Southeastern Pennsylvania Transportation Authority

DRAFT RAIL OPERATIONS SIMULATION REPORT

Norristown High Speed Line Extension

August 25, 2020

Prepared by:

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Transit & Rail Systems
Excellence Delivered As Promised

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0. REVISION HISTORY

Revision	Date	Comments
0.0	May 27, 2020	Initial Release (Draft)
1.0	August 25, 2020	Addition of single-track analysis and update to O&M Cost revisions in response to SEPTA comments (Draft)

1. EXECUTIVE SUMMARY

SEPTA is proposing an extension of the Norristown High Speed Line (NHSL), which currently provides service between 69th Street Transportation Center and Norristown Transportation Center. The extension would provide service from King of Prussia (First and Moore Station) where a stub terminal would be constructed, eastward to proposed First and American, Mall Boulevard, Allendale Road, and Henderson Road stations, then junctioning with the existing NHSL main line to Norristown or 69th Street stations.

This report describes the computer simulation methodology used to analyze the proposed physical infrastructure and operational changes that will expand service along the King of Prussia (KOP) Extension and increase service along the NHSL mainline. It provides insight into the viability of the proposed infrastructure and operations.

The overall findings indicate that the proposed infrastructure will be capable of supporting the anticipated future operating plan, even though the number of scheduled trains operated during a typical 24-hour working weekday period will increase from 202 to 539. Due to challenging lateral site constraints, the anticipated design of the wye junction will require a main line diverging move through a #8 turnout on both main tracks at the South Junction. While this is not ideal, the predicted adverse impact to trip time between 69th Street and Norristown is relatively small: nominally one minute in each direction.

The proposed 3-track, 2-platform configuration of the First and Moore stub terminal at the end of the proposed Kind of Prussia Extension is shown to be adequate for the anticipated traffic. All three tracks should be constructed. The terminal at 69th Street will require a fourth station platform track to support the proposed increase in traffic.

The anticipated fleet size requirement net of spares to support future operations is 27 cars. Simulation findings suggest that removing some Bryn Mawr short-turns would reduce the requirement by one to three cars. Bryn Mawr short-turn operations increase from 6 round trips in the existing operations to 23 round trips in the proposed future operations. Decreasing the number of short-turns from the proposed future operations would also provide more reliable service by reducing delays to thoroughfare trains following in the wake of short-turn trains.

A station-to-station trip time analysis showed the restoration of a 70 mph ATC signal aspect or code along the existing mainline – which was decommissioned following a 2017 operating incident – would improve typical running time of express trains between 69th Street and Norristown by 30 to 40 seconds in each direction.

A single-tracking analysis was performed to test the ability of the system to accommodate a planned track outage on the proposed branch between Henderson Road and Mall Boulevard stations. This section of track is the longest between interlockings and represents a “worst-case” outage. This analysis included a universal crossover between Henderson Road Station and the wye junction. It is concluded that 2 trains per hour per direction is supportable on the branch with one track removed from service.

Operations and Maintenance costs were computed using SEPTA’s three-factor formula. The formula considers train hours (to account for operator costs), vehicle miles (to account for traction power and maintenance), and an overhead cost for each “peak” vehicle in service, which means the number of vehicles required net of spares. O&M costs are estimated to increase by 79.6%, whereas the number of train trips per day is projected to increase by 167% post-construction: from 202 to 539.

2. INTRODUCTION

As part of the HNTB team, Gannett Fleming Transit and Rail Systems (GFT&RS) has built a "Base Case" simulation model of the existing Norristown High Speed Line (NHSL) between the 69th Street Transportation Center and the Norristown Transportation Center (NTC). The model was built using Rail Traffic Controller (RTC) from Berkeley Simulation Software. Building and running the Base Case model was the first step towards analyzing the proposed rail extension to King of Prussia.

After building and validating the Base Case simulation model, a Future Case model was created. This model includes a wye junction between Hughes Park and Dekalb Street stations that connects the proposed King of Prussia (KOP) Extension to the Norristown High Speed Line (NHSL). This report discusses the need for three platform tracks at the First and Moore Terminal and the need for a fourth terminal track at 69th Street Station. The report also addresses the wye junction and the impact of #8 (15 mph) turnouts at the South Junction[1] between Hughes Park and Dekalb stations.

The report provides results and commentary on proposed service levels, traffic density, and the overall viability of the proposed operations and infrastructure. Trip time comparisons to help gain insight into the effect of raising the maximum speed on the NHSL from 55 mph back to 70 mph are also provided.

[1] Southernmost wye junction

3. METHODOLOGY AND ASSUMPTIONS

A. Computer Simulation Software

Gannett Fleming developed and processed the Base Case and Future Case network simulation models using Berkeley Simulation Software's Rail Traffic Controller (RTC), Release Version 74K, dated March 20, 2019. RTC is a commercial software product available to the general engineering community and is widely used by Class 1 freight railroads as well as several commuter and regional passenger rail agencies and operators including SEPTA.

B. Rolling Stock

All trains simulated in the Base Case and Future Case models are assumed to consist of SEPTA-N5 powered units operating in singles or pairs. The vehicles were manufactured by ABB Traction beginning in 1989. Each self-propelled vehicle is programmed in RTC with the pertinent physical characteristics including carbody length, width and height, and weight. Tractive effort and braking data are also input into the software and can be modified to ensure trains are operating in simulation as closely as possible to reality in the field. Table 1 shows the physical characteristics of the N-5 vehicle.

Table 1 – Physical Characteristics of N-5 Cars

SEPTA NHSL N-5 Cars	
Length over couplers	65.50 ft.
Width	9.83 ft.
Height	14.00 ft.
Weight *	85,800 lb.

*includes 10% rotational mass

Passenger loading was set to 75 passengers per car, and passenger weight was assumed to be 175 pounds per passenger.

C. Source Data

Source data used for the simulation models is listed in Table 2. These documents provided the track physical characteristics, signal locations and control line logic, vehicle characteristics, and rail operations information used to create the Base Future Case models.

Table 2 – Source Data

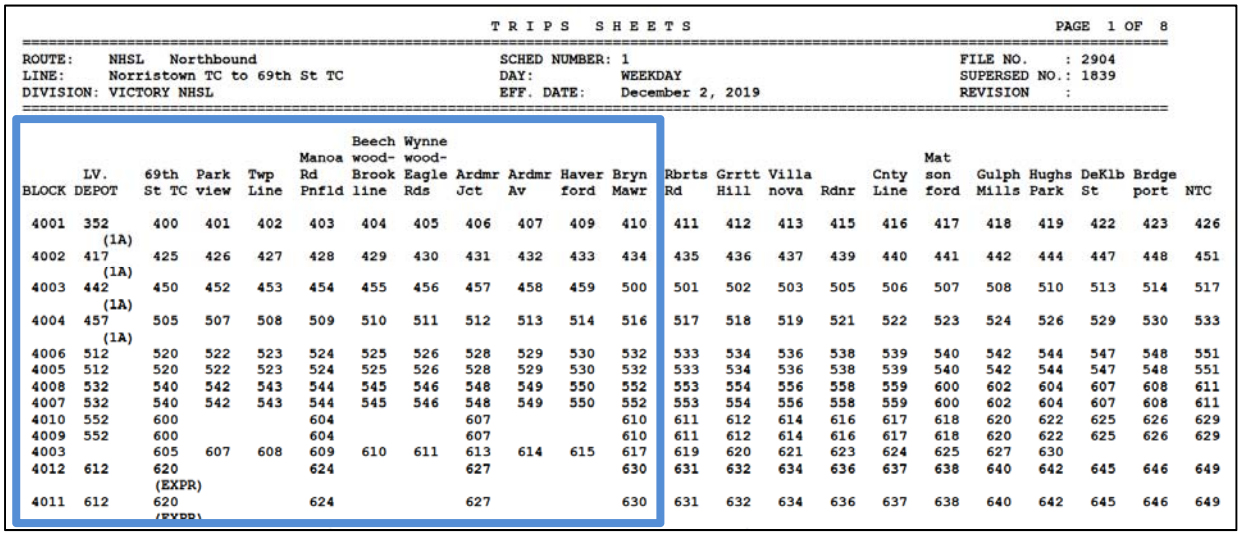
Name	Description	Date
NHSL_Fall2019-weekday_trip_sheets.pdf	Weekday Trip Sheets (for Base Case)	effective 12/2/2019
C4377_Norristown_Future_Simulation_20150903c2.pdf	Report prepared for draft EIS – used as source for Future Case train operations	9/3/2015
200217_RFI 050 Answer_Track Chart NHSL.pdf	Geometry Car Track Charts	12/2019 & 2/2020
200217_RFI 050 Answer_Color Track Chart NHSL.pdf	Geometry Car Track Charts (color)	12/2019 & 2/2020
KOP Rail_15 Percent_PLAN_FINAL.pdf	KOP Rail Extension general plan and elevation drawings (15% final)	9/30/2019

Name	Description	Date
200227_RFI 49_NHSL REV 6 02-14-2020.pdf	Cab Control Line drawings	6/21/19 & 2/14/20
N-5 Car System Technical Data.pdf	NHSL N-5 Car Specifications	12/1998
N-5 Dimensions and Weights.pdf	NHSL N-5 Car Carbody Information	3/1995
2018_SEPTA_REVENUE_VEHICLES_DRAFT_BOOK.pdf	Septa vehicle sheet	12/8/2004
RT_NHSL_Segment_Runtime_Summary_Table_Dir_Northbound_Weekday_Fall_2019.xls	SEPTA station to station running time summary report - Northbound	Weekday Fall 2019
RT_NHSL_Segment_Runtime_Summary_Table_Dir_Southbound_Weekday_Fall_2019.xls	SEPTA station to station running time summary report - Northbound	Weekday Fall 2019
Operating and Maintenance Cost Model Results.pdf	O&M Cost Model Results Report (for AECOM by LTK)	7/14/2016

D. Operations

1. Base Case Model

SEPTA provided weekday Trips Sheets (effective 12/2/2019) as source material for creating revenue train operations in the Base Case Model. Using the Trips Sheets, it was also possible to create the scheduled "deadhead" (non-revenue equipment) moves. Figure 1 shows an example of the Trips Sheet. The blue box in this figure defines a section that is magnified in Figure 2 for better viewing. Figure 3 is a screen image from RTC showing a partial list of trains that run in the Base Case simulation.



TRIPS SHEETS PAGE 1 OF 8

ROUTE: NHSL Northbound — SCHED NUMBER: 1 — FILE NO. : 2904
LINE: Norristown TC to 69th St TC — DAY: WEEKDAY — SUPERSED NO.: 1839
DIVISION: VICTORY NHSL — EFF. DATE: December 2, 2019 — REVISION :

BLOCK	LV. DEPOT	69th St TC	Park view	Twp Line	Manoa Rd Pnfld	Beech wood- Brook line	Wynne wood- Eagle Rds	Ardmr Jct	Ardmr Av	Haver ford	Bryn Mawr	Rbrts Rd	Grrtt Hill	Villa nova	Rdnr	Cnty Line	Mat son ford	Gulph Mills	Hughs Park	DeKlb St	Brdge port	NTC
4001	352 (1A)	400	401	402	403	404	405	406	407	409	410	411	412	413	415	416	417	418	419	422	423	426
4002	417 (1A)	425	426	427	428	429	430	431	432	433	434	435	436	437	439	440	441	442	444	447	448	451
4003	442 (1A)	450	452	453	454	455	456	457	458	459	500	501	502	503	505	506	507	508	510	513	514	517
4004	457 (1A)	505	507	508	509	510	511	512	513	514	516	517	518	519	521	522	523	524	526	529	530	533
4006	512	520	522	523	524	525	526	528	529	530	532	533	534	536	538	539	540	542	544	547	548	551
4005	512	520	522	523	524	525	526	528	529	530	532	533	534	536	538	539	540	542	544	547	548	551
4008	532	540	542	543	544	545	546	548	549	550	552	553	554	556	558	559	600	602	604	607	608	611
4007	532	540	542	543	544	545	546	548	549	550	552	553	554	556	558	559	600	602	604	607	608	611
4010	552	600			604			607			610	611	612	614	616	617	618	620	622	625	626	629
4009	552	600			604			607			610	611	612	614	616	617	618	620	622	625	626	629
4003		605	607	608	609	610	611	613	614	615	617	619	620	621	623	624	625	627	630			
4012	612	620 (EXPR)			624			627			630	631	632	634	636	637	638	640	642	645	646	649
4011	612	620 (EXPR)			624			627			630	631	632	634	636	637	638	640	642	645	646	649

Figure 1 – Example of Trips Sheet Information

BLOCK	LV. DEPOT	69th St TC	Park view	Twp Line	Manoa Rd Pnfld	Beech wood- Brook line	Wynne wood- Eagle Rds	Ardmr Jct	Ardmr Av	Haver ford	Bryn Mawr
4001	352 (1A)	400	401	402	403	404	405	406	407	409	410
4002	417 (1A)	425	426	427	428	429	430	431	432	433	434
4003	442 (1A)	450	452	453	454	455	456	457	458	459	500
4004	457 (1A)	505	507	508	509	510	511	512	513	514	516
4006	512	520	522	523	524	525	526	528	529	530	532
4005	512	520	522	523	524	525	526	528	529	530	532
4008	532	540	542	543	544	545	546	548	549	550	552
4007	532	540	542	543	544	545	546	548	549	550	552
4010	552	600			604			607			610
4009	552	600			604			607			610
4003		605	607	608	609	610	611	613	614	615	617
4012	612	620 (EXPR)			624			627			630
4011	612	620 (EXPR)			624			627			630

Figure 2 – Trip Sheet Information (Magnified View)

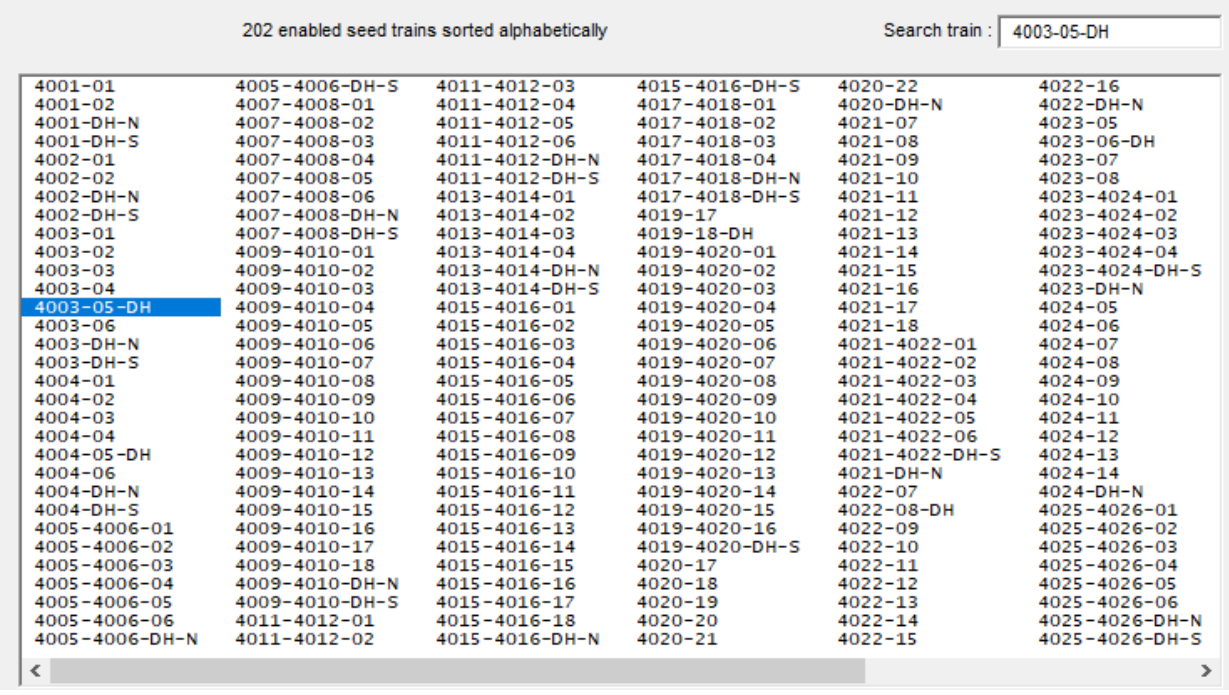


Figure 3 – RTC Image of Trains Simulated in Base Case (Partial List)

The train naming convention shown in Figure 3 references the Block number assigned to equipment in the trip sheets. Numbers and letters were appended to the "train name" to keep the names unique and to reference the order in which the trains are running. For instance, Train 4003-01 runs from 69th St. to Norristown and becomes 4003-02 (running from Norristown to 69th St). Additionally, the appendage "DH" indicates a deadhead equipment move. Trains with two four-digit numbers such as Train 4005-4006-01 indicate a two-car train; in this example, the train set uses Block numbers 4005 and 4006.

The weekday Trips Sheets indicate local and express train schedules, but it is the Consultant's understanding that many of the station stops are "flag stops"[2], especially during off-peak ours. Trains were simulated to stop at all stations as indicated on the Trips Sheets. However, system on-time performance (OTP) was just under 97% in simulation because late night (midnight to 3 AM) and early morning (4 AM to 5 AM) trains do not have enough schedule recovery time to stop at every flag stop station. This will be discussed further in the Analysis Results and Discussion section below.

Table 21 in the Appendix provides the hourly service levels as modeled in the Base Case simulation.

2. Future Case Model

Future Case operations were created as specified in the *SEPTA Norristown High Speed Line Extension Alternatives Analysis/Draft Environmental Impact Statement* report dated September 3, 2015 (referred henceforth as the draft EIS report). The operating plan was presented in "block of train" fashion similar to the Trip Sheets used for the Base Case model creation. This made it possible to track individual vehicle movements and create scheduled deadhead (non-revenue equipment) moves.

The schedule as presented in the draft EIS report requires a ***27-car fleet size*****,** net of spares. The required fleet size could be slightly reduced if some or all the Bryn Mawr short turns were eliminated. The Bryn Mawr short turns will be discussed further in the Analysis Results and Discussion section below.

Figure 4 below is an image from the draft EIS report showing a portion of the future operating plan. The "train blocks" (so-named in the Base Case Trip Sheets) are identified as "consists" and named alpha-numerically. As an example, the first train in the list (C-4) departs Norristown Transportation Center (NTC) at 6:42 AM and arrives at KOP (King of Prussia, 1st and Moore Station) at 7:00 AM. The train then "turns" (reverses) and departs KOP at 7:18 AM, arriving at NTC at 7:36 AM.

Two-car trains are identified by consists having the same schedule. For instance, Q1-2/Q2-2 departs KOP at 6:50 AM, then departs Bryn Mawr at 7:16 AM, and finally arrives at 69th St. 7:29 AM. The train turns and departs 69th St. at 7:49 AM and arrives at NTC at 8:12 AM.

[2] Trains will stop if on-board passengers signal the train crew or waiting passengers are visible on the platform – thus indicating a stop is requested for the purpose of embarking or disembarking. "Flag stop" is historical terminology for a conditional stop; traditionally, a waiting passenger was expected to display a flag or lantern to signal the oncoming train to stop to receive the waiting passenger(s).

Consist	NTC	KOP	Bryn Mawr	69th Street	69th Street	Bryn Mawr	KOP	NTC	Next Departure	Comment
C-4	6:42	7:00					7:18	7:36	7:42	
T-1				7:15	7:20	7:29	7:58		8:10	
O-2		6:30	6:56	7:09	7:30	7:39	8:08		8:20	
P-2		6:40	7:06	7:19	7:29			7:52	7:58	
S-2			7:08	7:23	7:31	7:44			7:48	
F-3	6:58		7:13	7:24	7:40	7:49	8:18		8:30	
G-4	7:02	7:20					7:38	7:56	8:02	
U-1				7:36	7:41	7:54			8:01	
Q1-2		6:50	7:16	7:29	7:49			8:12	8:18	
Q2-2		6:50	7:16	7:29	7:49			8:12	8:18	
B-3		7:00	7:26	7:39	7:45			8:08	8:22	
I-4			7:28	7:43	7:51	8:04			8:08	
H1-3	7:18		7:33	7:44	7:50	7:59	8:28		8:40	
H2-3	7:18		7:33	7:44	7:50	7:59	8:28		8:40	
J-3	7:22	7:40					7:58	8:16	8:26	
E-3		7:10	7:36	7:49	8:00	8:09	8:38		8:50	
D-3		7:20	7:46	7:59	8:20	8:29	8:58		9:10	
K-4	7:26		7:41	7:52						K Done
V1-1				8:04	8:09			8:32	8:38	
V2-1				8:04	8:09			8:32	8:38	
S-3			7:48	8:03	8:10	8:19	8:48		9:00	
N1-3	7:38		7:53	8:04	8:11	8:24			8:28	
N2-3	7:38		7:53	8:04						N2 Done

Figure 4 – Excerpt of Operating Plan Table from Draft EIS Report

Train stopping patterns were determined by closely examining the time-distance (string) charts provided in the draft EIS report. Figure 5 shows an example of the string charts from the draft EIS report.

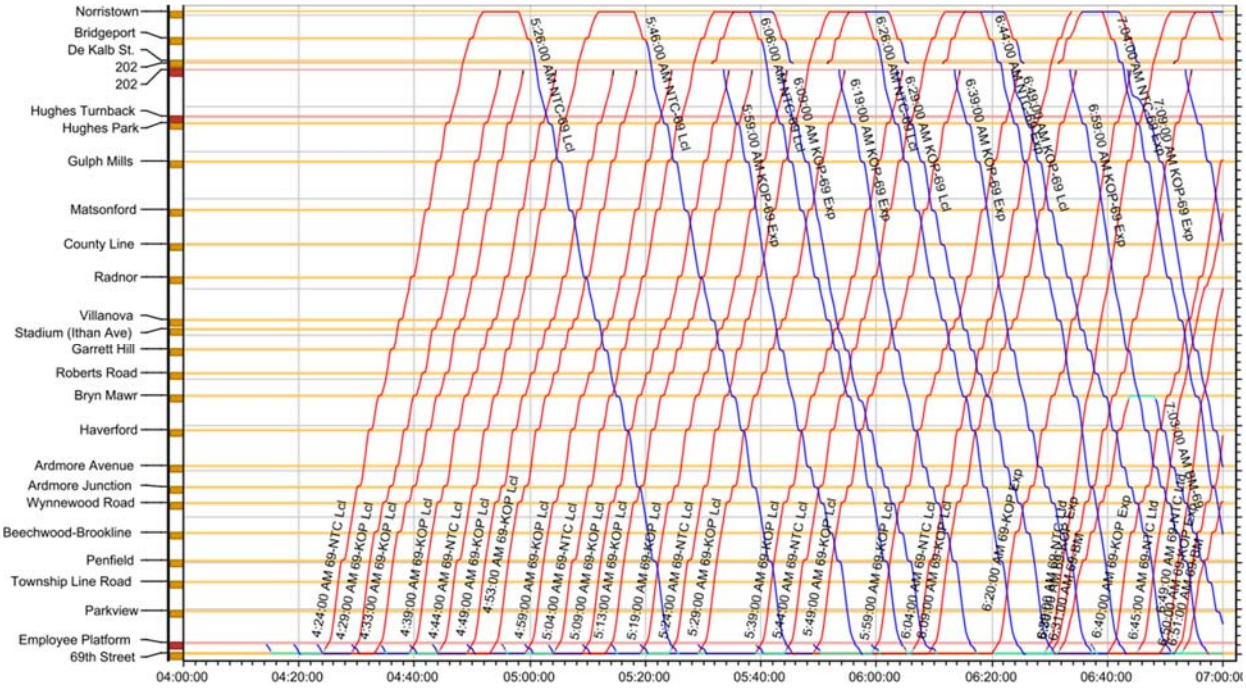


Figure 5 – String Chart Image (0400h – 0700h) from EIS Report

Service levels define how train operations are serving passengers. The "Concept of Operations" goal for servicing the anticipated NHSL travel demand after construction of the proposed KOP Extension is shown in Table 3. These service level goals are reflected in the RTC simulation model train operations.

