in “retrofitting” a zone express operation onto a railway designed only for local service. System safety review determined that—as a minimum—fully active gate and flasher protection would be required for operation over these crossings at speed.

The operational design of the evening express considered other options such as operating only the Flyers south on the northbound track. Stringline analysis validated by field tests showed that this would cause delays to local trains. The best “reverse fit” of an evening zone express, given the existing system configuration, was in operating the entire Bayonne Line “left handed” during evening peak hours. The dispatching pattern around which schedules were developed is illustrated in [Figure 6](#), and the stringline for the evening operation is illustrated in [Figure 7](#).

The low speed design of the turnouts is an important factor in determining the dispatching pattern. The Flyers cross over within low speed (25 mph) territory, thereby minimizing the time lost. Due to congestion at Yard North, Locals cross over at another low speed interlocking (Yard South). Because Yard South is comprised of 15 mph turnouts within 55 mph territory, an approximately penalty of 30 s is incurred to the running time of local trains.

Note that the basis of operation for the morning Flyers differs from the evening in that the zone express “chases” a West Side Branch train from Exchange Place. The schedule point for designing evening timetables is the 2 min after West Side Locals.

[Table 2](#) provides a summary of engineering systems which were critical to the Flyer operation.

### **Next Steps**

Construction of MOS-2 is nearing completion and conceptual design of MOS-3 extensions in Bayonne and northward into Bergen County are well underway. Expedited train movements have been an on-going consideration throughout the development of MOS-2 and -3, in contrast to MOS-1 where the Flyers were retrofitted into a system designed only for Local trains. MOS-2 operations north of Hoboken will likely combine a zone express service with overtake tracks, while MOS-3 may entail multiple zone express trains overlaid in the manner demonstrated by the P&W.