Table 3 – Concept of Operation – Service Level Goals

Service Between	Peak TPH	Off-Peak TPH
69th St. - Bryn Mawr (short turn)	4	0
69th St. - KOP Extension	6	3
69th St. - NTC	4	3
KOP Extension - NTC	3	3

When comparted with the current level of service, the service level goals for future operations increase Bryn Mawr short turn frequency from 6 round trips per day to 23 round trips per day. Nineteen (19) existing short turns between 69th Street and Hughes Park are eliminated, and service between 69th Street and NTC is increased by approximately 10 round trips per day.

E. Infrastructure

1. Base Case Model

Geometry Car Track Charts were used to determine and model track layout between 69th Street and Norristown. The Track Charts provided an approximate[3] location for switches (turnouts and crossovers), home signal locations, passenger stations, track curvature, track gradient, and track speed. It should be noted that track speeds are shown as high as 70 mph. The signal control logic, however, only provides for speeds up to 55 mph due to elimination of a 70-mph speed command after a 2017 operating incident. This means that train do not run above 55 mph on the NHSL in reality or in simulation. Figure 6 and Figure 7 provide examples of the Geometry Car Track Charts. Figure 7 shows a smaller territory and is easier to read.

[3] Locations are considered "approximate" because curves, speeds and gradient information needed to be scaled (measured) in the source data drawings. Passenger stations were located with a single milepost notation, so platform edge locations were estimated. In some cases, Google Earth was consulted.

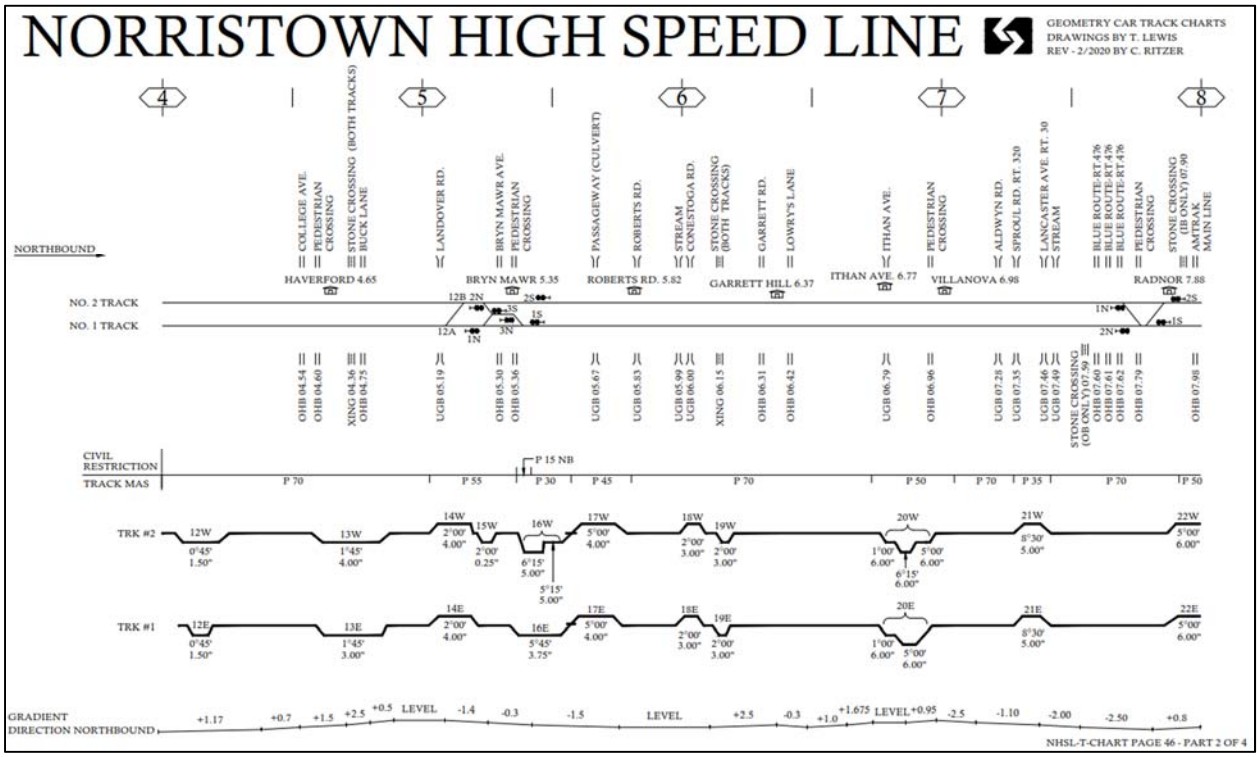


Figure 6 – Image from NHSL Geometry Car Track Charts

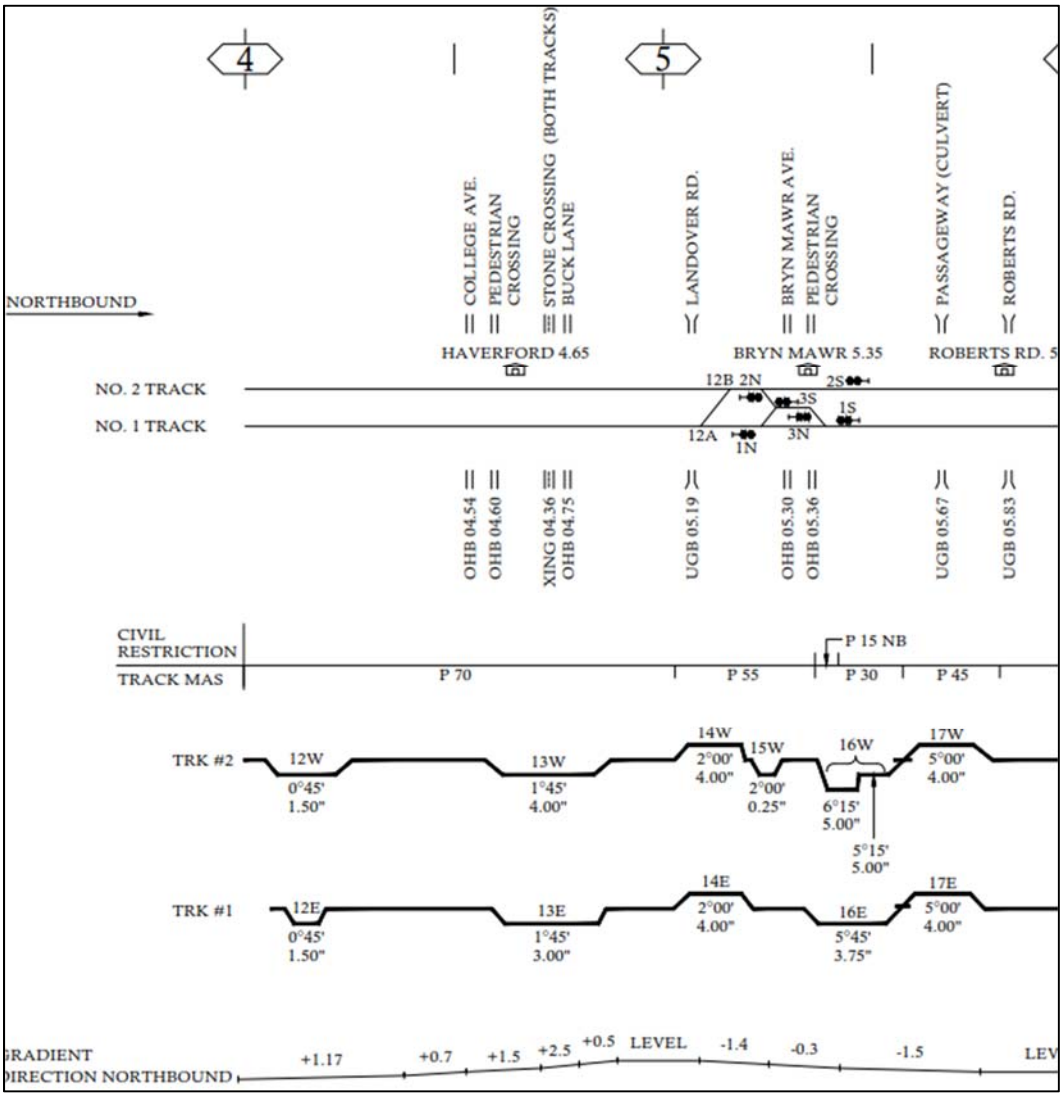


Figure 7 – Image from NHSL Geometry Car Track Charts (Enlarged View)

After the Base Case infrastructure was built, the Consultant received signal control line drawings. The drawings contained more detailed engineering stationing for track switches (turnouts), grades, and curves. The model was not refined based on this new data because no significant discrepancies were found between the control line drawings and the Track Charts. Figure 8 provides an image of the Base Case NHSL model as built in RTC.

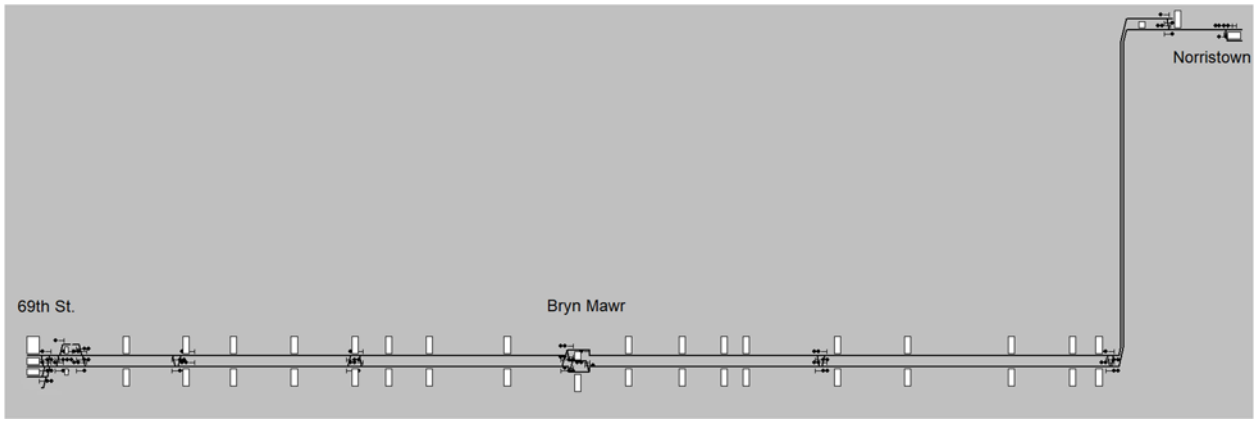


Figure 8 – Norristown Hight Speed Line – RTC Model

2. Future Case Model

The Future Case model infrastructure includes the addition of a wye junction between Hughes Park and Dekalb Street, with switch points at approximately MP 11.57 (South Jct.) and MP 11.94 (North Jct.). The wye junction is the access to the proposed King of Prussia Line. Figure 9 shows an overview of the Future Case model in RTC, and Figure 10 provides a closer look at the wye junction.

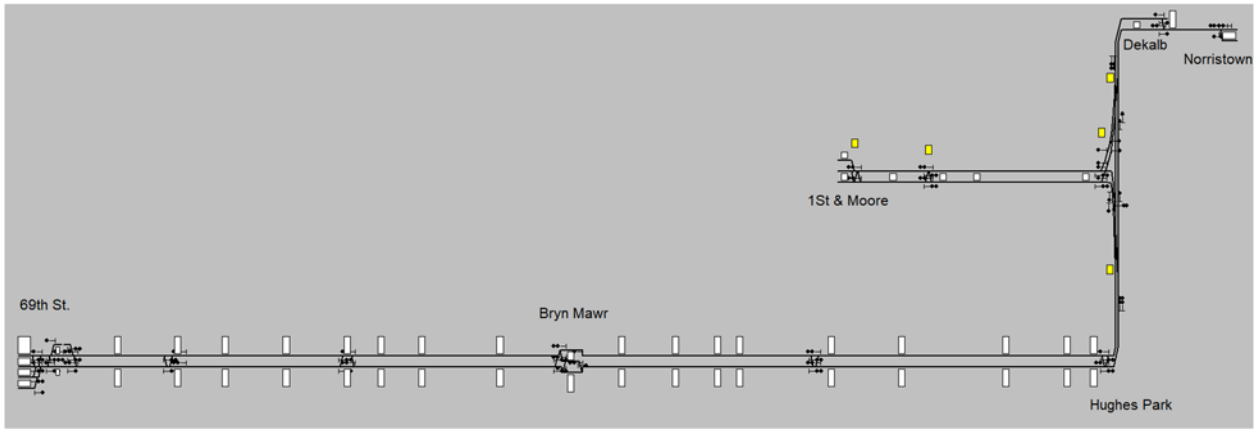


Figure 9 – Future Case Infrastructure Overview – RTC Model

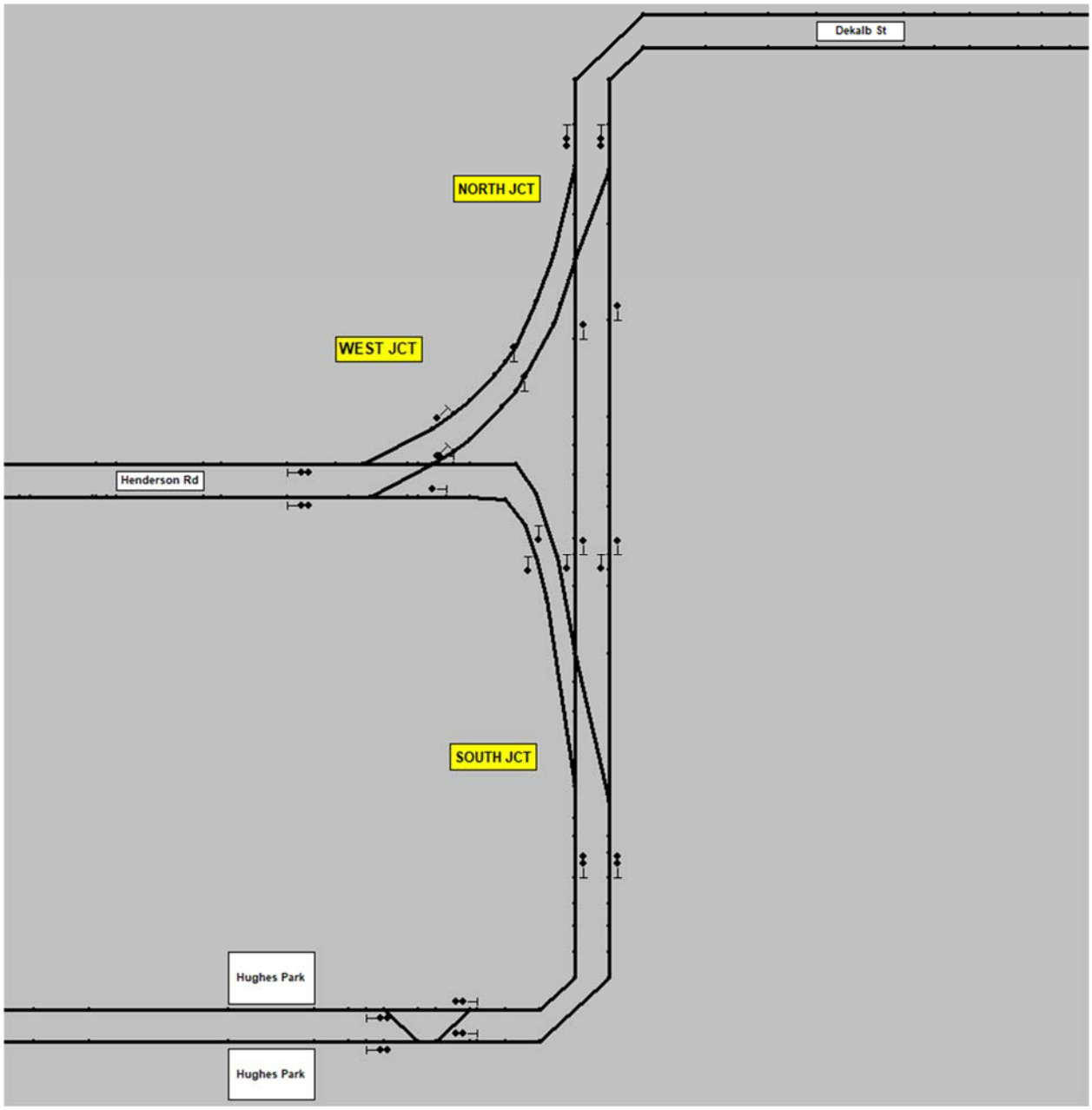


Figure 10 – Future Case Infrastructure at Wye Junction – RTC Model

Proposed South Junction, representing the point at which the south leg of the proposed wye is to join the existing NHSL main line, presented a design challenge due to physical site constraints. The 15% design therefore includes a re-alignment of the existing NHSL tracks such that the northbound mainline route from Hughes Park to Dekalb Street will be via the diverging leg of a proposed #8 (15 mph) turnout on both of the existing main tracks at the South Junction. The impact on trip times is discussed in the Analysis Results and Discussion section of the report.

The proposed King of Prussia extension includes five passenger stations beginning with the terminal station, First and Moore, and continuing eastward to First and American, Mall Boulevard, Allendale Road, and Henderson Road. Track length from the stub terminal at 1st and Moore to

the turnouts at West Junction is approximately 3-1/4 miles. Track layout includes Moore Interlocking at the terminal, Mall Interlocking just west of Mall Boulevard Station, and West Junction at the wye.

Moore is configured as a universal interlocking with an additional crossover from Track 1 to 2 west of the universal. This configuration enables parallel moves so a westbound train can arrive on Track 3 (top track) while an eastbound train departs Track 1 (middle track). Mall is also configured as a universal interlocking. This allows flexibility to divert traffic during track maintenance or unplanned track outages. Figure 11 shows the layout of the King of Prussia Extension as modeled in RTC.

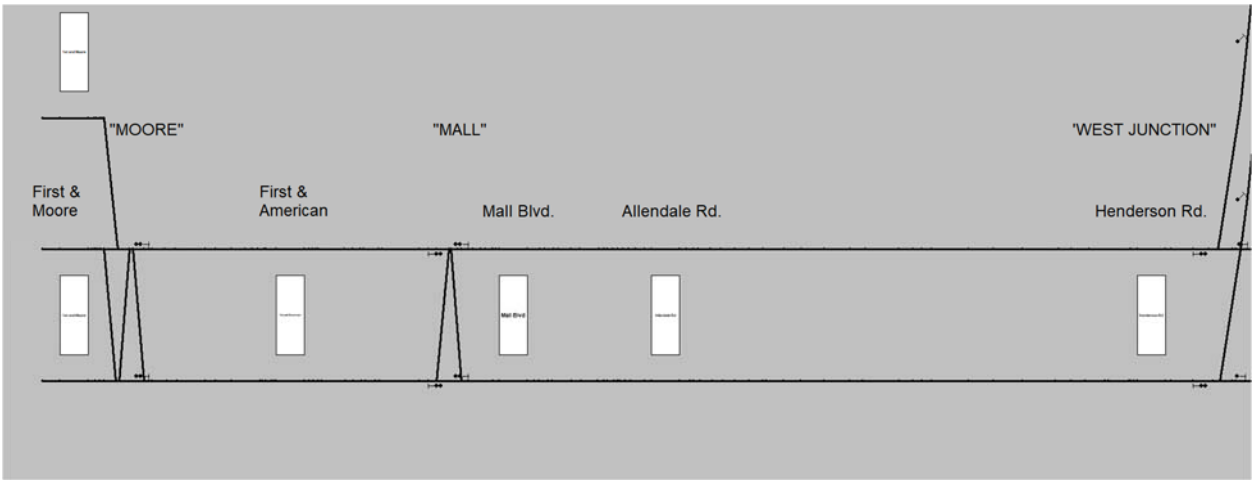


Figure 11 – King of Prussia Extension – RTC Model

Simulation confirmed that three terminal platform tracks are required at First and Moore to support the service level of the operating plan. Figure 12 shows a view First and Moore in simulation at 7:30 AM.

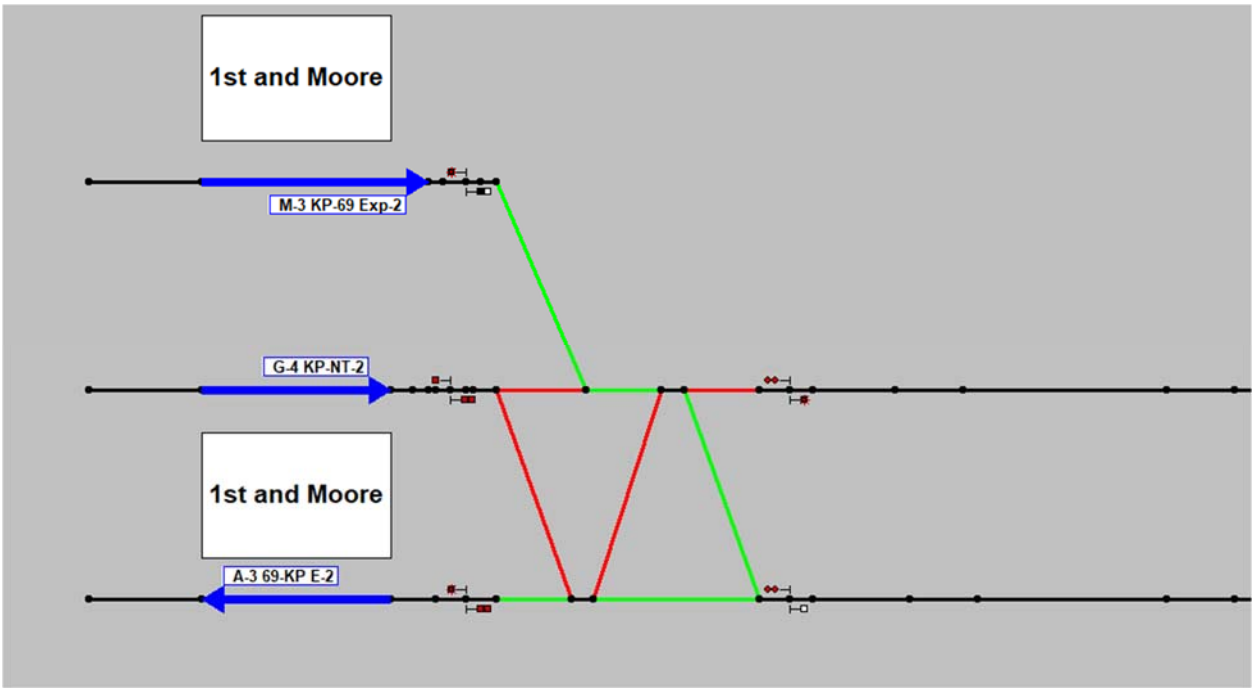


Figure 12 – First and Moore Platform Usage 0730h

Finally, because of the additional level of train service on the NHSL, additional platform capacity is required at 69th St. Station. The Future Case RTC model includes a fourth track with platform access at 69th St. Station. Figure 13 shows an image from simulation (at 7:27 AM) where 69th St. Station is fully subscribed.

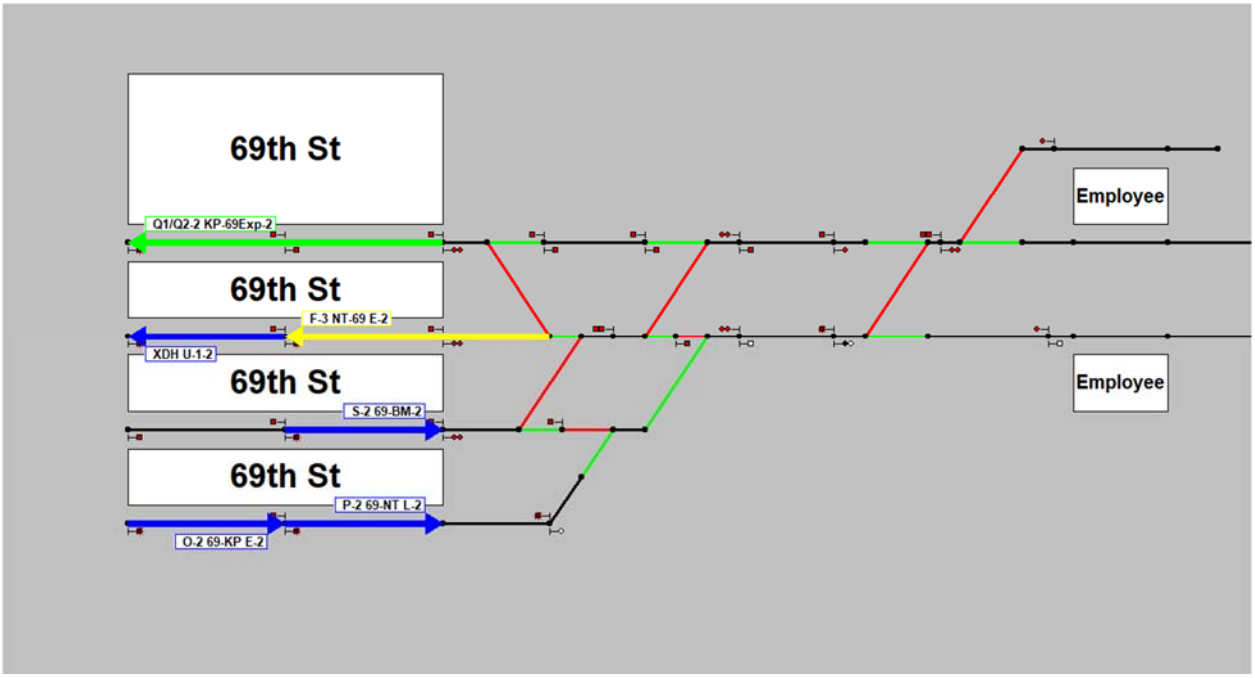


Figure 13 – 69th Street Platform Usage 0727h

F. Signal System and Control Lines

The NHSL is equipped with a cab signal system. The supported speed code rates are shown below in Table 4.

Table 4 – Speed Codes for Cab System

Code Rate	Associated Speed
R (x)	Block occupied (interlocking) - Stop and stay
x	Block occupied - Stop, then proceed at 15 mph
0	Proceed at 15 mph ready to stop at next signal
15	Proceed at 15 mph
30	Proceed at 30 mph
45	Proceed at 45 mph
55	Proceed at 55 mph
70	Proceed at 70 mph (only used on KOP Extension)

1. Base Case Model

The Consultant was provided with a signal control line (routings plan) drawing for the existing NHSL that was updated on 2/14/2020. The control lines reflect the limitation of track speed to 55 mph on the main line. The maximum speed modeled on the NHSL main line for existing and future operations in RTC is therefore 55 mph.

2. Future Case Model

Gannett Fleming produced a preliminary block plan and control line design concept that was used to support the KOP Extension modeling and for the proposed wye. The design can be found in the Appendix (Section 9.C). Unlike the NHSL (with control lines limiting speeds to 55 mph), the control line drawings for the Extension are designed to support speeds of up to 70 mph.

4. CALIBRATION OF BASE CASE MODEL

Calibration is the process by which simulated trip time results are brought into compliance with actual field conditions. A well-calibrated model provides an essential simulation baseline and reliable benchmark results for comparison with those from model runs that mimic anticipated future conditions.

The calibration exercise is a check that the infrastructure database is fundamentally sound and that the simulated performance of the trains themselves reasonably approximates train performance and train handling in the field. It relies on spreadsheet comparison of simulation model output with field data. Traditionally, a reasonable calibration goal is to achieve a station-to-station running time difference between field and simulation performance of 10% or less and an overall origin-to-destination running time difference of 5% or less.

The Consultant was provided with a "Segment Run Time Summary Report" from SEPTA showing station-to-station running times (for southbound and northbound directions) on the existing NHSL. The samples were obtained from weekday train trips run in the Fall of 2019. At least two samples of each train in the schedule were taken and the average of those samples is provided in the tables. Figure 14 shows an image from the southbound report. Train departure times are shown down the left side of the table and the station pairs are shown across the top. The timing to traverse the station pairs is shown in decimal minutes. While the data in the run time summary reports is extensive, it does not indicate the actual stopping pattern of the sampled trains (i.e., whether trains stopped at flag-stop stations).

TRIP DEPART TIME		0102:BRYNMAWR-HAVERFOR			0102:HUGHSPAR-GULPHMIL			0102:NTC-BRDGEPOR			0203:BRDGEPOR-DEKA		
		ACTUAL RUNTIME	SCHED RUNTIME	SAMPLES	ACTUAL RUNTIME	SCHED RUNTIME	SAMPLES	ACTUAL RUNTIME	SCHED RUNTIME	SAMPLES	ACTUAL RUNTIME	SCHED RUNTIME	SAMPLES
TRIP NO.	04:38							1.6	2.00	6	1.3	1.00	6
	05:10							1.8	2.00	8	1.5	1.00	8
	05:25							1.7	2.00	10	1.4	1.00	10
	05:43							1.8	2.00	6	1.4	1.00	6
	05:58							7.3	4.00	9	2.7	2.00	9
	06:18							4.7	4.00	8	3.0	2.00	8
	06:35				3.8	2.00	12						
	06:38							4.2	4.00	8	2.7	2.00	8
	06:55				1.9	2.00	7						
	06:58							4.1	4.00	12	2.9	2.00	12
	07:15				11.3	4.00	8						
	07:18							4.6	4.00	12	2.8	2.00	12
	07:35				7.3	2.00	9						
	07:38							4.1	4.00	10	2.9	2.00	10
	07:51	1.8	2.00	12									
	07:55				10.0	2.00	8						
	07:58							4.3	4.00	8	2.8	2.00	8
	08:11	1.7	2.00	7									
	08:15				7.3	2.00	13						
	08:18							3.9	4.00	9	2.7	2.00	9

Figure 14 – Image from Segment Run Time Summary Report (Southbound)

Three trains were selected in the RTC simulation model for calibration against the summary field data:

- Train 4009-4010-07 is a northbound local train from 69th St. to Norristown, departing 69th St. at 10:15 AM.
- Train 4009-4010-07 is a northbound express train from 69th St. to Norristown, departing 69th St. at 8:20 AM.
- Train 4015-4016-06 is a southbound local train from Norristown to 69th St., departing Norristown at 10:24 AM.

There are no southbound express trains from Norristown indicated in the NHSL operating plan.

A. Calibration Runs (First Pass)

Table 5 through Table 7 provide trip-time comparisons between the RTC simulation and field data. In these three tables, the simulated trains are stopping at all stations per their operating schedule. In reality, trains will be skipping Flag Stop stations if there are no passengers boarding or alighting.

Note that the "*Delta (RTC - SEPTA)*" column represents the RTC trip time minus the SEPTA trip time (in minutes and seconds). A negative number in this column indicates RTC is running fast compared to the sampled field data. This delta is also represented as a percentage. It is important to note that many of the stations are quite close to one another and therefore have short station-to-station running times. A timing difference of 8 seconds over a 56 second trip time computes to a 14% difference, so it is important to keep the numbers in perspective.

Run time differences greater than 20% are flagged (blue or red) for further investigation as detailed on following pages. Cells flagged in ***blue*** indicate RTC simulated running times that are too slow. Cells flagged in ***red*** indicate RTC running times that are too fast. These flagged locations are investigated in "Second-Pass" calibration runs. See next subsection.

Table 5 – Northbound Local Train 4009-4010-07 (All Scheduled Stops)

Station	RTC Simulation			SEPTA Field Trip Time (mm:ss)	Delta (RTC - SEPTA)		RTC Fast/Slow
	Train Arrival	Train Departure	Interval (mm:ss)		mm:ss	%	
69th St.		10:15:00					
Parkview	10:17:36	10:17:54	0:02:54	0:02:55	- 00:01	0.57%	Fast
Township Line	10:19:00	10:19:18	0:01:24	0:00:59	00:25	42.37%	Slow
Pennfield	10:20:13	10:20:31	0:01:13	0:00:51	00:22	43.14%	Slow
Beechwood	10:21:36	10:21:54	0:01:23	0:00:56	00:27	48.21%	Slow
Wynnewood Rd	10:23:00	10:23:18	0:01:24	0:01:02	00:22	35.48%	Slow
Ardmore Jct.	10:24:04	10:24:22	0:01:04	0:00:56	00:08	14.29%	Slow
Ardmore Ave	10:25:16	10:25:34	0:01:12	0:01:10	00:02	2.86%	Slow
Haverford	10:26:46	10:27:04	0:01:30	0:01:35	- 00:05	5.26%	Fast
Bryn Mawr	10:28:16	10:28:34	0:01:30	0:01:29	00:01	1.12%	Slow
Roberts Rd	10:29:55	10:30:13	0:01:39	0:01:31	00:08	8.79%	Slow
Garrett Hill	10:31:13	10:31:31	0:01:18	0:01:10	00:08	11.43%	Slow

Station	RTC Simulation			SEPTA Field Trip Time (mm:ss)	Delta (RTC - SEPTA)		RTC Fast/Slow
	Train Arrival	Train Departure	Interval (mm:ss)		mm:ss	%	
Villanova	10:32:37	10:32:55	0:01:24	0:01:34	- 00:10	10.64%	Fast
Radnor	10:34:28	10:34:46	0:01:51	0:01:45	00:06	5.71%	Slow
County Line	10:36:00	10:36:18	0:01:32	0:01:11	00:21	29.58%	Slow
Matsonford	10:37:32	10:37:50	0:01:32	0:01:08	00:24	35.29%	Slow
Gulph Mills	10:39:16	10:39:34	0:01:44	0:01:35	00:09	9.47%	Slow
Hughes Park	10:40:50	10:41:08	0:01:34	0:02:14	- 00:40	29.85%	Fast
Dekalb St	10:43:56	10:44:14	0:03:06	0:03:11	- 00:05	2.62%	Fast
Bridgeport	10:45:24	10:45:42	0:01:28	0:01:26	00:02	2.33%	Slow
Norristown	10:47:53	10:50:23	0:02:11	0:02:08	00:03	2.34%	Slow
69th - Norristown			**0:32:53**	**0:30:46**	**02:07**	**6.88%**	**Slow**

Table 6 – Northbound Express Train 4007-4008-05 (All Scheduled Stops)

Station	RTC Simulation			SEPTA Field Trip Time (mm:ss)	Delta (RTC - SEPTA)		RTC Fast/Slow
	Train Arrival	Train Departure	Interval (mm:ss)		mm:ss	%	
69th St		8:20:00					
Pennfield	8:23:49	8:24:07	0:04:07	0:04:17	- 00:10	3.89%	Fast
Ardmore Jct.	8:26:24	8:26:42	0:02:35	0:02:27	00:08	5.44%	Slow
Bryn Mawr	8:29:13	8:30:00	0:03:18	0:04:09	- 00:51	20.48%	Fast
Roberts Rd	8:31:21	8:31:39	0:01:39	0:01:43	- 00:04	3.88%	Fast
Garrett Hill	8:32:39	8:32:57	0:01:18	0:01:11	00:07	9.86%	Slow
Villanova	8:34:03	8:34:21	0:01:24	0:01:23	00:01	1.20%	Slow
Radnor	8:35:54	8:36:12	0:01:51	0:01:49	00:02	1.83%	Slow
County Line	8:37:26	8:37:44	0:01:32	0:01:14	00:18	24.32%	Slow
Matsonford	8:38:58	8:39:16	0:01:32	0:01:07	00:25	37.31%	Slow
Gulph Mills	8:40:42	8:41:00	0:01:44	0:01:40	00:04	4.00%	Slow
Hughes Park	8:42:16	8:42:34	0:01:34	0:01:46	- 00:12	11.32%	Fast
Dekalb St	8:45:22	8:45:40	0:03:06	0:02:53	00:13	7.51%	Slow
Bridgeport	8:46:50	8:47:08	0:01:28	0:01:26	00:02	2.33%	Slow
Norristown	8:49:19	8:51:49	0:02:11	0:02:17	- 00:06	4.38%	Fast
69th - Norristown			**0:29:19**	**0:29:22**	**- 00:03**	**0.17%**	**Fast**

Table 7 – Southbound Local Train 4015-4016-06 (All Scheduled Stops)

Station	RTC Simulation			SEPTA Field Trip Time (mm:ss)	Delta (RTC - SEPTA)		RTC Fast/Slow
	Train Arrival	Train Departure	Interval (mm:ss)		mm:ss	%	
Norristown		10:24:00					
Bridgeport	10:25:57	10:26:15	0:02:15	0:02:10	00:05	3.85%	Slow
Dekalb St	10:27:27	10:27:45	0:01:30	0:01:21	00:09	11.11%	Slow
Hughes Park	10:30:31	10:30:49	0:03:04	0:04:17	- 01:13	28.40%	Fast
Gulph Mills	10:32:05	10:32:23	0:01:34	0:01:35	- 00:01	1.05%	Fast
Matsonford	10:33:54	10:34:12	0:01:49	0:01:32	00:17	18.48%	Slow
County Line	10:35:30	10:35:48	0:01:36	0:01:02	00:34	54.84%	Slow
Radnor	10:37:03	10:37:21	0:01:33	0:01:04	00:29	45.31%	Slow
Villanova	10:38:57	10:39:15	0:01:54	0:02:03	- 00:09	7.32%	Fast
Garrett Hill	10:40:19	10:40:37	0:01:22	0:01:22	- 00:00	0.00%	
Roberts Rd	10:41:33	10:41:51	0:01:14	0:01:03	00:11	17.46%	Slow
Bryn Mawr	10:42:56	10:43:14	0:01:23	0:01:01	00:22	36.07%	Slow
Haverford	10:44:26	10:44:44	0:01:30	0:01:40	- 00:10	10.00%	Fast
Ardmore Ave	10:45:57	10:46:15	0:01:31	0:01:20	00:11	13.75%	Slow
Ardmore Jct.	10:47:06	10:47:24	0:01:09	0:00:53	00:16	30.19%	Slow
Wynnewood Rd	10:48:07	10:48:25	0:01:01	0:01:03	- 00:02	3.17%	Fast
Beechwood	10:49:29	10:49:47	0:01:22	0:01:11	00:11	15.49%	Slow
Pennfield	10:50:51	10:51:09	0:01:22	0:01:09	00:13	18.84%	Slow
Township Line	10:52:00	10:52:18	0:01:09	0:01:03	00:06	9.52%	Slow
Parkview	10:53:26	10:53:44	0:01:26	0:01:00	00:26	43.33%	Slow
69th St	10:57:02	10:59:32	0:03:18	0:03:56	- 00:38	16.10%	Fast
Norristown-69th			**0:33:02**	**0:31:45**	**01:17**	**4.04%**	**Slow**

In the above tables, the overall difference (terminal to terminal) between the RTC (simulation) and SEPTA (field) data is close to or below the target goal of +/- 5%. There are, however, some station to station differences (flagged blue) where RTC is running much slower that what the field data is indicating, and three locations (flagged red) where RTC is running much faster than what the field data is indicating. These locations were addressed in a second and third pass of the calibration exercise, as follows.

B. Calibration Runs (Second Pass)

For each of the cases in the "First Pass" where the RTC station-to-station running times were slow or fast enough to warrant flagging (blue or red) in the above tables, the model was checked to ensure that there were no signal or speed errors causing the issues.

With no errors found, the Second Pass calibration runs were conducted to address the slow-running station pairs. This was done by creating three separate calibration models – one for each of the trains shown in the above tables. Each simulation model was altered such that the train did not stop at the blue-flagged stations. Instead, the trains were coded to run through the stations at a restricted speed of 15 mph (a speed estimation made by the Consultant to emulate the

operator slowing down until the he or she can determine by observation that no passengers are waiting to board at the platform).

Table 8 through Table 10 provide the results of the Second Pass calibrations runs. The tables indicate that after simulating Second Pass runs, there are no station pairs where RTC is more than 20% slower than what is indicated by the field data. Second Pass results also show overall (terminal to terminal) RTC running times deviate by less than 3% from the field data.

Table 8 – Northbound Local Train 4009-4010-07 (With Skipped Stops)

Station	RTC Simulation			SEPTA Field Trip Time (mm:ss)	Diff. (RTC-SEPTA)		RTC Fast/Slow
	Train Arrival	Train Departure	Interval (mm:ss)		mm:ss	%	
69th St.		10:15:00					
Parkview	10:17:36	10:17:54	0:02:54	0:02:55	- 00:01	0.57%	Fast
Township Line	10:18:57	10:18:57	0:01:03	0:00:59	00:04	6.78%	Slow
Pennfield	10:19:49	10:19:49	0:00:52	0:00:51	00:01	1.96%	Slow
Beechwood	10:20:50	10:20:50	0:01:01	0:00:56	00:05	8.93%	Slow
Wynnewood Rd	10:21:53	10:21:53	0:01:03	0:01:02	00:01	1.61%	Slow
Ardmore Jct.	10:22:39	10:22:57	0:01:04	0:00:56	00:08	14.29%	Slow
Ardmore Ave	10:23:51	10:24:09	0:01:12	0:01:10	00:02	2.86%	Slow
Haverford	10:25:21	10:25:39	0:01:30	0:01:35	- 00:05	5.26%	Fast
Bryn Mawr	10:26:51	10:27:09	0:01:30	0:01:29	00:01	1.12%	Slow
Roberts Rd	10:28:30	10:28:48	0:01:39	0:01:31	00:08	8.79%	Slow
Garrett Hill	10:29:48	10:30:06	0:01:18	0:01:10	00:08	11.43%	Slow
Villanova	10:31:12	10:31:30	0:01:24	0:01:34	- 00:10	10.64%	Fast
Radnor	10:33:03	10:33:21	0:01:51	0:01:45	00:06	5.71%	Slow
County Line	10:34:30	10:34:30	0:01:09	0:01:11	- 00:02	2.82%	Fast
Matsonford	10:35:42	10:35:42	0:01:12	0:01:08	00:04	5.88%	Slow
Gulph Mills	10:37:10	10:37:28	0:01:46	0:01:35	00:11	11.58%	Slow
Hughes Park	10:38:44	10:39:02	0:01:34	0:02:14	- 00:40	29.85%	Fast
Dekalb St	10:41:50	10:42:08	0:03:06	0:03:11	- 00:05	2.62%	Fast
Bridgeport	10:43:18	10:43:36	0:01:28	0:01:26	00:02	2.33%	Slow
Norristown	10:45:47	10:48:17	0:02:11	0:02:08	00:03	2.34%	Slow
Total			**0:30:47**	**0:30:46**	**00:01**	**0.05%**	**Slow**

Table 9 – Northbound Express Train 4007-4008-05 (With Skipped Stops)

Station	RTC Simulation			SEPTA Field Trip Time (mm:ss)	Delta (RTC-SEPTA)		RTC Fast/Slow
	Train Arrival	Train Departure	Interval (mm:ss)		mm:ss	%	
69th St.		8:20:00					
Pennfield	8:23:49	8:24:07	0:04:07	0:04:17	- 00:10	3.89%	Fast
Ardmore Jct.	8:26:24	8:26:42	0:02:35	0:02:27	00:08	5.44%	Slow
Bryn Mawr	8:29:13	8:30:00	0:03:18	0:04:09	- 00:51	20.48%	Fast

Station	RTC Simulation			SEPTA Field Trip Time (mm:ss)	Delta (RTC-SEPTA)		RTC Fast/Slow
	Train Arrival	Train Departure	Interval (mm:ss)		mm:ss	%	
Roberts Rd	8:31:21	8:31:39	0:01:39	0:01:43	- 00:04	3.88%	Fast
Garrett Hill	8:32:39	8:32:57	0:01:18	0:01:11	00:07	9.86%	Slow
Villanova	8:34:03	8:34:21	0:01:24	0:01:23	00:01	1.20%	Slow
Radnor	8:35:54	8:36:12	0:01:51	0:01:49	00:02	1.83%	Slow
County Line	8:37:21	8:37:21	0:01:09	0:01:14	- 00:05	6.76%	Fast
Matsonford	8:38:33	8:38:33	0:01:12	0:01:07	00:05	7.46%	Slow
Gulph Mills	8:40:01	8:40:19	0:01:46	0:01:40	00:06	6.00%	Slow
Hughes Park	8:41:35	8:41:53	0:01:34	0:01:46	- 00:12	11.32%	Fast
Dekalb St	8:44:41	8:44:59	0:03:06	0:02:53	00:13	7.51%	Slow
Bridgeport	8:46:09	8:46:27	0:01:28	0:01:26	00:02	2.33%	Slow
Norristown	8:48:38	8:51:08	0:02:11	0:02:17	- 00:06	4.38%	Fast
Total			**0:28:38**	**0:29:22**	**- 00:44**	**2.50%**	**Fast**

Table 10 – Southbound Local Train 4015-4016-06 (With Skipped Stops)

Station	RTC Simulation			SEPTA Field Trip Time (mm:ss)	Delta (RTC-SEPTA)		RTC Fast/Slow
	Train Arrival	Train Departure	Interval (mm:ss)		mm:ss	%	
Norristown		10:24:00					
Bridgeport	10:25:57	10:26:15	0:02:15	0:02:10	00:05	3.85%	Slow
Dekalb St	10:27:27	10:27:45	0:01:30	0:01:21	00:09	11.11%	Slow
Hughes Park	10:30:31	10:30:49	0:03:04	0:04:17	- 01:13	28.40%	Fast
Gulph Mills	10:32:05	10:32:23	0:01:34	0:01:35	- 00:01	1.05%	Fast
Matsonford	10:33:53	10:33:53	0:01:30	0:01:32	- 00:02	2.17%	Fast
County Line	10:35:07	10:35:07	0:01:14	0:01:02	00:12	19.35%	Slow
Radnor	10:36:17	10:36:17	0:01:10	0:01:04	00:06	9.37%	Slow
Villanova	10:37:54	10:38:12	0:01:55	0:02:03	- 00:08	6.50%	Fast
Garrett Hill	10:39:16	10:39:34	0:01:22	0:01:22	- 00:00	0.00%	
Roberts Rd	10:40:30	10:40:48	0:01:14	0:01:03	00:11	17.46%	Slow
Bryn Mawr	10:41:49	10:41:49	0:01:01	0:01:01	- 00:00	0.00%	Fast
Haverford	10:43:01	10:43:19	0:01:30	0:01:40	- 00:10	10.00%	Fast
Ardmore Ave	10:44:32	10:44:50	0:01:31	0:01:20	00:11	13.75%	Slow
Ardmore Jct.	10:45:37	10:45:37	0:00:47	0:00:53	- 00:06	11.32%	Fast
Wynnewood Rd	10:46:22	10:46:40	0:01:03	0:01:03	00:00	0.00%	Slow
Beechwood	10:47:44	10:48:02	0:01:22	0:01:11	00:11	15.49%	Slow
Pennfield	10:49:06	10:49:24	0:01:22	0:01:09	00:13	18.84%	Slow
Township Line	10:50:15	10:50:33	0:01:09	0:01:03	00:06	9.52%	Slow
Parkview	10:51:36	10:51:36	0:01:03	0:01:00	00:03	5.00%	Slow
69th St	10:54:55	10:57:25	0:03:19	0:03:56	- 00:37	15.68%	Fast
Total			**0:30:55**	**0:31:45**	**- 00:50**	**2.62%**	**Fast**

It is important to note that the models used for Second Pass calibration were created specifically to model field calibration conditions. They are therefore specialized models for calibration only. The Base Case model that was prepared for formal analysis and delivery assumes that all trains stop at all stations indicated in their respective schedules. This is a standard simulation technique in situations that involve conditional station stops. Importantly, the Future Case model incorporates the same technique.