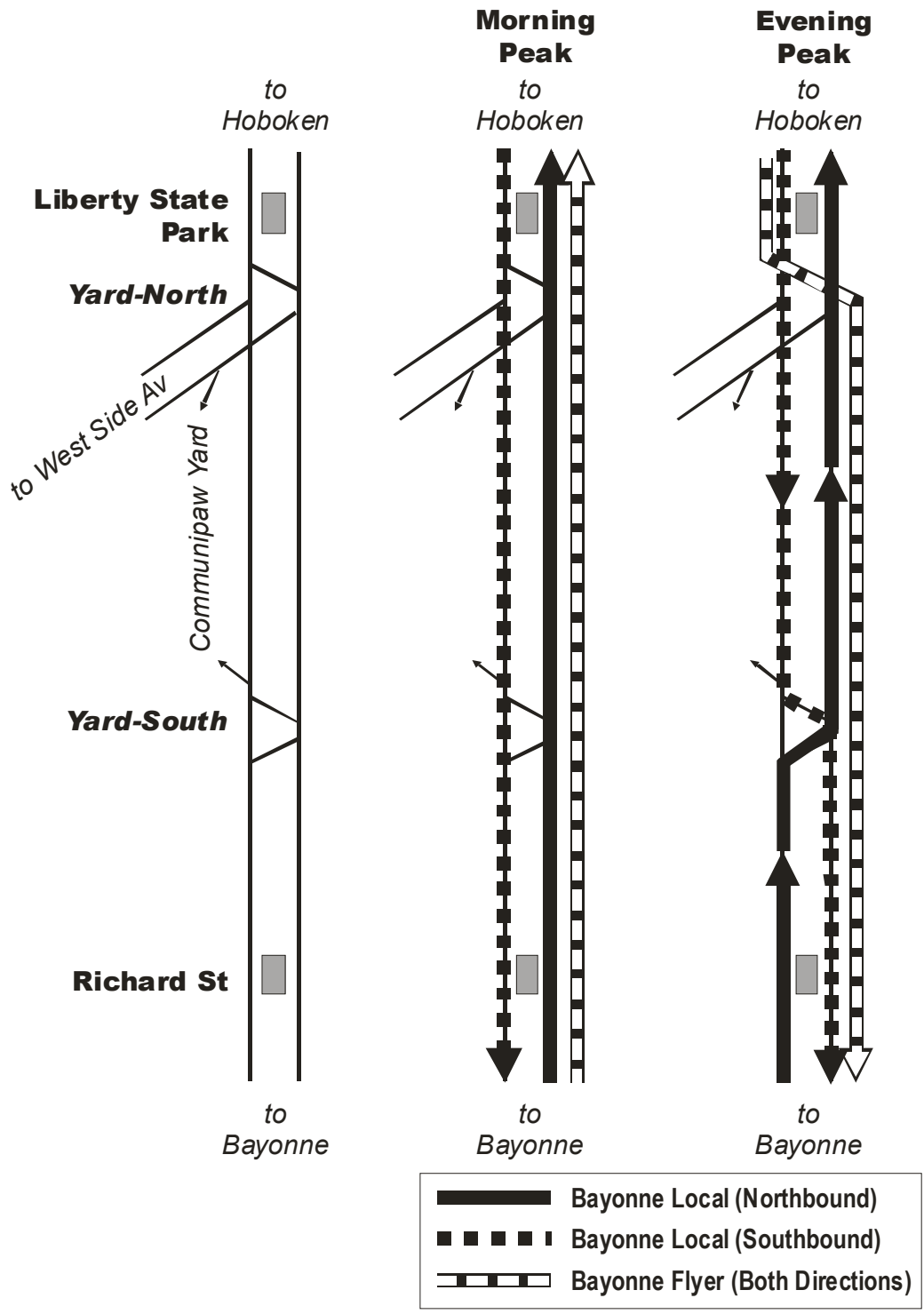
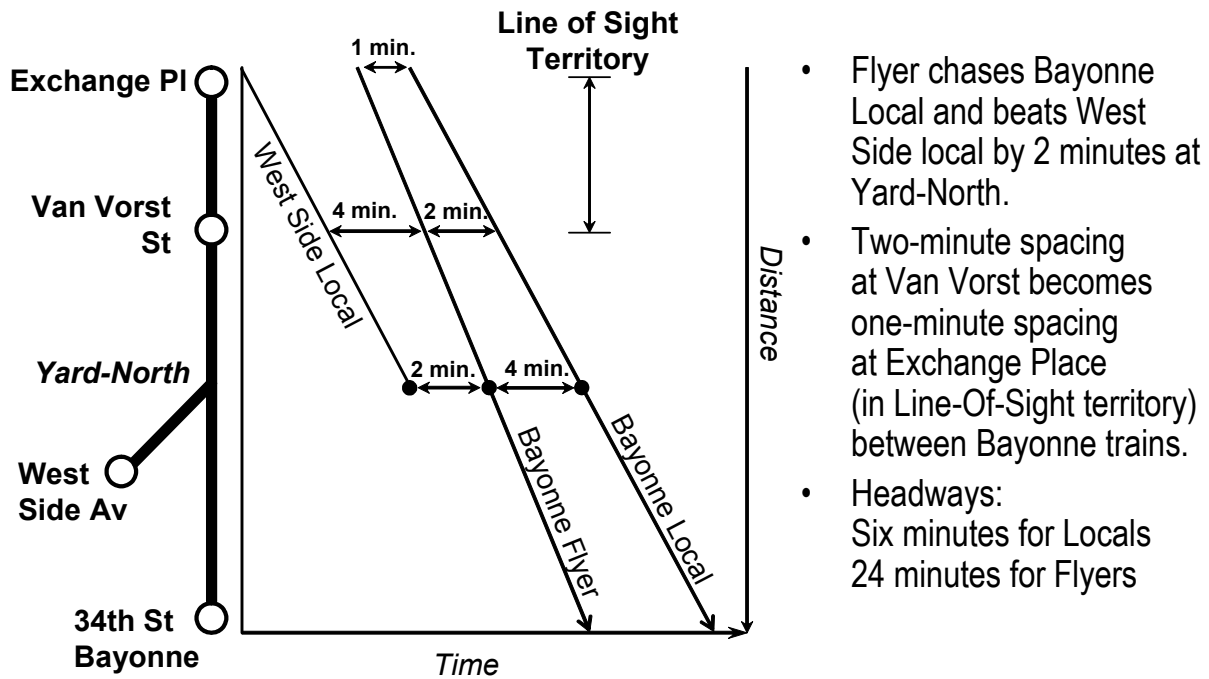


FIGURE 6 Time–distance diagram for northbound morning flyer.





**FIGURE 7 Time–distance diagram for southbound evening flyer.**

**TABLE 2 Systems Utilized for Flyer System**

System	Functionality Utilized	Desired Improvement
Track	High Speed.	Low speed crossovers are unsuitable. Need higher speed.
Train Control	2-min headway capability permits “zone” express operating on 5-min headway. Reverse signaling at 2-min headway permits evening Flyer.	None.
Stations	Island platforms on Bayonne Line conform to reverse operation. Signage does not conform to reverse operations.	Pedestrian walkways across southbound tracks are unsuitable for express.
Supervisory Control (ICS)	Permits convenient reversal of Bayonne Line and effective and timely train management.	Overview display required at control center to improve SA.
Right of Way	Exclusive run on Bayonne Line favors high speed and precise scheduling.	

## CONCLUSION

Innovative operational practices to expedite train movements can reap benefits in terms of customer service and operational efficiency. They are often confounded, however, by current LRT design and deployment methods. This is partly attributable to design methods that follow a “stovepipe” approach to individual engineering disciplines and components, rather than directing focus on optimizing railway functionality and flexibility as a comprehensive entity. It is also attributable, in part, to a failure to address the ultimate potential of a railway at the definition/developmental stage and to subsequently articulate and document the operational requirements that are necessary to support the stated mission.

Implementation of the HBLR Bayonne Flyers demonstrates that a comprehensive design approach that combines attention to the details of operational planning and critical engineering systems can yield significant dividends in system performance. It illustrates a model relationship between operations and systems design that resulted in the implementation of the first zone express service on a modern LRT system, showing the way that leads to moving beyond vanilla.

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