Third Pass Calibration investigated the locations where RTC appeared to be running too fast with regard to field data.

C. Calibration (Third Pass)

Each of the trains analyzed in the calibration exercise represent a specific stopping pattern in the Base Case model- northbound local, northbound express, southbound local. All travel between 69th Street and Norristown.

Three representative trains were chosen, each of them running in a specific time slot. The time slot was selected in an effort to avoid peak travel time and potential train delay reflected in the field data. As noted in the above calibration tables, there is one station pair in each train run where the RTC trip time is shorter (hotter) than the field data for the train in the same time slot.

Third Pass of the calibration exercise examines the field data more closely. It examines the average station-to-station trip times for all trains (in all train slots) that use each of the stopping patters represented in the calibration. For the purpose of this report, these timings will be referred to as "field averages".

Table 11 shows trip-time comparisons for the three station pairs where RTC is running "hot" compared to the calibration data. Field average trip times are added to the table and used for the comparison with RTC. It is likely that the trains running in the specific train slots used for calibration experienced some sort of delay in the field between these station pairings. The average timings, however, are much closer to RTC output, and relay confidence that the simulation is running properly.

Table 11 – RTC Running Times Compared with Field Average

Train	Station Pair		Running Time			% Diff from Field Average	RTC Fast/Slow
	From	To	RTC (mm:ss)	Field (mm:ss)	Field Average (mm:ss)		
NB Local	Gulph Mills	Hughes Park	0:01:34	0:02:14	0:01:41	6.93%	Fast
NB Express	Ardmore Jct.	Bryn Mawr	0:03:18	0:04:09	0:03:51	14.29%	Fast
SB Local	Dekalb St	Hughes Park	0:03:04	0:04:17	0:03:20	8.00%	Fast

Two of the three locations where RTC was running hot when compared to the field data are within the target goal of +/-10% for station-to-station trip times when compared to the average field data. Regarding the Ardmore Jct. to Bryn Mawr running times, it is possible that operators in the field are slowing down as they pass Ardmore Ave. and Haverford stations. This could not be determined from the available data.

5. ANALYSIS RESULTS AND DISCUSSION

A. Base Case Simulation

All trains in the Base Case simulation were assumed to stop at all stations in their respective operating schedules. The simulation results showed the system on-time performance (OTP) to be "only" 96.9%. Figure 15 shows the simulation results for the Base Case simulation.

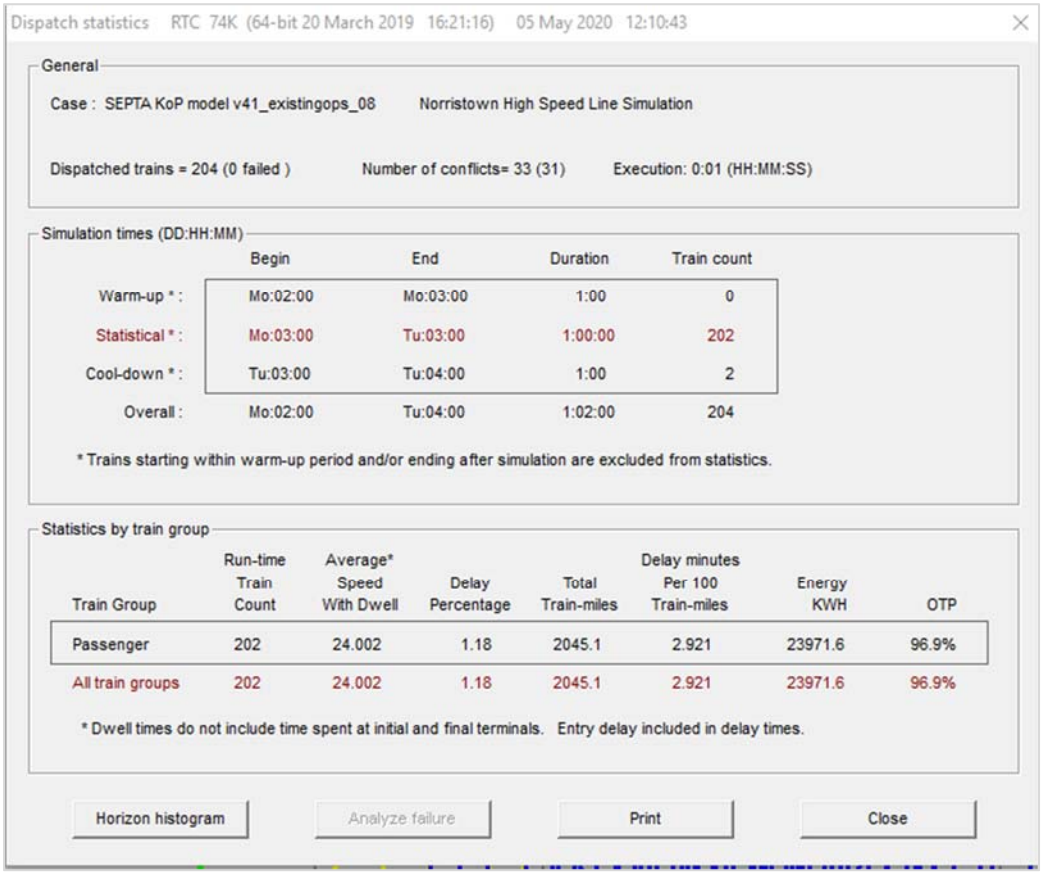


Figure 15 – Base Case Simulation Results

After reviewing the time-distance (string) charts, it was clear that early morning trains were not running on time in simulation and thus were the cause of the lower-than-expected OTP. Figure 16 below shows the Base Case simulation string charts. These can also be found in the Appendix (Figure 30) in a larger format. The early morning trains do not encounter delay from other trains, but they became later and later as they progressed from terminal of origin to the destination terminal.

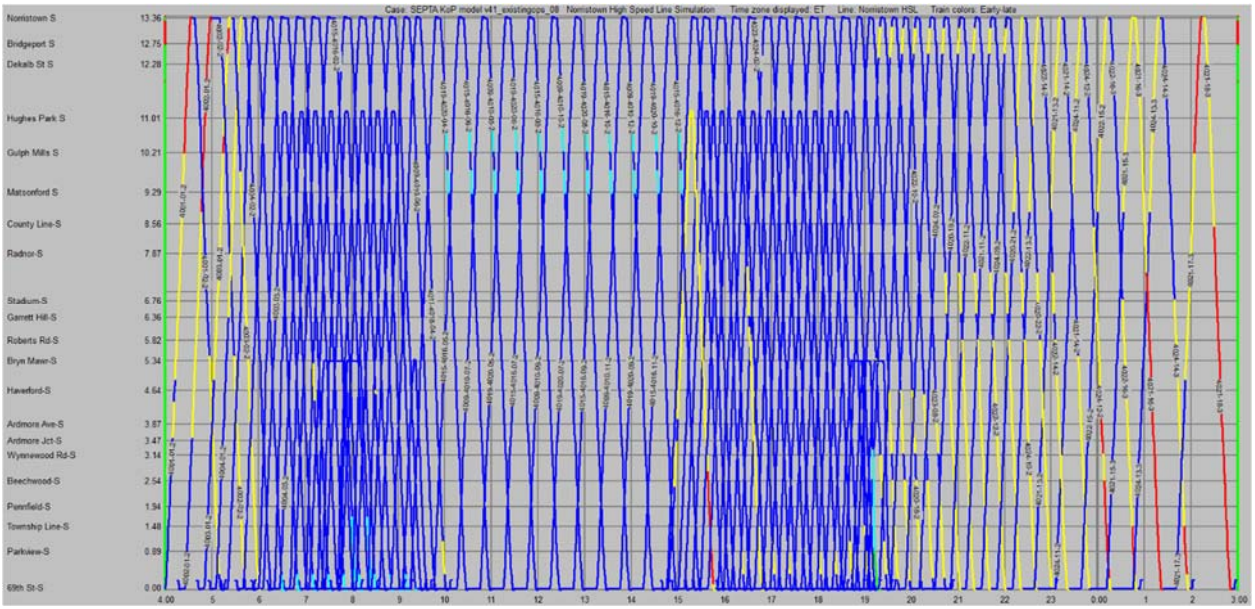


Figure 16 – Base Case String Chart – Trains Making All Stops

LEGEND:

- Early (1 minute early or more)
- On Time (between 1 min. early and 3 min. late)
- Late (between 3 min. late and 6 min. late)
- Very Late (more than 6 min. late)

It is likely that these early morning trains, in practice, do not stop at all local station stops because some of them are conditional stops (flag stops). The Base Case simulation model was therefore modified, removing seven "random" station stops from trains 4001-01, 4002-01, 4003-01, 4004-01 (operating between 4:00 and 5:00 AM). Seven "random" station stops were also removed from trains 4024-12, 4022-16, 4021-16, 4024-14, 4021-17, 4021-18 (operating between midnight and 3:00).

Figure 17 shows the simulation results after these modifications were made. OTP is now 100%. Figure 18 (Figure 31 in the Appendix) reflects an improvement the string charts as well. This exercise provides further assurance that the simulation of the Base Case is accurate.

Dispatch statistics RTC 74K (64-bit 20 March 2019 16:21:16) 05 May 2020 12:12:28

General

Case : SEPTA KoP model v41_existingops_09 Norristown High Speed Line Simulation

Dispatched trains = 204 (0 failed) Number of conflicts= 33 (31) Execution: 0:01 (HH:MM:SS)

Simulation times (DD:HH:MM)

	Begin	End	Duration	Train count
Warm-up * :	Mo:02:00	Mo:03:00	1:00	0
Statistical * :	Mo:03:00	Tu:03:00	1:00:00	202
Cool-down * :	Tu:03:00	Tu:04:00	1:00	2
Overall :	Mo:02:00	Tu:04:00	1:02:00	204

* Trains starting within warm-up period and/or ending after simulation are excluded from statistics.

Statistics by train group

Train Group	Run-time Train Count	Average* Speed With Dwell	Delay Percentage	Total Train-miles	Delay minutes Per 100 Train-miles	Energy KWH	OTP
Passenger	202	24.255	1.03	2045.1	2.520	23835.3	100.0%
All train groups	202	24.255	1.03	2045.1	2.520	23835.3	100.0%

* Dwell times do not include time spent at initial and final terminals. Entry delay included in delay times.

Horizon histogram | Analyze failure | Print | Close

Figure 17 – Base Case Simulation Results – Modified Early AM Trains

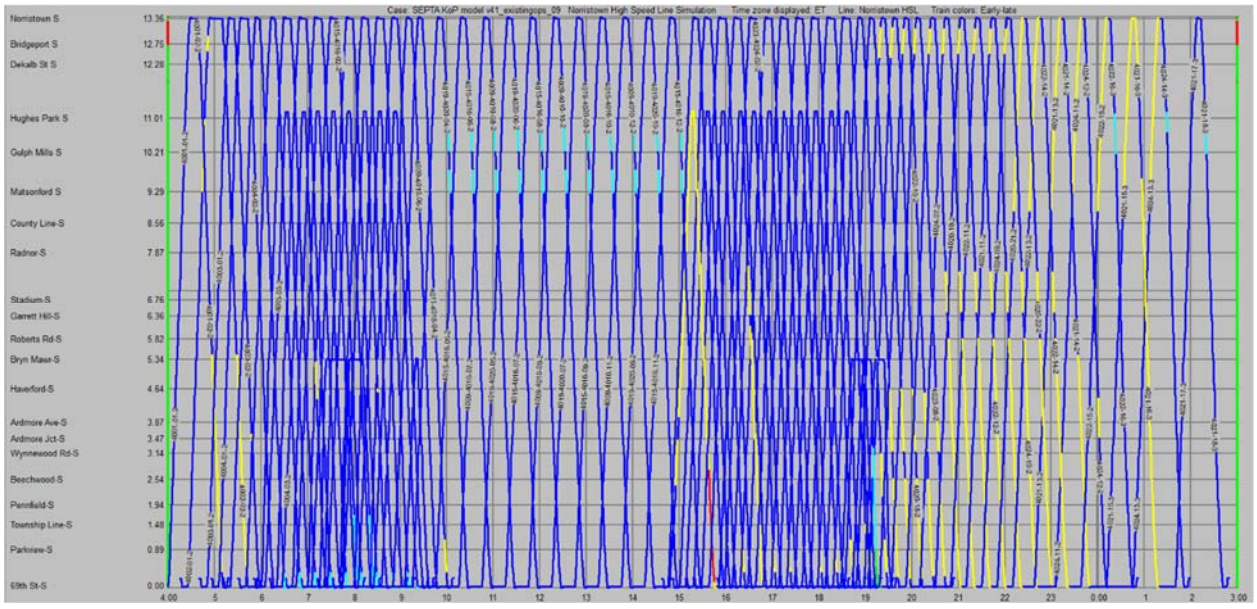


Figure 18 – Base Case String Chart – Early AM Modified Stopping Pattern

LEGEND:

- Early (1 minute early or more)
- On Time (between 1 min. early and 3 min. late)
- Late (between 3 min. late and 6 min. late)
- Very Late (more than 6 min. late)

B. Future Case Simulation

1. Operations and Simulation Results

The operating plan for the Future Case simulation model complies with the Concept of Operations service level goals as outlined in Table 3 (Section 3.D) above. Table 12 provides an hourly accounting of the service level for each of the four services shown in Table 3. Each train appears only once in the tally.

Table 12 – Future Case Service Levels – Trains Per Hour

Timing Location [4] ->		Bryn Mawr		Hughes Park		Hughes Park		Dekalb Street	
Service ->		69th - Bryn Mawr		69th - NTC		69th – KOP Ext.		KOP Ext. - NTC	
From	To	NB	SB	NB	SB	To KOP	From KOP	From KOP	To KOP
4:00	5:00	0	0	1	0	2	0	0	0
5:00	6:00	0	0	3	3	8	3	2	1
6:00	7:00	1	1	3	3	6	6	3	3
7:00	8:00	3	2	4	4	6	6	3	3
8:00	9:00	5	5	4	4	6	6	3	3
9:00	10:00	0	1	4	4	4	5	3	3
10:00	11:00	0	0	3	3	3	3	3	3
11:00	12:00	0	0	3	3	3	3	3	3
12:00	13:00	0	0	3	3	3	3	3	3
13:00	14:00	0	0	3	3	3	3	3	3
14:00	15:00	0	0	3	3	3	3	3	3
15:00	16:00	2	2	3	3	5	3	3	3
16:00	17:00	4	3	4	4	6	6	3	3
17:00	18:00	4	4	4	4	6	6	3	3
18:00	19:00	4	4	4	4	5	6	3	3
19:00	20:00	0	1	4	4	3	5	3	3
20:00	21:00	0	0	3	3	3	3	3	3
21:00	22:00	0	0	3	3	3	3	3	3
22:00	23:00	0	0	3	3	3	3	3	3
23:00	0:00	0	0	3	3	3	3	3	3
0:00	1:00	0	0	2	3	1	3	3	3
1:00	2:00	0	0	0	3	0	0	2	0
2:00	3:00	0	0	0	0	0	0	0	0
3:00	4:00	0	0	0	0	0	0	0	0

[4] The timing point determines the time range within which the train is counted.

Table 13 below provides information about traffic density of the proposed Future Case operations. Trains-per-hour (TPH) were computed over a 24-hour period at four locations: Allendale Rd., Parkview, Hughes Park, and Dekalb St.

Note that this table does not provide service level. Instead, it examines traffic density at select locations within an hourly timeframe. Unlike Table 12, trains may be counted more than once during their terminal to terminal traversal. For example, a train departing 69th Street and traveling to 1st and Moore on the KOP extension will be counted at three locations: Parkview, Hughes Park, and Allendale Road.

Table 13 – Future Operations – Trains-Per-Hour

Timing Point –>		Allendale Road		Parkview		Hughes Park		Dekalb Street	
From	To	WB	EB	NB	SB	NB	SB	NB	SB
4:00	5:00	1	0	7	0	3	0	1	0
5:00	6:00	10	6	10	4	11	6	5	4
6:00	7:00	9	9	12	9	9	9	6	6
7:00	8:00	9	9	14	13	10	10	7	7
8:00	9:00	9	9	13	14	10	10	7	7
9:00	10:00	7	7	6	11	8	9	7	7
10:00	11:00	6	6	6	6	6	6	6	6
11:00	12:00	6	6	6	6	6	6	6	6
12:00	13:00	6	6	6	6	6	6	6	6
13:00	14:00	6	6	6	6	6	6	6	6
14:00	15:00	6	6	7	6	6	6	6	6
15:00	16:00	7	7	11	8	8	6	6	6
16:00	17:00	8	9	14	12	10	10	7	7
17:00	18:00	9	9	14	14	10	10	7	7
18:00	19:00	9	9	12	14	9	10	7	7
19:00	20:00	7	7	6	11	7	9	7	7
20:00	21:00	6	6	6	6	6	6	6	6
21:00	22:00	6	6	6	6	6	6	6	6
22:00	23:00	6	6	6	6	6	6	6	6
23:00	0:00	6	6	6	6	6	6	6	6
0:00	1:00	4	6	1	6	3	6	5	6
1:00	2:00	0	2	0	4	0	3	2	3
2:00	3:00	0	0	0	1	0	0	0	0
3:00	4:00	0	0	0	0	0	0	0	0

Proposed future operations are quite a bit denser than the existing traffic density on the NHSL, especially during off-peak hours. In other words, overall average headways along the existing mainline will be shorter. Figure 19 shows the dispatch statistics generated from the RTC simulation. Note there are 539 trains in simulation compared to 202 in the Base Case simulation, yet the OTP for the Future Case is a respectable 99.4 % for a non-randomized simulation. System performance will be discussed later in this section.

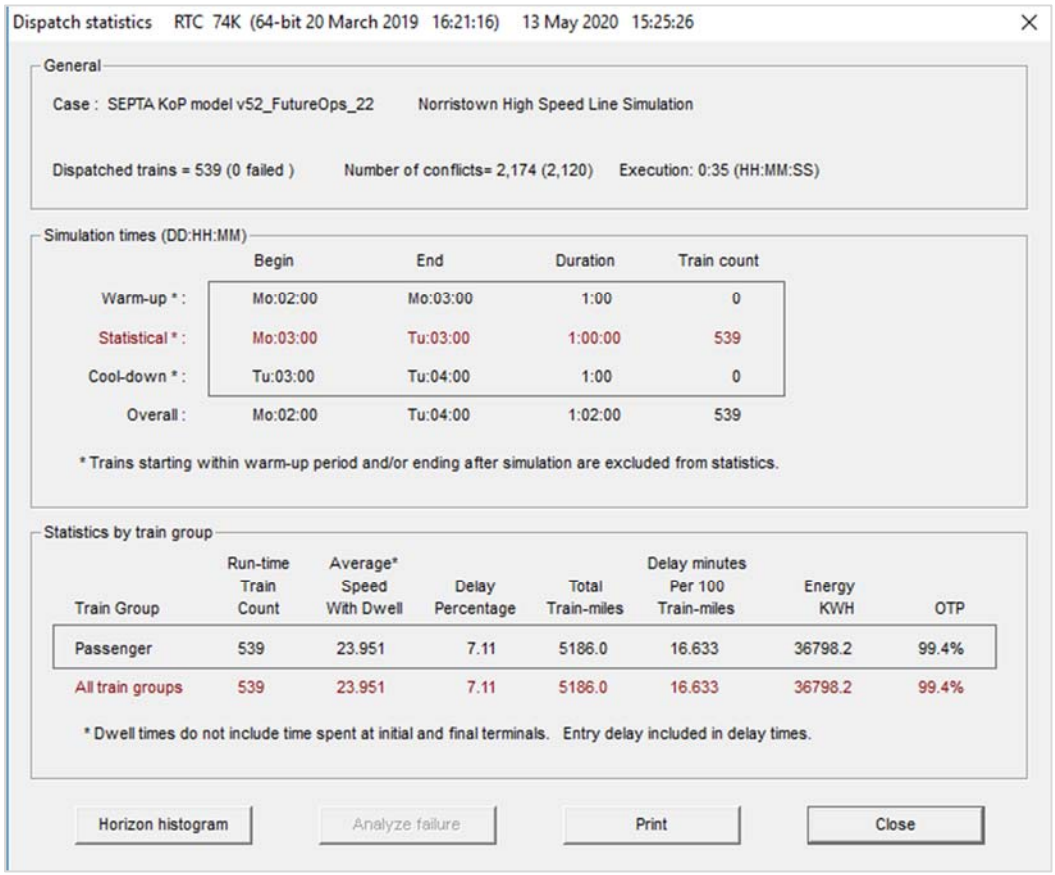


Figure 19 – Future Case Simulation Results

Figure 20 provides a full-day view of the time-distance (string) charts for the KOP Extension. This image can be found in larger format in the Appendix (Figure 32). The string charts indicate that trains are running on-time on the KOP Extension.

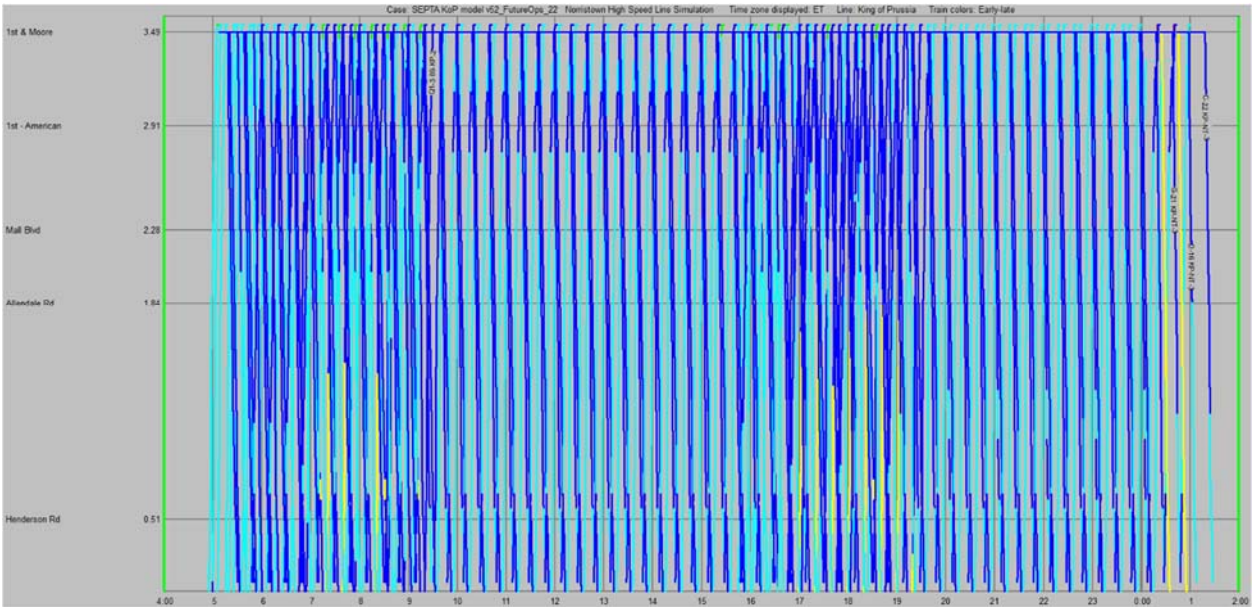


Figure 20 – Future Case String Chart – KOP Extension – Full Day

LEGEND:
Early (1 minute early or more)
On Time (between 1 min. early and 3 min. late)
Late (between 3 min. late and 6 min. late)
Very Late (more than 6 min. late)

Figure 21 provides a full-day view of the string charts for the mainline (NHSL). This can be found in larger format in the Appendix (Figure 33). The string charts reveal that there are trains in the morning and evening peak that are running late. These time periods will be examined more closely.

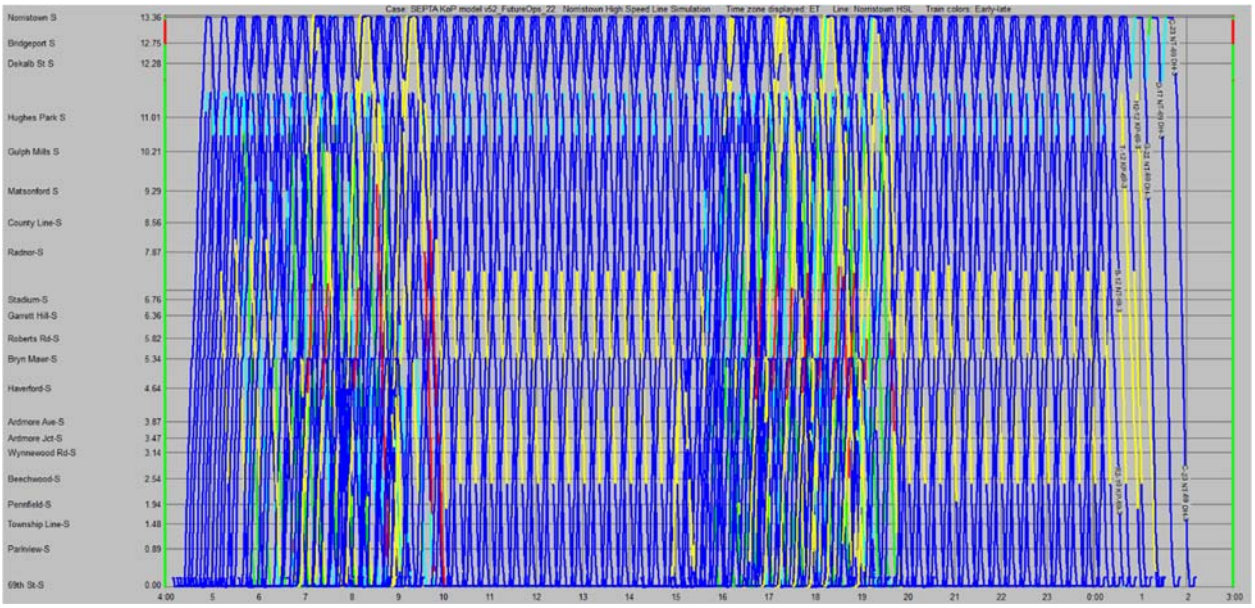


Figure 21 – Future Case String Chart – NHSL – Full Day

LEGEND:
Early (1 minute early or more)
On Time (between 1 min. early and 3 min. late)
Late (between 3 min. late and 6 min. late)
Very Late (more than 6 min. late)

Figure 22 (Figure 34 in the Appendix) provides a closer look at train delays that occur during the morning peak. The blue arrows in the string chart point to short-turn trains from 69th St. to Bryn Mawr. These trains are followed by trains traveling from 69th St. to the KOP Extension. Red arrows point to these trains. The KOP trains are delayed by the Bryn Mawr short-turn trains.

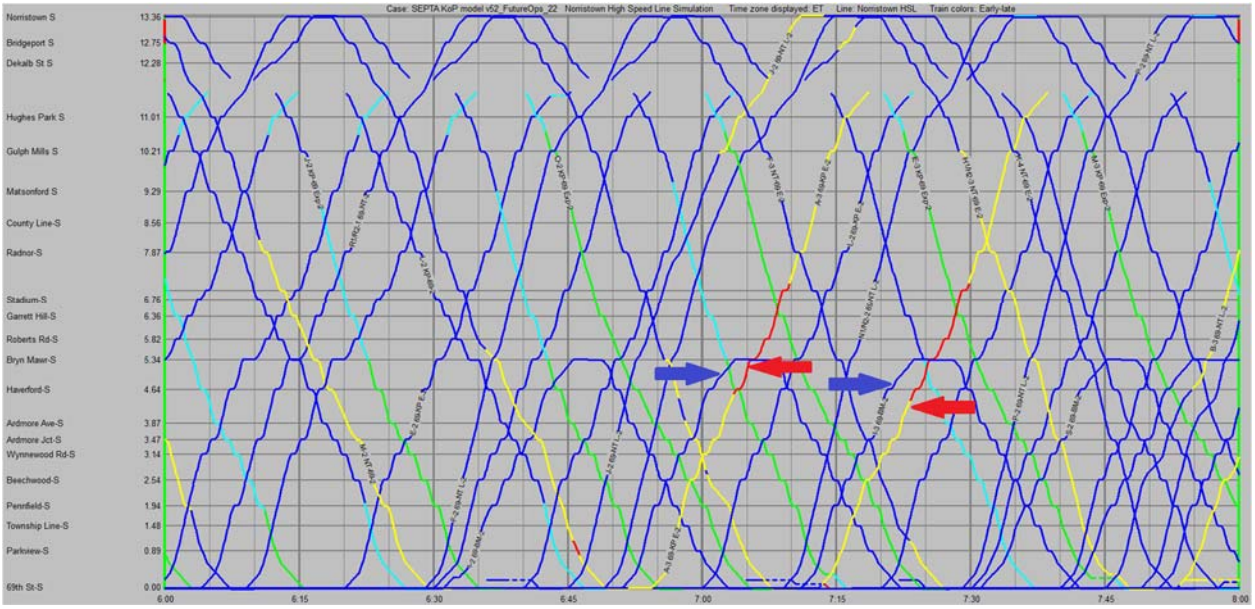


Figure 22 – Future Case String Chart – NHSL – 0600h – 0800h

LEGEND:

- Early (1 minute early or more)
- On Time (between 1 min. early and 3 min. late)
- Late (between 3 min. late and 6 min. late)
- Very Late (more than 6 min. late)

Figure 23 (Figure 35 in Appendix) shows a case where a Bryn Mawr train (blue arrow) delays a Norristown train (red arrows) and causes the northbound Norristown train to be delayed enough that its southbound trip to 69th St. is delayed also.

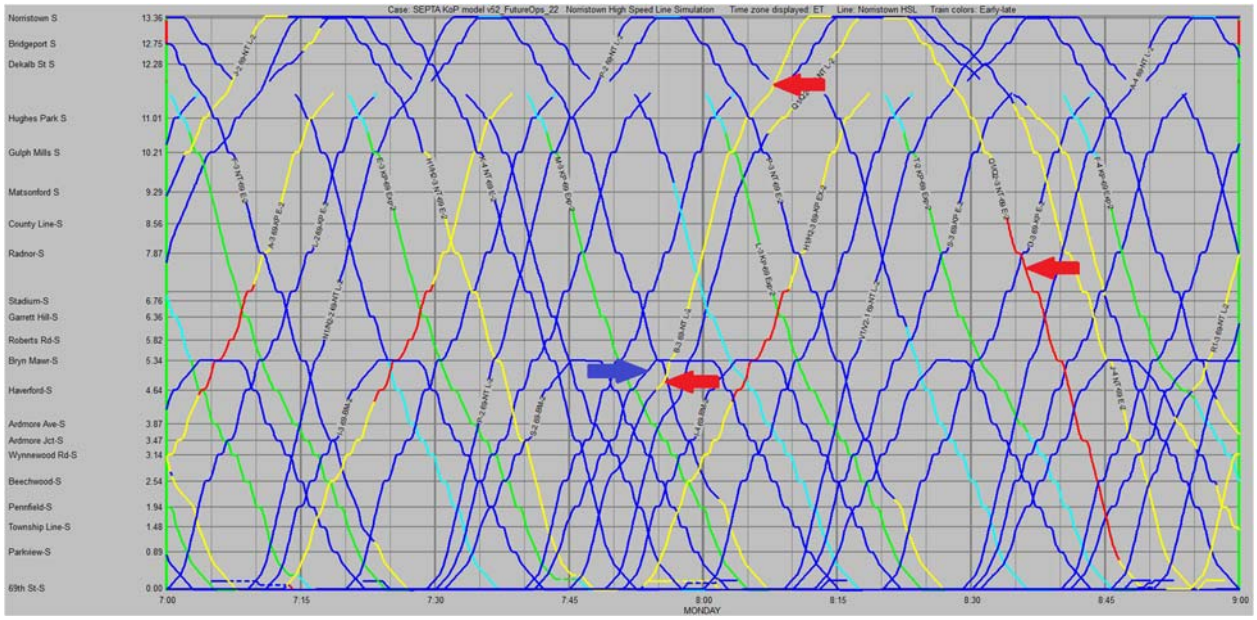


Figure 23 – Future Case String Chart – NHSL – 0700h – 0900h

LEGEND:

- Early (1 minute early or more)
- On Time (between 1 min. early and 3 min. late)
- Late (between 3 min. late and 6 min. late)
- Very Late (more than 6 min. late)

Similar delays occur during the afternoon peak, as shown below in Figure 24 (Figure 36 in the Appendix).

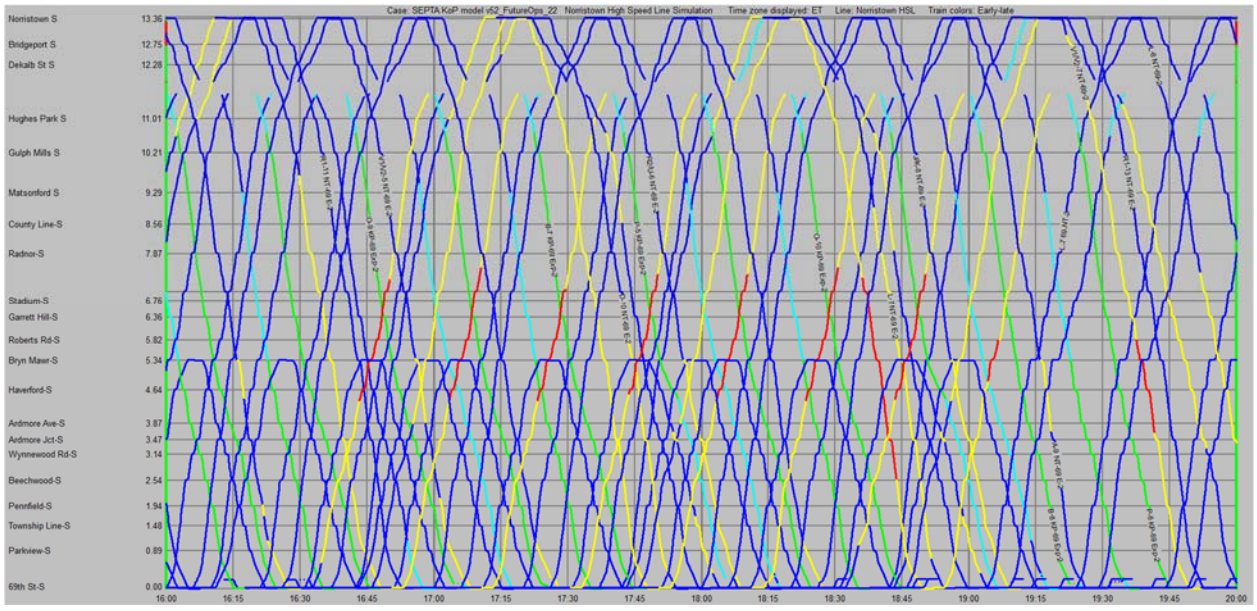


Figure 24 – Future Case String Chart – NHSL – 1600h – 2000h

LEGEND:

- Early (1 minute early or more)
- On Time (between 1 min. early and 3 min. late)
- Late (between 3 min. late and 6 min. late)
- Very Late (more than 6 min. late)

When delay patterns like those shown in the string charts above occur in a simulation that has not been randomized[5], it is an indication that the schedule will likely result in consistent every-day delays in the field. It is recommended that SEPTA re-evaluate the frequency of trains that will short-turning at Bryn Mawr against the forecast travel demand to and from that station. If the travel demand can be adequately addressed by thoroughfare trains, possible some or all of the Bryn Mawr short-turns could be eliminated from the schedule. This will simultaneously improve operating reliability and slightly reduce the required vehicle fleet size.

2. Turnout at South Junction

As discussed earlier in this report, design limitations at the wye junction will require NHSL "main line" trains to take a diverging move at South Junction over a #8 (15 mph turnout). To help determine the impact on trip times, Table 14 compares the running times between Hughes Park and Dekalb St. Stations in the existing model with running times in the Future Case (with the proposed #8 turnout in place). Running times assume the trains stop at both stations.

Table 14 – Running Time Difference Between Hughes Park and Dekalb Street

Running Time Between Hughes Park and Dekalb St.					
Direction of Travel	**From**	**To**	**Existing (mm:ss)**	**Future (mm:ss)**	**Difference (mm:ss)**
NB	Hughes Park	Dekalb Street	03:07	04:09	+01:02
SB	Dekalb Street	Hughes Park	03:02	03:49	+00:47

It should be noted that the control line logic for this territory (North and South Junction and preceding signals) has not been optimized and it is anticipated that optimization could somewhat mitigate the anticipated adverse impact on future running times to and from the NTC but will not eliminate the delta.

To illustrate this point, refer to the RTC image of Hughes Park and South Junction shown below in Figure 25. The blue line with the arrow in the image was added to show the location where a train heading from Hughes Park to Dekalb Street will first receive a "best signal code" of 15 mph at the northbound "leaving" signal of the interlocking just north of Hughes Park (see the left end of the blue line). The distance to the home signal at South Junction (tip of the blue arrow) is approximately 1,960 feet. It will take almost 1:30 (m:ss) to traverse 1,960 at 15 mph. Adding a signal or a signal timer within this signal block would allow trains to travel a portion of the distance at a higher speed, thus shortening the overall run time and reducing the anticipated adverse impact on running times between 69th Street the NTC compared to the existing running times.

[5] Randomization is the process of introducing "random" delay into a simulation. For instance, station dwell times may be randomized such that they are extended by up to 10 seconds in simulation. This is a way to mimic minor unexpected delays and events that occur on a daily basis in a rail system.

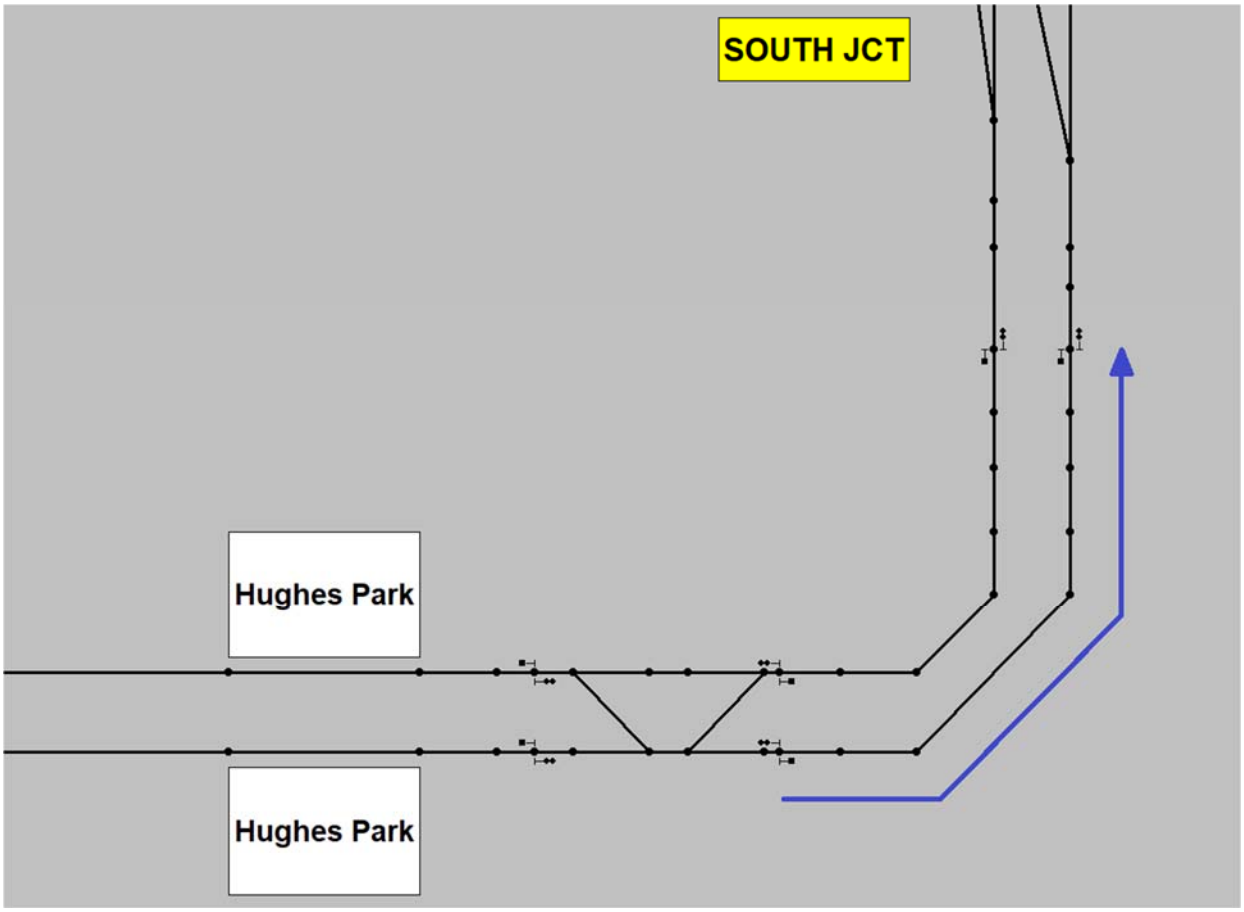


Figure 25 – Hughes Park to South Junction in RTC

3. Increasing NHSL Speed to 70 MPH

It was observed in simulation that, occasionally, trains traveling eastbound on the KOP extension arrive at the wye junction ahead of a northbound or southbound NHSL mainline train. In fact, the speed on the NHSL was 70 mph when the operating plan was developed back in 2015. These minor timing issues can be remedied with small adjustments to KOP train schedules, or simply by requiring KOP trains to wait at the wye junction for their appropriate time slot.

This report does not seek to determine how a change in speed would affect the running of the overall network, but offers a comparison of how trip times would be affected if the top speed of the NHSL was restored to 70 mph. Services with the fewest scheduled station stops would gain the most from restoration of the 70-mph speed code. Table 15 shows trip time comparisons for northbound “Limited” service and southbound “Express” service. In each direction, the overall trip time savings is just over 30 seconds.

Table 15 –Trip Time* Comparison – 55 MPH vs 70 MPH System Speed

69th Street to Norristown - Limited				
From	**To**	**Trip Time (mm:ss) System Maximum Speed** 55 mph	70 mph	**Delta (mm:ss)**
69th St	Gulph Mills	14:32	13:56	00:36
Gulph Mills	Hughes Park	01:34	01:34	00:00
Hughes Park	Norristown	06:44	06:44	00:00
	Total	**22:50**	**22:14**	**00:36**
Norristown to 69th Street - Express				
From	**To**	**Trip Time (mm:ss) System Maximum Speed** 55 mph	70 mph	**Delta (mm:ss)**
Norristown	Bridgeport	02:14	02:14	00:00
Bridgeport	Dekalb St	01:28	01:28	00:00
Dekalb St	Hughes Park	03:49	03:49	00:00
Hughes Park	Gulph Mills	01:35	01:33	00:02
Gulph Mills	Radnor	03:33	03:32	00:01
Radnor	Villanova	01:54	01:54	00:00
Villanova	Bryn Mawr	02:43	02:34	00:09
Bryn Mawr	Ardmore Jct.	02:48	02:34	00:14
Ardmore Jct.	69th St	06:29	06:23	00:06
	Total	**26:33**	**26:01**	**00:32**

*Trip times include mid-line dwells, but not terminal dwells

6. SINGLE-TRACK OUTAGE ANALYSIS

A. Introduction

A variant of the Future Case simulation model was developed in order to determine the effects of operating the proposed King of Prussia branch with one track out of service for maintenance during the midday off peak period. The analysis investigates a "worst-case" single track outage on the proposed King of Prussia branch between "MID" (west of proposed Mall Blvd Station) and the "WEST JUNCTION" (east of proposed Henderson Road Station). Two design modifications were implemented in the simulation model to support this effort. First, a conceptual universal crossover was added to the infrastructure model between the west leg of the wye junction and Henderson Road Station. The crossover will restrict the single-track outage to the branch line and avoid disruption on the existing NHSL main tracks north and south of the wye junction. Second, a modified operating plan was developed to support the track outage discussed on the following page.

B. Assumptions and Methodology

1. Infrastructure

According to the provided 15% design, a single-track outage on the longest segment of the branch (east of "MID" Interlocking) would extend significantly onto the mainline, to Hughes Park to the south and to Norristown to the north. This is because no service crossover at or adjacent to the wye was included in that design. To reduce the adverse impacts on operations of a single-track outage on the branch, a universal crossover was added as shown below in Figure 26. In the simulation model, the universal was made part of proposed "WEST JUNCTION" Interlocking.

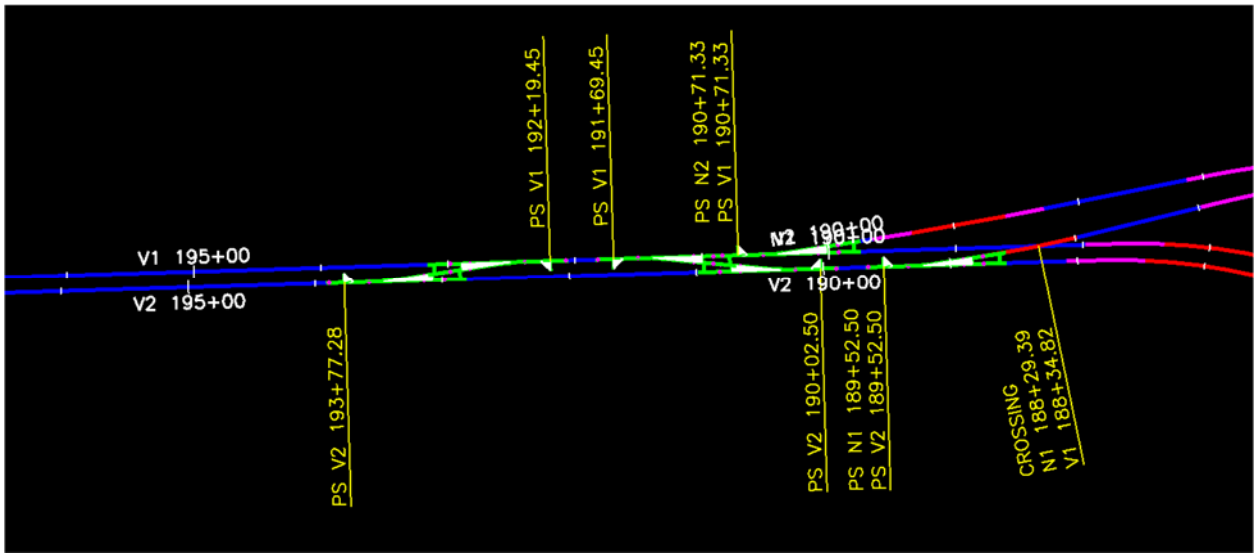


Figure 26 – Conceptual Universal Crossover Near Henderson Road Station

To accommodate the universal crossover, the location of Henderson Road Station was shifted westward approximately 350 feet. These changes to the proposed design were implemented in a copy of the Future Case network simulation model.

Minor adjustments to the position of the track switches at “NORTH JUNCTION” and “SOUTH JUNCTION” Interlockings were made in the conceptual design to achieve the necessary space for the universal crossover. These small adjustments were not implemented in simulation because the differences were negligible and would have no measurable impact on simulation results.

2. Track Outage

The North Track on the proposed King of Prussia branch was assumed to be out-of-service in simulation between “MID” and “WEST JUNCTION” interlockings from 0900h to 1500h in network simulation as is typical for a planned outage for maintenance purposes. The single-track outage is highlighted in Figure 27 by a red box. Trains serving Henderson Road, Allendale Road, and Mall Boulevard stations in the westbound direction were adjusted to utilize the South Track to access those stations whereas normally they would operate via the North Track.

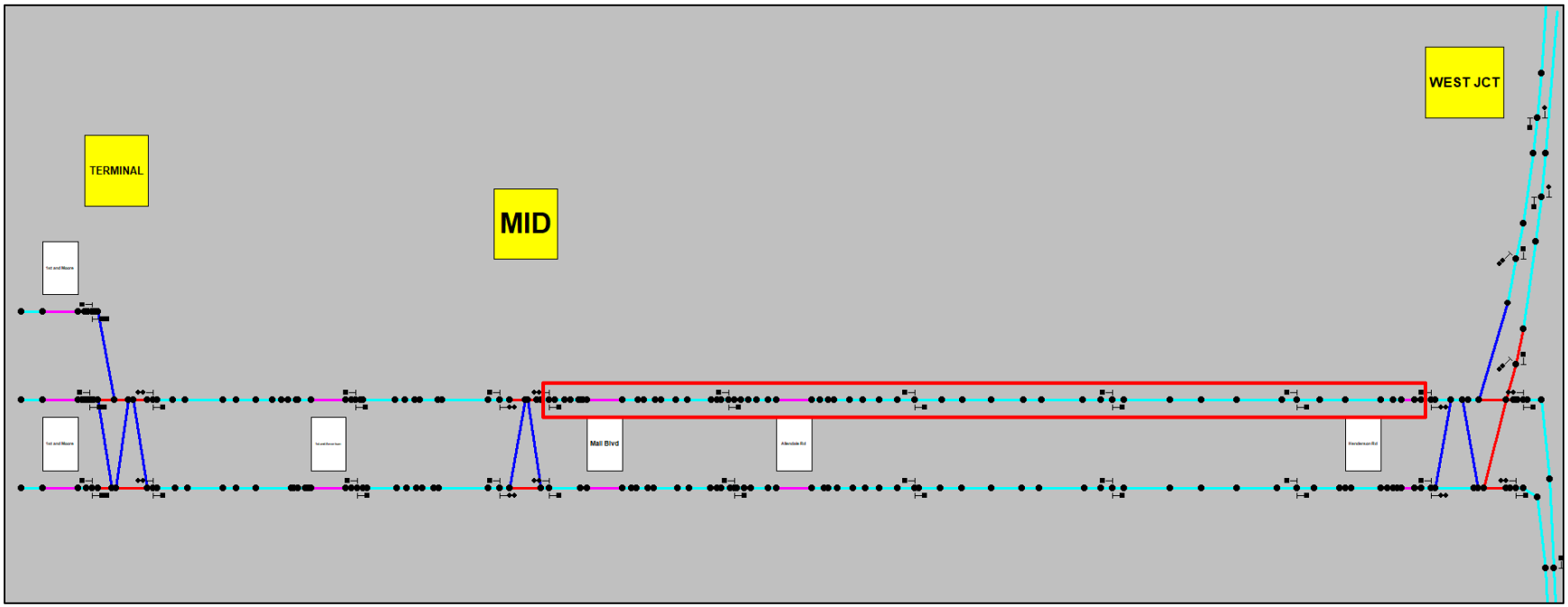


Figure 27 – Screen Image of Simulation Model with Track Outage

3. Operations

A new operating plan was developed to accommodate a reduced service level of 2 trains per hour (30-minute service) per direction on the branch during the outage. The modified service levels by trip type are given below in Table 16.

Table 16 – Service Levels by Trip Type – KOP Rail – Track Outage

Trip Type	Peak TPH	Off-peak TPH	Outage TPH
69th-BM	4	0	0
69th-KOP	6	3	1
69th-NTC	4	3	3
KOP-NTC	3	3	1

The peak and off-peak service levels shown in the above table are based on the draft EIS report. The outage levels reduce service to a single train per hour between 69th street and the King of Prussia Branch and a single train per hour between Norristown and the branch. This results in two trains per hour per direction on the branch during the outage. The service on the existing NHSL remains unaffected at three trains per hour, which is the normal off-peak service level.

The operating plan was developed (and the simulation was run) from the beginning of service until approximately 1900h (7:00 PM).

For simplicity, all trains in this simulation are single car N5 consists rather than the mix of one and two-car consists used in normal operations. This has no impact on the operational results.

C. Simulation Results and Discussion

Figure 28 shows the dispatch statistics generated from the RTC simulation with the North Track of the proposed branch out of service between 0900h and 1500h between ‘MID’ and ‘WEST JUNCTION’.

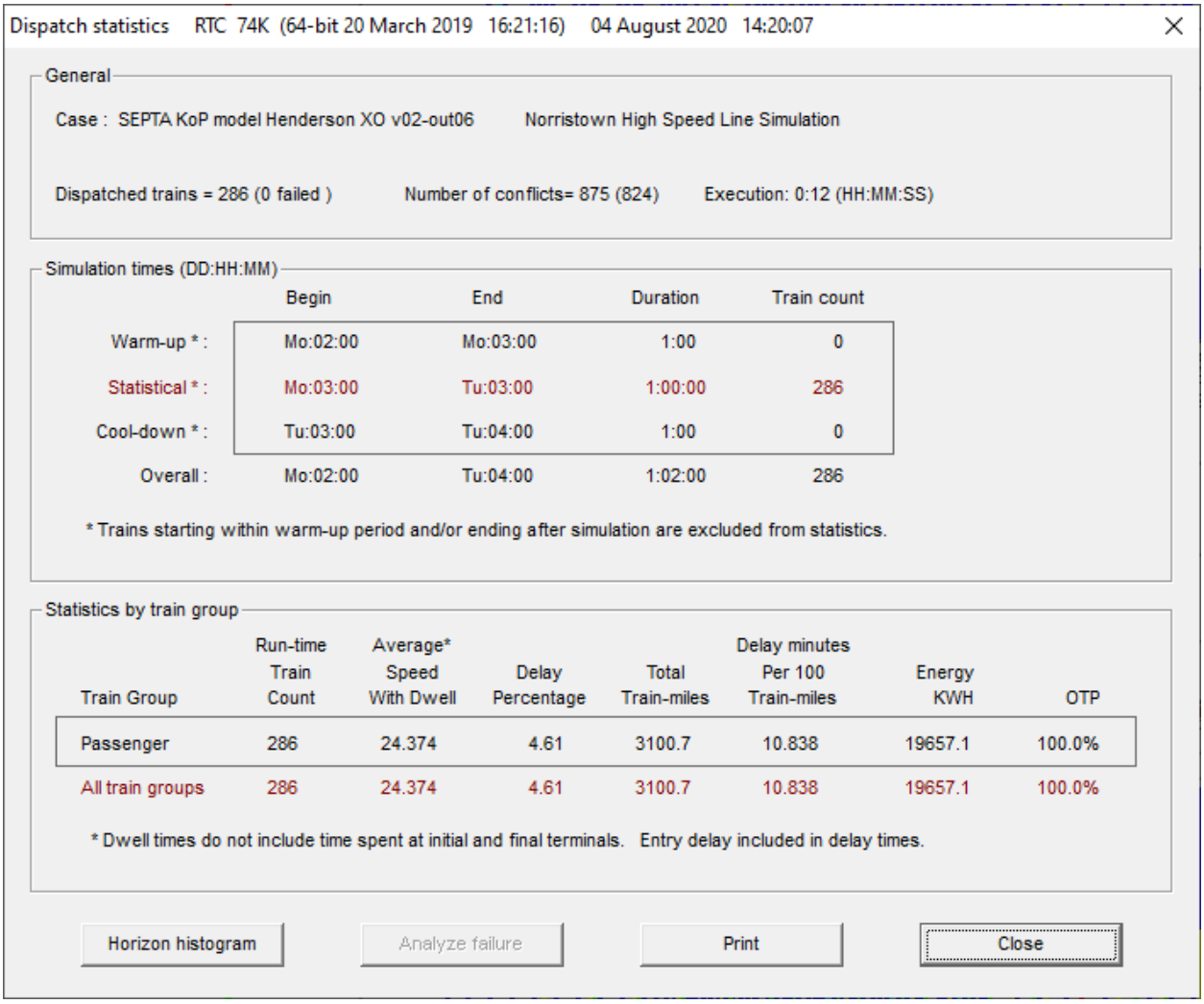


Figure 28 – Single-Tracking Case Simulation Results

These results demonstrate that with a universal crossover between Henderson Road Station and the wye junction, the proposed King of Prussia branch is able to support two trains per hour in each direction with recoverable delays when operating with a “worst-case” single-track outage during the off-peak in simulation.

A time-distance chart for the branch is provided below in Figure 29, showing the outage period from 0900h to 1500h. The area shaded in red indicates the limits of the single-track outage on the branch. The colors of the lines indicate train lateness. There are no instances of trains having stopped or slowed at the limits of single-track outage territory to wait for the available track to clear. This is another indication that operating 2 TPH on the branch in both directions is supportable in the event of a single-track outage.

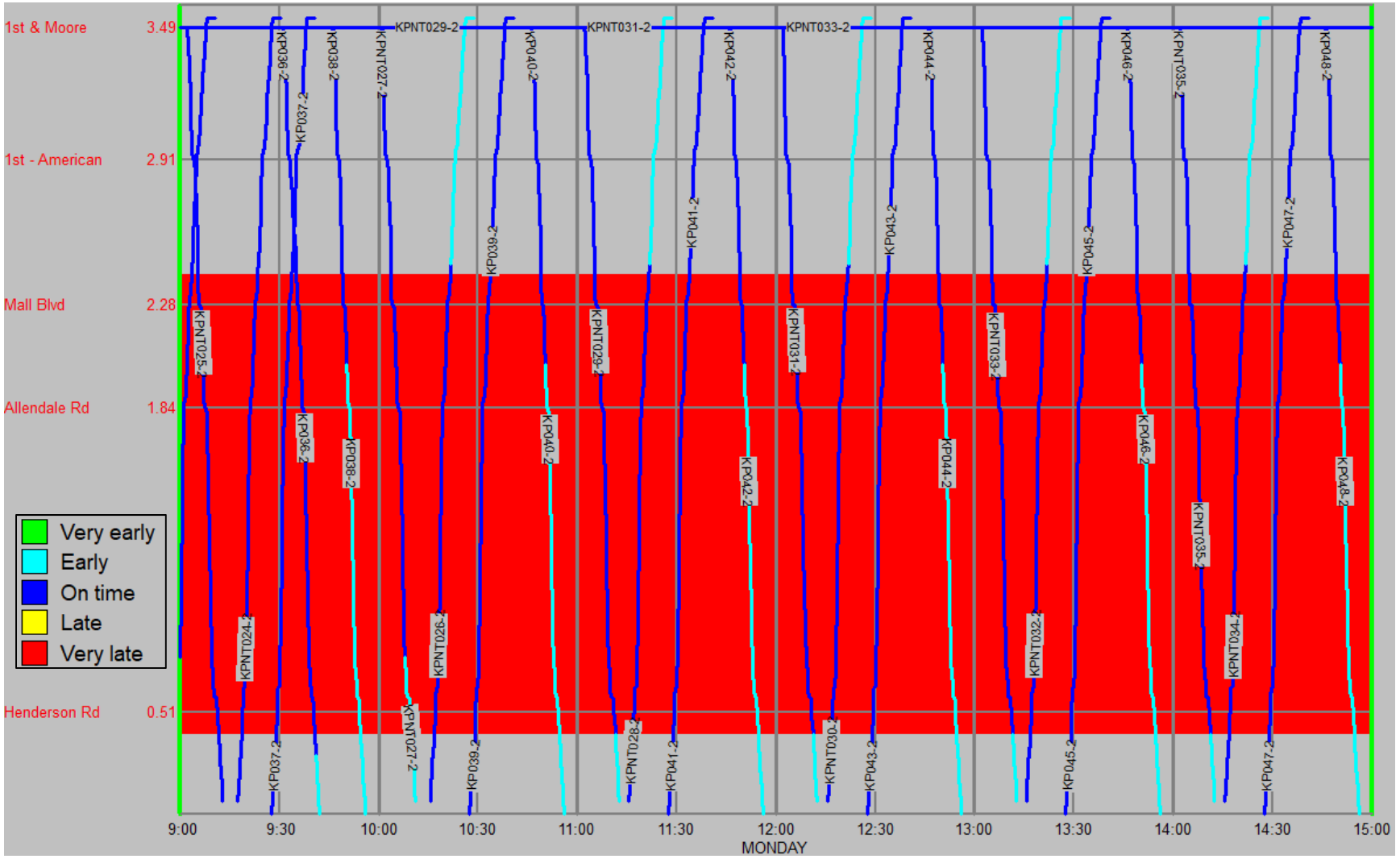


Figure 29 – Single-Tracking String Chart – KOP Branch – 0900h – 1500h

7. OPERATION AND MAINTENANCE COST ANALYSIS

This section references the separate *SEPTA Norristown High Speed Line Extension Alternatives Analysis Draft Environmental Impact Statement - Operating & Maintenance Cost Model Results* report dated July 14, 2016 (hereafter referred to as the O&M Cost Report), but with updated 2019 cost values provided by SEPTA.

SEPTA's three-factor formula was used to estimate annual cost of operations and maintenance for the Base and Future Case simulation models. The formula as copied from the O&M Cost Report is:

Total O&M cost = ($69.45 x Vehicle Hours) + ($3.40 x Vehicle Miles) + ($429,720 x Peak Vehicles)

Because SEPTA operates one-car and two-car trains in the study territory, the following interpretations were made to clarify the three-factor formula:

Total O&M cost = ($69.45 x **Train** Hours) + ($3.40 x **Vehicle** Miles) + ($429,720 x Peak **Vehicles**)

Where **vehicles** are individual units (railcars) and **trains** are "consists" of one or two vehicles. **Train**-hours is the metric used in conjunction with the $69.45 hourly cost because this is defined in the O&M Cost Report as operator wages, payroll taxes, and benefits. **Vehicle** miles are used with the $3.40 mileage cost because this is defined as the cost for providing traction power, the cost of wayside maintenance materials, supplies, and labor.

SEPTA confirmed that the **first 27 peak vehicles** have an allocated overhead cost of $429,720 each and **each vehicle beyond the first 27** has an overhead cost of $48,140.

Weekday train hours and train miles were computed using computer network simulation output from the Base Case and Future Case simulation models. From the O&M Cost Report, SEPTA-provided factors were used to convert weekday train volume into Saturday and Sunday/holiday volume. Table 17 provides the conversion of weekday values into weekend/holiday volume.

Table 17 – Conversion of Single Weekday into Annualized Values

	Days Per Year	% Daily Value	Adjusted Days
Weekday Values = Daily x 255 days per year	255	100%	255
Saturday Values = 52% of daily x 52 days per year	52	52%	27.04
Sunday/holiday Values = 40% of daily x 58 days per year	58	40%	23.2
Totals	**365**		**305.24**

Based on Table 17, the daily train-hours and vehicle-miles are multiplied by 305.24 to yield yearly figures, as this was SEPTA's formula as of 2014. The metrics can easily be adjusted should SEPTA determine that future weekend/holiday service levels along the expanded NHSL network will differ from the numbers shown above.

A. Base Case O&M Computation

Table 18 provides total train/vehicle hours and miles per day/per year and breaks out those numbers in terms of revenue and non-revenue service. In the Base Case simulation, the peak vehicle fleet requirement is 18. That is, 18 units/cars are required to maintain service during peak period. Total **train hours**[6] and total **vehicle miles** are used in the O&M formula.

Table 18 – O&M Computation – Base Case (Existing 2020)

	Per Day	Per Year	Unit Cost	Yearly Cost
Total Train Hours	113.9	34,767	$ 69.45	$ 2,414,568
Total Vehicle Hours	186.8	57,019		
Rev Train Hours	108.2	33,027		
Rev Vehicle Hours	179.0	54,638		
DH Train Hours	5.7	1,740		
DH Vehicle Hours	7.8	2,381		
Total Train Miles	2045.1	624,246		
Total Vehicle Miles	3375.5	1,030,338	$ 3.4	$ 3,503,149
Rev. Train Miles	2010.8	613,777		
Rev. Vehicle Miles	3336.3	1,018,372		
DH Train Miles	34.3	10,470		
DH Vehicle Miles	39.2	11,965		
Peak Vehicles	18	18	$ 429,720	$ 7,734,960
Total				**$ 13,652,677**

B. Future Case O&M Computation

Table 19 provides total train/vehicle hours and miles per day/per year for the Future Case simulation. The numbers are also broken out in terms of revenue and non-revenue service. In the Future Case simulation, the peak train number of vehicles in service is 27. Total train hours and total vehicle miles are used in the O&M formula.

[6] If it was intended that vehicle-hours be used instead of train-hours in the computation of O&M hourly cost, vehicle hours are provided in the tables (Base and Future Case) and can be substituted easily.

Table 19 – O&M Computation – Future Case

	Per Day	Per Year	Unit cost	Yearly Cost
Total Train Hours	317.9	97,036	$ 69.45	$ 6,739,150
Total Vehicle Hours	356.9	108,940		
Rev Train Hours	308.8	94,258		
Rev Vehicle Hours	346.5	105,766		
DH Train Hours	9.1	2,778		
DH Vehicle Hours	10.4	3,174		
Total Train Miles	5186.0	1,582,975		
Total Vehicle Miles	5957.7	1,818,528	$ 3.4	$ 6,182,995
Rev. Train Miles	5131.5	1,566,339		
Rev. Vehicle Miles	5900.6	1,801,099		
DH Train Miles	54.5	16,636		
DH Vehicle Miles	57.1	17,429		
Peak Vehicles	27	27		
Peak Vehicles (27)	27	27	$ 429,720	$ 11,602,440
Peak Vehicles (>27)	0	0	$ 48,140	$ -
Total				**$ 24,524,585**

Table 20 provides a comparison of the existing and anticipated future O&M Costs as if the Extension was ready to open now. In other words, the future O&M cost estimate assumes that the King of Prussia Extension is already constructed and commissioned. Therefore, the comparative O&M costs do not account for intervening inflation. The significance of this is that while the O&M calculation for the existing service reflects approximately the current value of money (based on 2019 unit costs), the O&M costs relevant to the anticipated future service levels and vehicle fleet size after the proposed Extension is commissioned will begin to occur at a time in the future to be determined, but clearly several years away.

Table 20 – Base and Future Case O&M Comparison

	Hours, Miles and Vehicle Units			Yearly O&M Cost		
	Current	Future	Delta	Current	Future	Delta
Total Train Hours	34,767	97,036	62,269	$2,414,568	$ 6,739,150	$4,324,582
Total Vehicle Miles	1,030,338	1,818,528	788,190	$3,503,149	$ 6,182,995	$2,679,846
Peak Vehicles	18	27	9	$7,734,960	$11,602,440	$3,867,480
Total O&M Cost				**$13,652,677**	**$24,524,585**	**$10,871,908**
Overall Delta %						**79.6%**

8. CONCLUSIONS AND RECOMMENDATIONS

A. Operations

While the proposed Future Operating Plan is sound, it is recommended that the Bryn Mawr short turns be reviewed for reason already discussed. Morning peak thoroughfare trains experience less delay than afternoon trains due to the Bryn Mawr short-turns, but it is recommended that SEPTA consider removing or rescheduling four Bryn Mawr trips during the morning peak. Figure 34 and Figure 35 in the Appendix illustrate the delays incurred during the morning peak in deterministic (non-randomized) simulation.

The Bryn Mawr short-turns have a much greater impact during the afternoon peak period. Ten northbound thoroughfare trains are delayed by Bryn Mawr short-turns in the afternoon (see Figure 36 in the Appendix). It is recommended that SEPTA consider removing and/or rescheduling all ten Bryn Mawr short-turns between 1630h and 1930h during the evening peak.

Removing some of the Bryn Mawr short-turns would have the added benefit of reducing the anticipated 27-car fleet size requirement (net of spares) by one to three cars.

Operations and maintenance (O&M) costs for the existing service based on the Base Case model were computed to be $13,652,677. O&M cost for the Future Case was computed to be $24,524,585, an increase of $10,871,908, or 79.6%. The proposed increase in the number of trains operating in a 24-hour weekday period in the Future Case compared with existing is 167%.

B. Infrastructure

Simulation also indicates that the proposed King of Prussia Extension infrastructure is sound. The simulation confirms that three station tracks are required at First and Moore, and that a fourth station track is required at 69th Street.

At the wye junction, the diverging leg of the proposed #8 (15 mph) turnouts for trains operating to and from 69th Street and Norristown is not ideal but is necessary due to design constraints. The added trip time, however, should be no more than one minute provided the design of the required signal system modifications is optimized.

With the addition of conceptual crossover between the wye junction and Henderson Road, single-tracking the branch with 2 trains per hour in each direction was supportable with no delays accrued as a result.

9. APPENDIX

A. Base Case Service Levels

Table 21 – Base Case Service Levels – Trains Per Hour

Location of Timing Pt ->		Bryn Mawr		Hughes Park		Hughes Park	
Service ->		69 – Bryn Mawr		69 – Hughes Park		69 - NTC	
From	To	NB	SB	NB	SB	NB	SB
4:00	5:00	0	0	0	0	2	1
5:00	6:00	0	0	0	0	3	3
6:00	7:00	0	0	2	2	3	3
7:00	8:00	2	1	3	3	3	3
8:00	9:00	0	1	3	3	3	3
9:00	10:00	1	1	0	0	3	3
10:00	11:00	0	0	0	0	2	2
11:00	12:00	0	0	0	0	2	2
12:00	13:00	0	0	0	0	2	2
13:00	14:00	0	0	0	0	2	2
14:00	15:00	0	0	0	0	2	2
15:00	16:00	0	0	3	3	3	3
16:00	17:00	0	0	3	3	3	3
17:00	18:00	0	0	3	3	3	3
18:00	19:00	2	1	2	2	4	3
19:00	20:00	1	2	0	0	4	4
20:00	21:00	0	0	0	0	3	4
21:00	22:00	0	0	0	0	3	3
22:00	23:00	0	0	0	0	2	3
23:00	0:00	0	0	0	0	2	2
0:00	1:00	0	0	0	0	2	2
1:00	2:00	0	0	0	0	1	1
2:00	3:00	0	0	0	0	1	1
3:00	4:00	0	0	0	0	0	0
	Total ->	6	6	19	19	58	58

B. Future Case – Station to Station Trip Times

Table 22 – Future Case – RTC Station to Station Trip Times

Station to Station Timings*		
69th Street to Bryn Mawr		
From	To	Time
69th St	Pennfield	04:04
Pennfield	Beechwood	01:23
Beechwood	Wynnewood Rd	01:23
Wynnewood Rd	Ardmore Jct.	01:03
Ardmore Jct.	Haverford	02:12
Haverford	Bryn Mawr	02:39
	total	12:44
Bryn Mawr to 69th Street		
From	To	Time
Bryn Mawr	Haverford	02:01
Haverford	Ardmore Ave	01:31
Ardmore Ave	Ardmore Jct.	01:08
Ardmore Jct.	Wynnewood Rd	01:00
Wynnewood Rd	Beechwood	01:22
Beechwood	Pennfield	01:22
Pennfield	Township Line-S	01:09
Township Line-S	Parkview	01:25
Parkview	69th St	03:13
	total	14:11
69th Street to KOP (1st and Moore) - Express		
From	To	Time
69th St	Beechwood	04:44
Beechwood	Wynnewood Rd	01:23
Wynnewood Rd	Ardmore Jct.	01:03
Ardmore Jct.	Haverford	02:01
Haverford	Bryn Mawr	01:29
Bryn Mawr	Roberts Rd	01:37
Roberts Rd	Villanova	01:58
Villanova	Radnor	01:51
Radnor	Gulph Mills	03:31
Gulph Mills	Hughes Park	01:34
Hughes Park	Henderson Rd	04:26
Henderson Rd	Allendale Rd	02:06
Allendale Rd	Mall Blvd	01:33
Mall Blvd	1st - American	01:55
1st - American	1st & Moore	02:35
	total	33:46

*Station to Station times include mid-line station dwells, not terminal dwells

Station to Station Timings*		
69th Street to KOP (1st and Moore) - Local		
From	To	Time
69th St	Wynnewood Rd	05:34
Wynnewood Rd	Ardmore Jct.	01:03
Ardmore Jct.	Haverford	02:01
Haverford	Bryn Mawr	02:22
Bryn Mawr	Roberts Rd	01:37
Roberts Rd	Garrett Hill	01:17
Garrett Hill	Stadium	01:08
Stadium	Villanova	00:53
Villanova	Radnor	01:51
Radnor	Matsonford	02:24
Matsonford	Gulph Mills	01:45
Gulph Mills	Hughes Park	01:34
Hughes Park	Henderson Rd	04:26
Henderson Rd	Allendale Rd	02:06
Allendale Rd	Mall Blvd	01:33
Mall Blvd	1st - American	01:55
1st - American	1st & Moore	02:35
	total	36:04
69th Street to KOP (1st and Moore) - Local (early AM stopping pattern)		
From	To	Time
69th St	Beechwood	04:44
Beechwood	Wynnewood Rd	01:23
Wynnewood Rd	Ardmore Jct.	01:03
Ardmore Jct.	Ardmore Ave	01:12
Ardmore Ave	Haverford	01:30
Haverford	Bryn Mawr	01:29
Bryn Mawr	Roberts Rd	01:37
Roberts Rd	Stadium	01:43
Stadium	Villanova	00:53
Villanova	Radnor	01:51
Radnor	Matsonford	02:24
Matsonford	Gulph Mills	01:45
Gulph Mills	Hughes Park	01:34
Hughes Park	Henderson Rd	04:26
Henderson Rd	Allendale Rd	02:06
Allendale Rd	Mall Blvd	01:33
Mall Blvd	1st - American	01:55
1st - American	1st & Moore	02:35
	total	35:43

*Station to Station times include mid-line station dwells, not terminal dwells

Station to Station Timings*		
69th Street to Norristown - Limited		
From	To	Time
69th St	Gulph Mills	14:32
Gulph Mills	Hughes Park	01:34
Hughes Park	Norristown	06:44
	total	22:50
69th Street to Norristown - Express		
From	To	Time
69th St	Ardmore Jct.	05:59
Ardmore Jct.	Bryn Mawr	02:49
Bryn Mawr	Villanova	02:57
Villanova	Radnor	01:51
Radnor	Gulph Mills	03:31
Gulph Mills	Hughes Park	01:34
Hughes Park	Dekalb St N	04:09
Dekalb St N	Bridgeport	01:28
Bridgeport	Norristown	02:02
	total	26:20
69th Street to Norristown - Local		
From	To	Time
69th St	Pennfield	04:04
Pennfield	Ardmore Jct.	02:34
Ardmore Jct.	Haverford	02:01
Haverford	Bryn Mawr	02:21
Bryn Mawr	Garrett Hill	02:16
Garrett Hill	Villanova	01:23
Villanova	Radnor	01:51
Radnor	Matsonford	02:24
Matsonford	Gulph Mills	01:45
Gulph Mills	Hughes Park	01:34
Hughes Park	Bridgeport	05:08
Bridgeport	Norristown	01:58
	total	29:19

*Station to Station times include mid-line station dwells, not terminal dwells

Station to Station Timings*		
KOP (1st and Moore) to 69th Street - Express		
From	To	Time
1st & Moore	1st - American	01:24
1st - American	Mall Blvd	01:40
Mall Blvd	Allendale Rd	01:32
Allendale Rd	Henderson Rd	02:59
Henderson Rd	Hughes Park	03:47
Hughes Park	Gulph Mills	01:35
Gulph Mills	Garrett Hill	05:30
Garrett Hill	Haverford	02:55
Haverford	Ardmore Ave	01:31
Ardmore Ave	Ardmore Jct.	01:08
Ardmore Jct.	Wynnewood Rd	01:00
Wynnewood Rd	Beechwood	01:22
Beechwood	Pennfield	01:22
Pennfield	69th St	04:38
	total	32:23
KOP (1st and Moore) to 69th Street - Local		
From	To	Time
1st & Moore	1st - American	01:24
1st - American	Mall Blvd	01:40
Mall Blvd	Allendale Rd	01:32
Allendale Rd	Henderson Rd	02:59
Henderson Rd	Hughes Park	03:47
Hughes Park	Gulph Mills	01:35
Gulph Mills	Matsonford	01:49
Matsonford	County Line	01:35
County Line	Radnor	01:33
Radnor	Stadium	02:09
Stadium	Garrett Hill	01:07
Garrett Hill	Roberts Rd	01:14
Roberts Rd	Bryn Mawr	02:36
Bryn Mawr	Haverford	01:29
Haverford	Ardmore Ave	01:31
Ardmore Ave	Ardmore Jct.	01:08
Ardmore Jct.	Wynnewood Rd	01:00
Wynnewood Rd	Beechwood	01:22
Beechwood	69th St	05:21
	total	36:51

*Station to Station times include mid-line station dwells, not terminal dwells

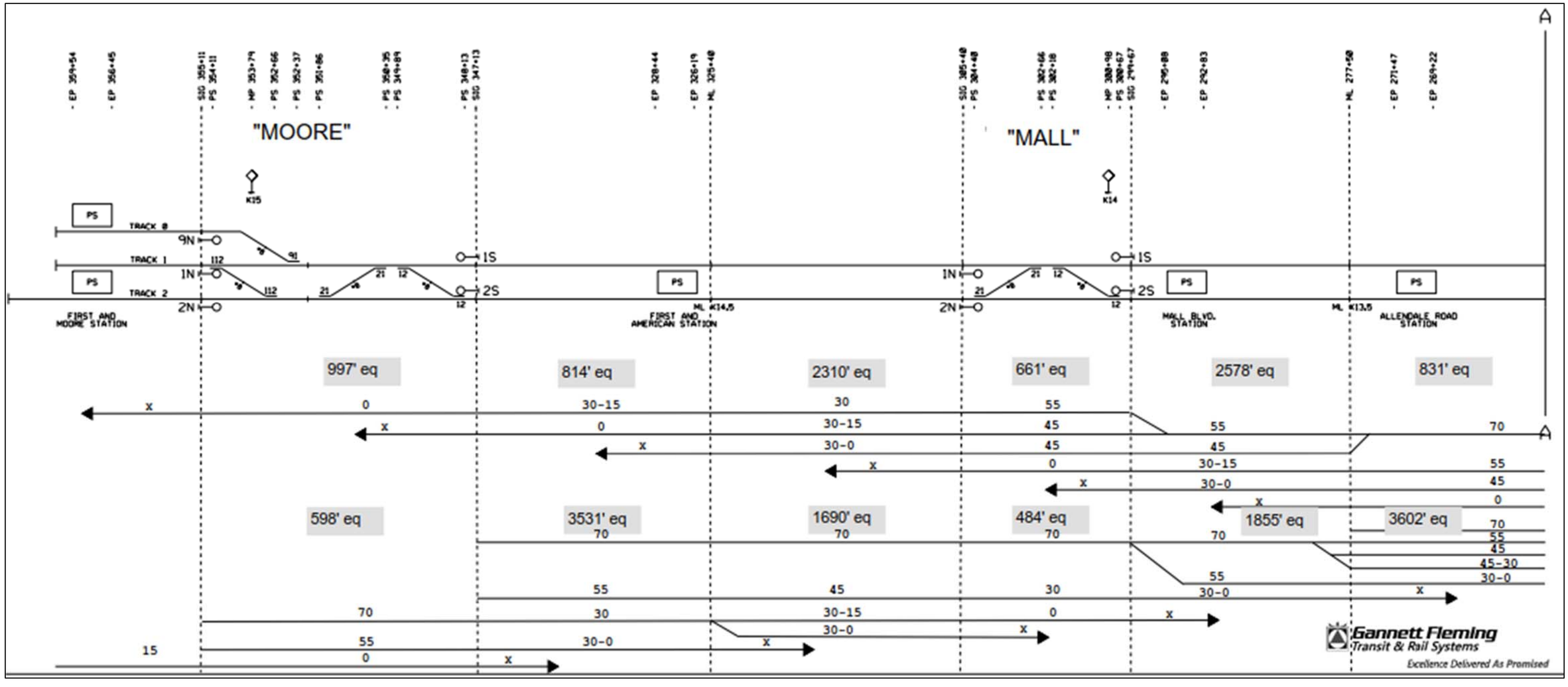
Station to Station Timings*		
Norristown to 69th Street - Express		
From	To	Time
Norristown	Bridgeport	02:14
Bridgeport	Dekalb St S	01:28
Dekalb St S	Hughes Park	03:49
Hughes Park	Gulph Mills	01:35
Gulph Mills	Radnor	03:33
Radnor	Villanova	01:54
Villanova	Bryn Mawr	02:43
Bryn Mawr	Ardmore Jct.	02:48
Ardmore Jct.	69th St	06:29
	total	26:33
Norristown to 69th Street - Local		
From	To	Time
Norristown	Bridgeport	02:14
Bridgeport	Hughes Park	04:39
Hughes Park	Gulph Mills	01:35
Gulph Mills	Matsonford	01:49
Matsonford	Radnor	02:25
Radnor	Villanova	01:54
Villanova	Garrett Hill	01:21
Garrett Hill	Bryn Mawr	02:00
Bryn Mawr	Haverford	01:29
Haverford	Ardmore Jct.	01:59
Ardmore Jct.	Pennfield	02:30
Pennfield	69th St	04:38
	total	28:33
Norristown to KOP (1st and Moore)		
From	To	Time
Norristown	Bridgeport	02:16
Bridgeport	Dekalb St S	01:39
Dekalb St S	Henderson Rd	03:26
Henderson Rd	Allendale Rd	02:06
Allendale Rd	Mall Blvd	01:33
Mall Blvd	1st - American	01:55
1st - American	1st & Moore	02:35
	total	15:30

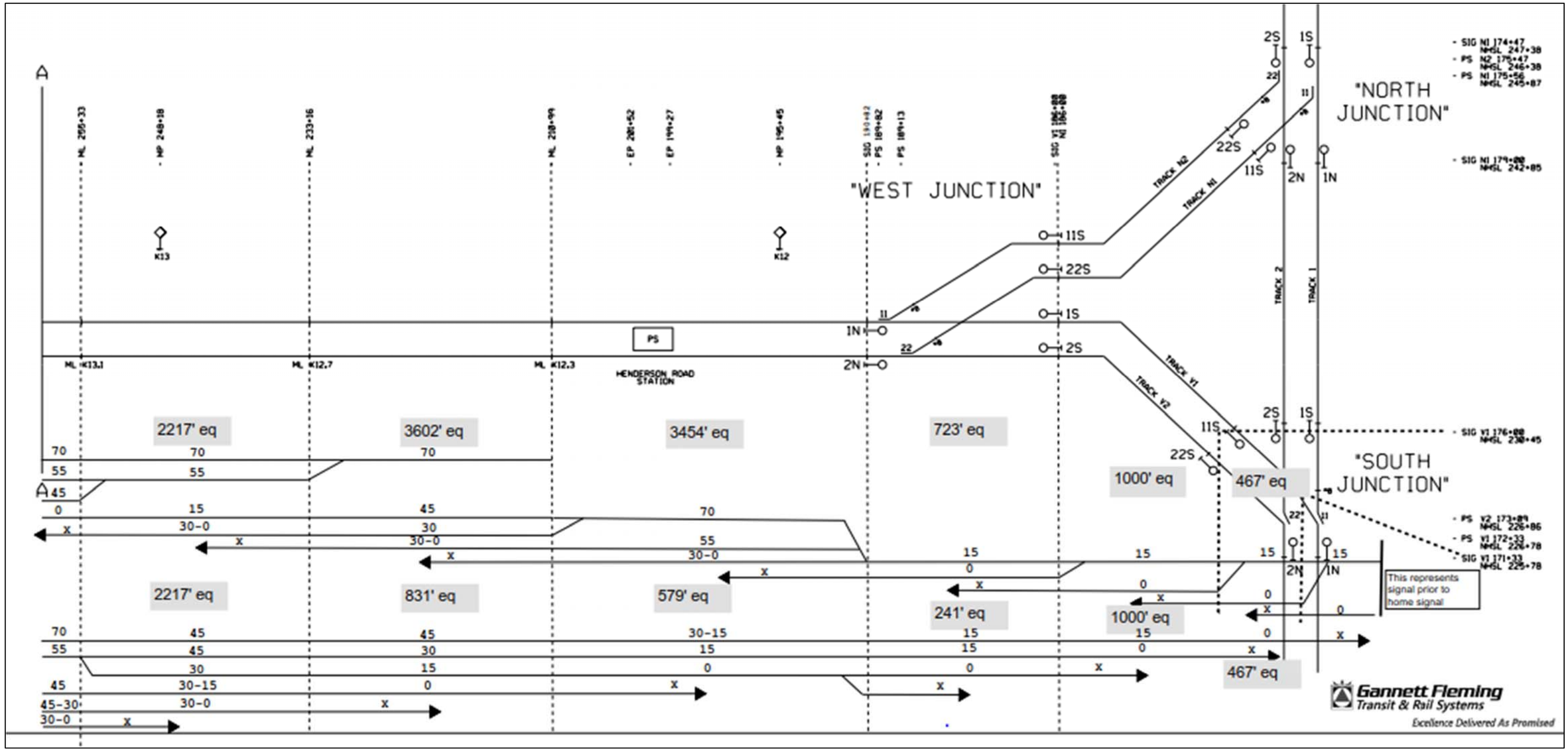
*Station to Station times include mid-line station dwells, not terminal dwells

Station to Station Timings*		
KOP (1st and Moore) to Norristown		
From	To	Time
1st & Moore	1st - American	01:55
1st - American	Mall Blvd	01:40
Mall Blvd	Allendale Rd	01:32
Allendale Rd	Henderson Rd	02:59
Henderson Rd	Dekalb St N	03:13
Dekalb St N	Bridgeport	01:28
Bridgeport	Norristown	02:00
	total	14:47

*Station to Station times include mid-line station dwells, not terminal dwells

C. Preliminary Block and Control Line Layout




"NORTH JUNCTION"
"WEST JUNCTION"
"SOUTH JUNCTION"
HENDERSON ROAD STATION
PS
TRACK N2
TRACK N1
TRACK Y1
TRACK Y2
TRACK 2
TRACK 1
ML 255+33
MP 248+18
ML 233+16
ML 218+99
EP 202+52
EP 199+27
MP 195+45
SIG N1 174+47 NMGL 247+38
PS N2 179+47 NMGL 246+38
PS N1 175+56 NMGL 245+87
SIG N1 179+88 NMGL 242+85
SIG Y1 176+88 NMGL 230+45
PS Y2 173+89 NMGL 226+86
PS Y1 172+33 NMGL 226+78
SIG Y1 171+33 NMGL 225+78
ML K13.1
ML K12.7
ML K12.3
K13
K12
2217' eq
3602' eq
3454' eq
723' eq
1000' eq
467' eq
2217' eq
831' eq
579' eq
241' eq
1000' eq
467' eq
This represents signal prior to home signal
Gannett Fleming
Transit & Rail Systems
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D. Base Case String Charts

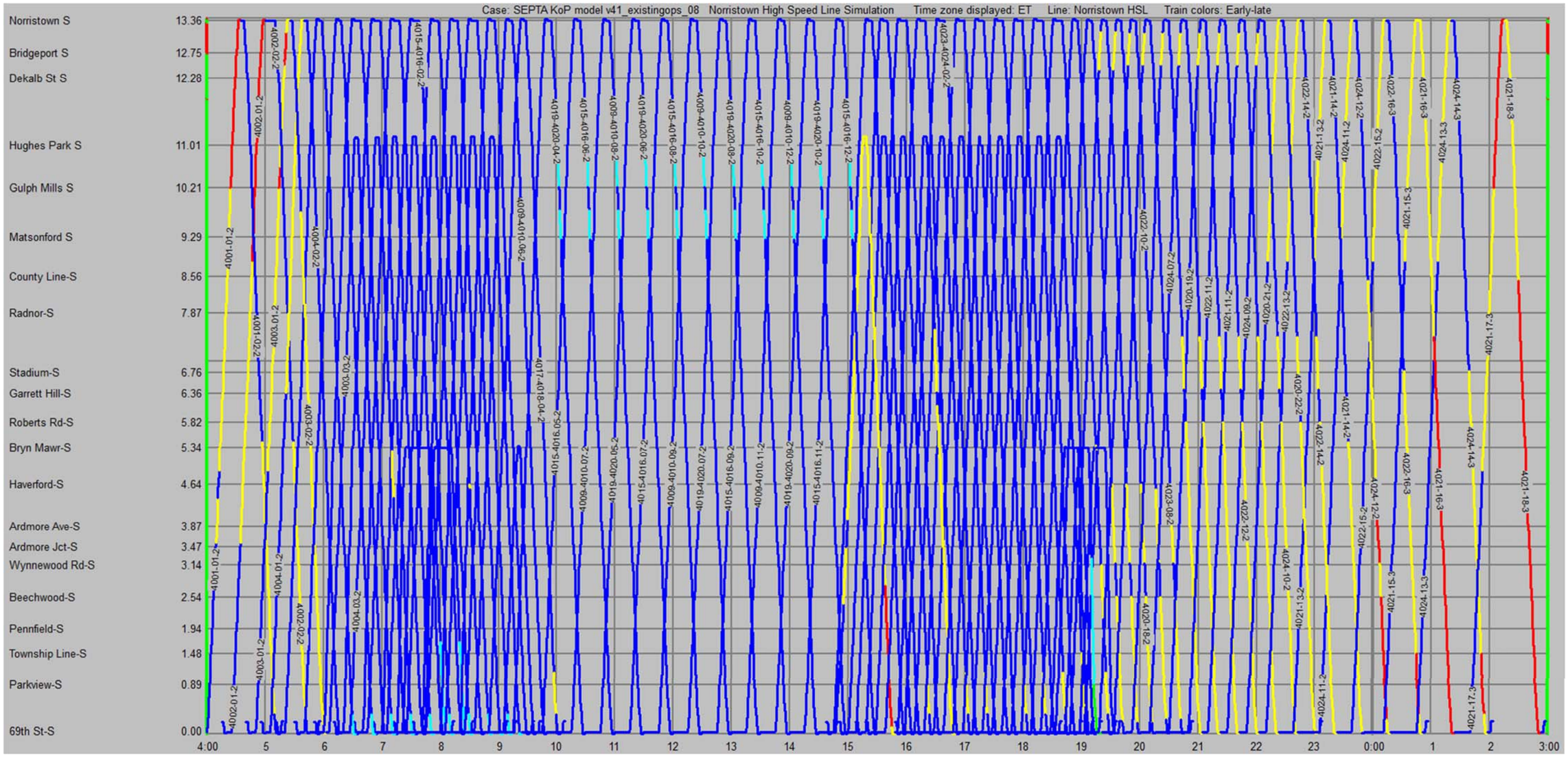

Figure 30 – Base Case String Chart – Trains Making All Stops

LEGEND:

- Early (1 minute early or more)
- On Time (between 1 min. early and 3 min. late)
- Late (between 3 min. late and 6 min. late)
- Very Late (more than 6 min. late)

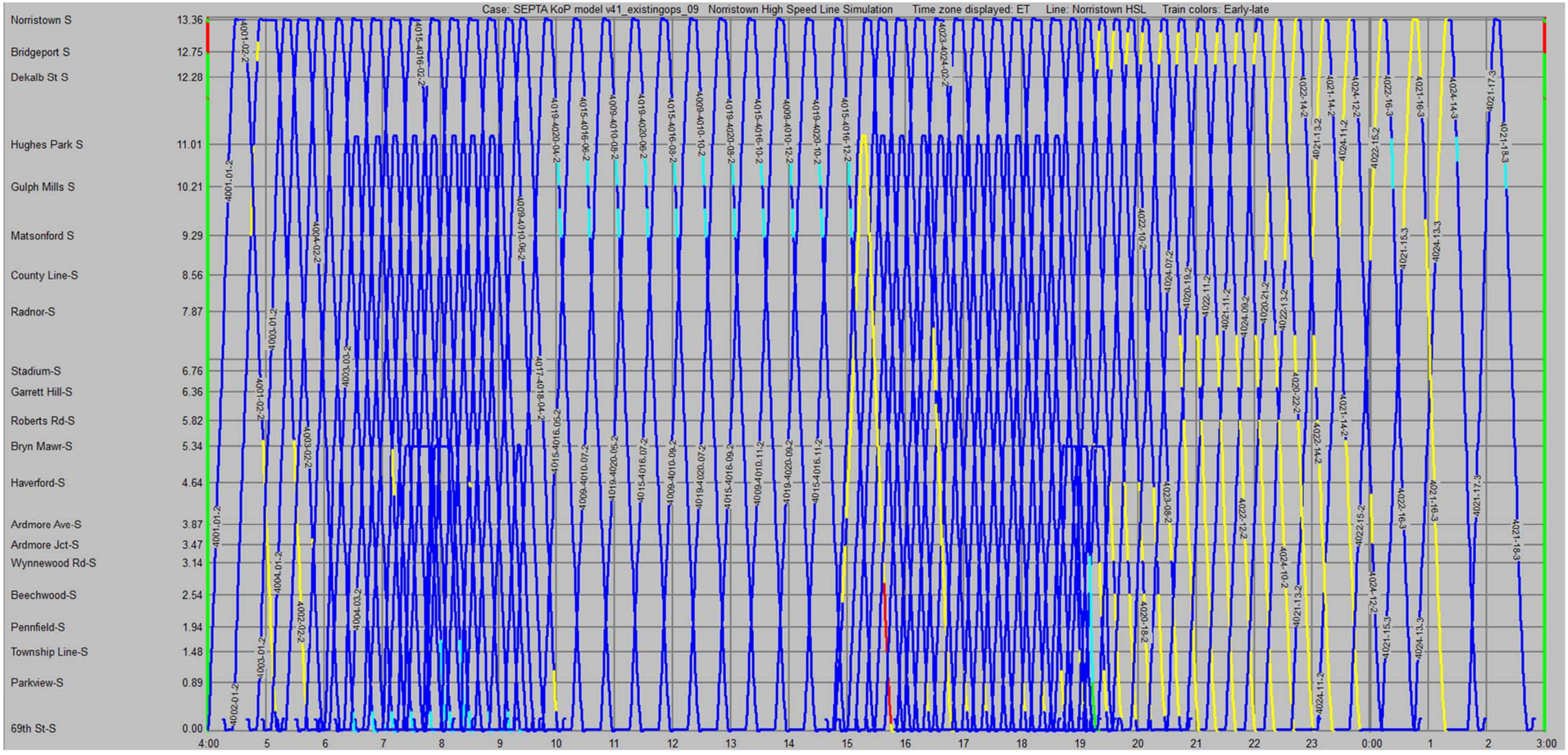

Figure 31 – Base Case String Chart – Early AM Modified Stopping Pattern

LEGEND:

- Early (1 minute early or more)
- On Time (between 1 min. early and 3 min. late)
- Late (between 3 min. late and 6 min. late)
- Very Late (more than 6 min. late)

E. Future Case String Charts

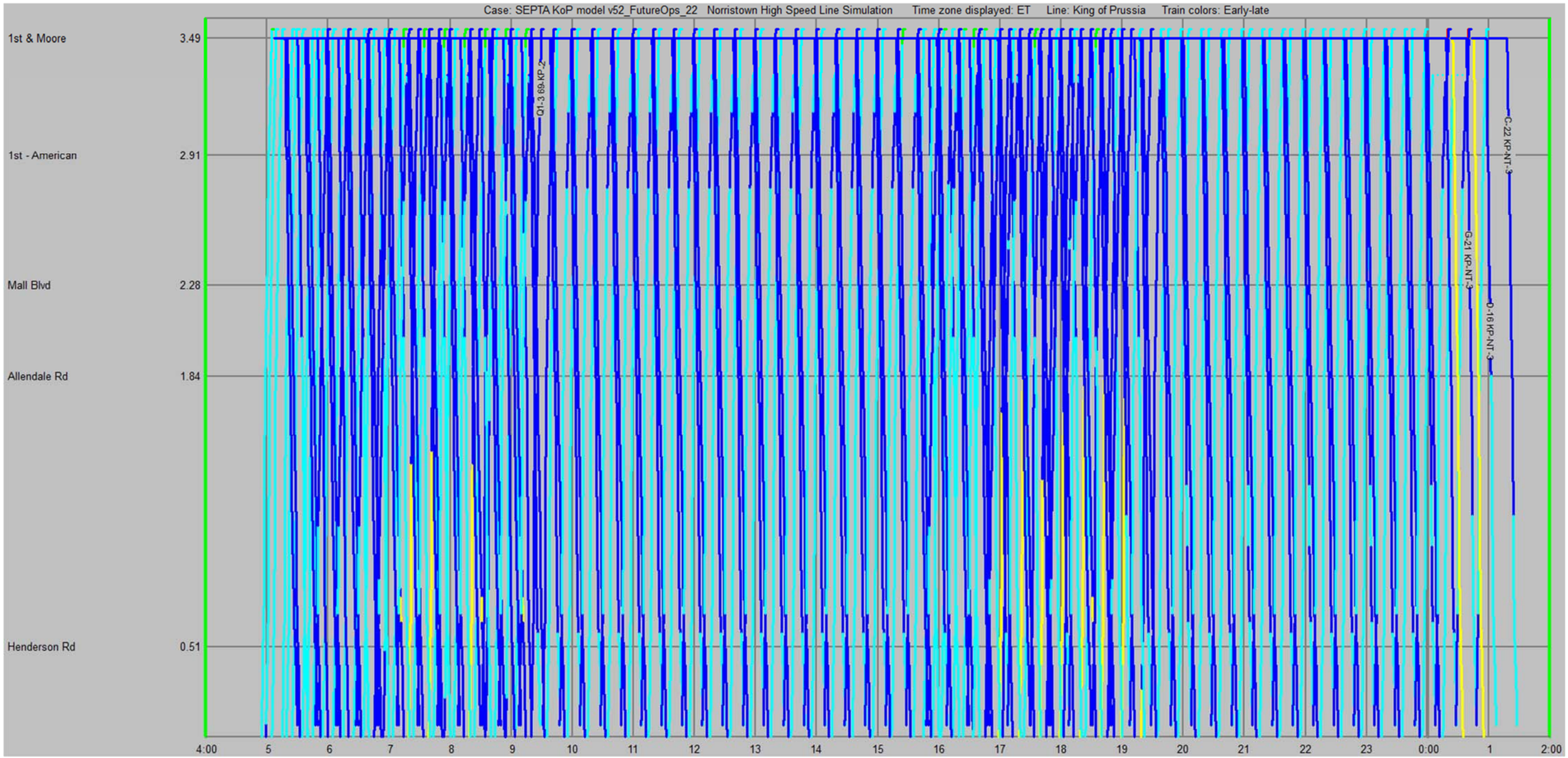

Figure 32 – Future Case String Chart – KOP Extension – Full Day

LEGEND:

- Early (1 minute early or more)
- On Time (between 1 min. early and 3 min. late)
- Late (between 3 min. late and 6 min. late)
- Very Late (more than 6 min. late)

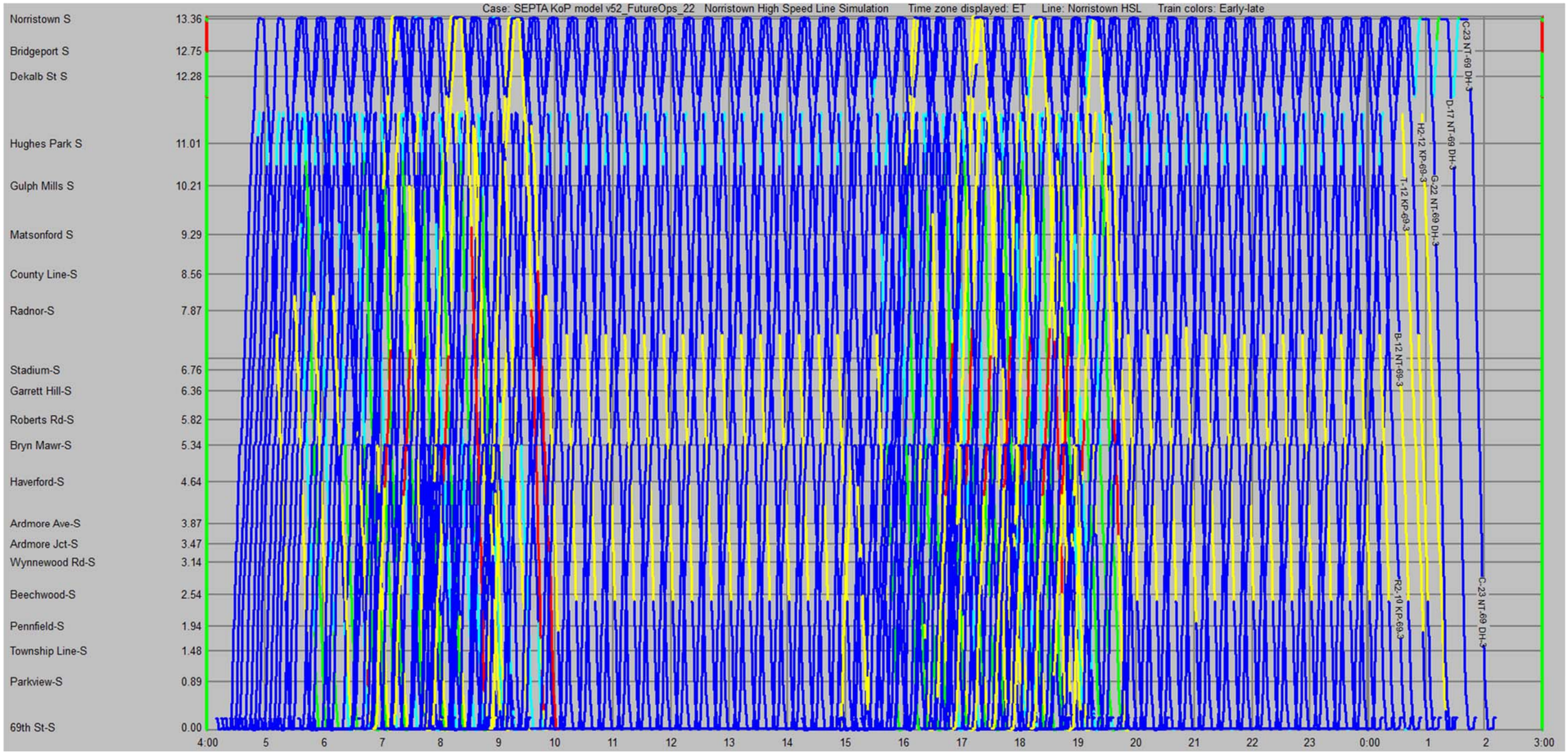

Figure 33 – Future Case String Chart – NHSL – Full Day

LEGEND:

- Early (1 minute early or more)
- On Time (between 1 min. early and 3 min. late)
- Late (between 3 min. late and 6 min. late)
- Very Late (more than 6 min. late)

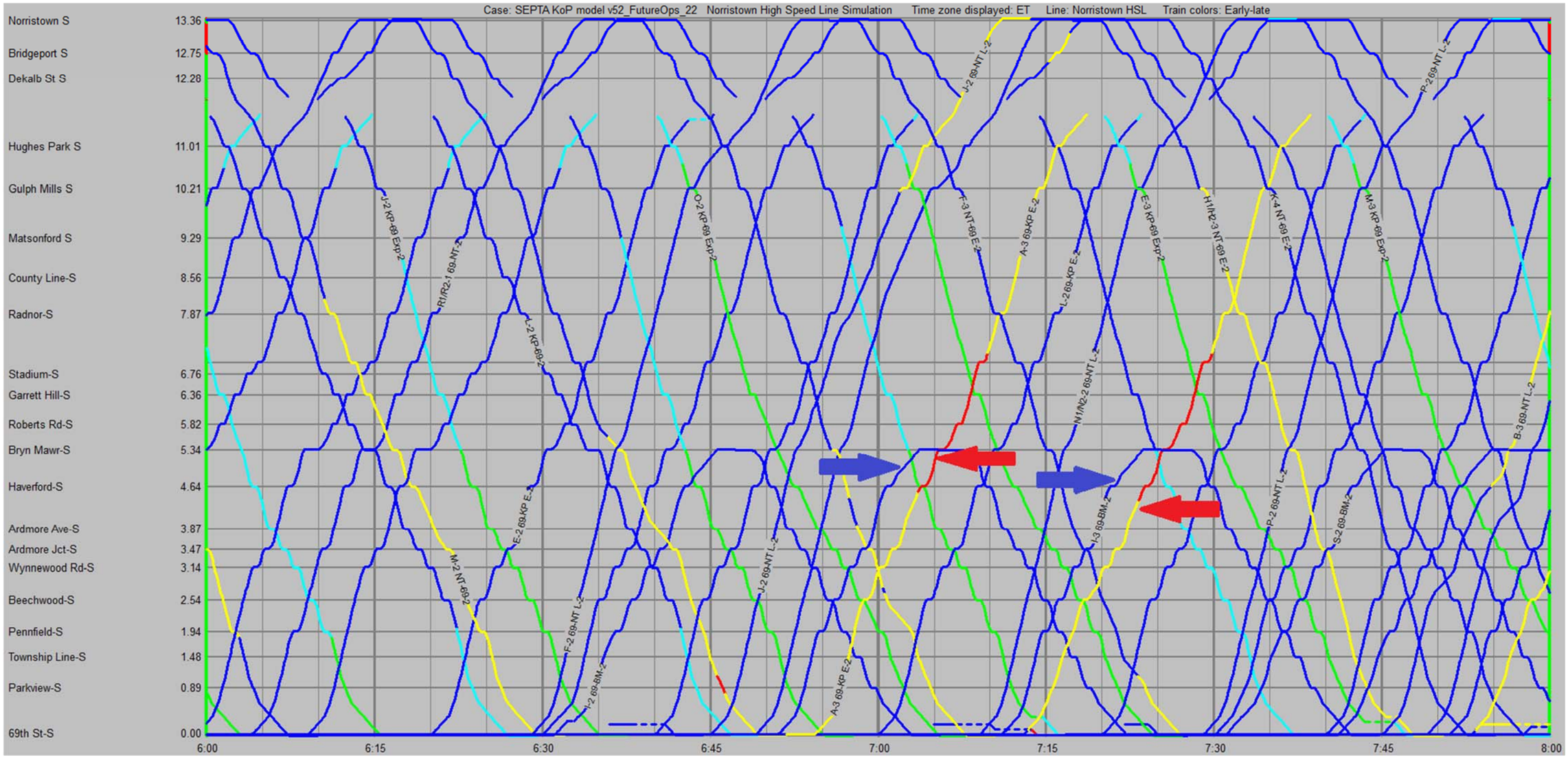

Figure 34 – Future Case String Chart – NHSL – 0600h – 0800h

LEGEND:

- Early (1 minute early or more)
- On Time (between 1 min. early and 3 min. late)
- Late (between 3 min. late and 6 min. late)
- Very Late (more than 6 min. late)

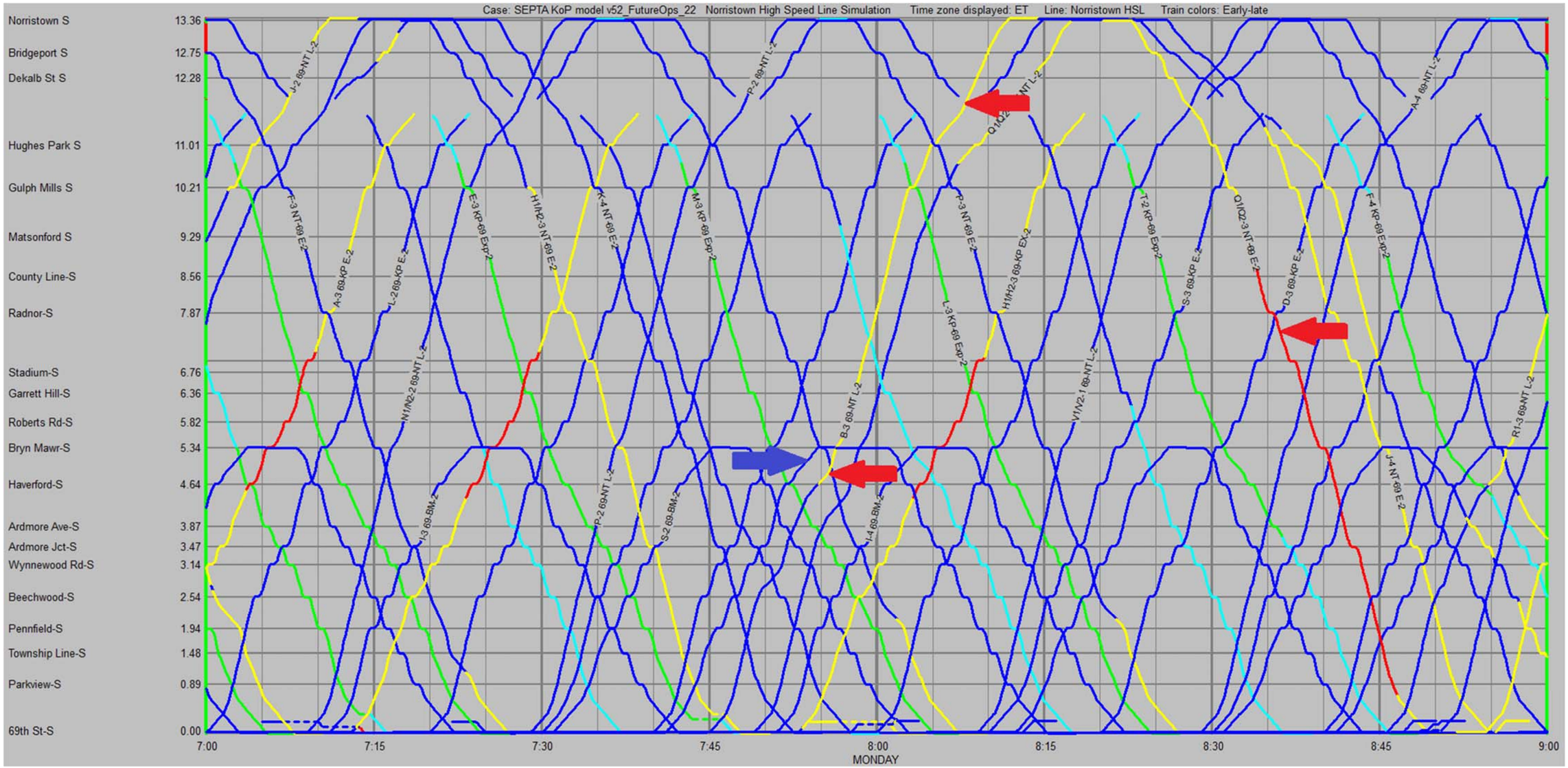

Figure 35 – Future Case String Chart – NHSL – 0700h – 0900h

LEGEND:

- Early (1 minute early or more)
- On Time (between 1 min. early and 3 min. late)
- Late (between 3 min. late and 6 min. late)
- Very Late (more than 6 min. late)

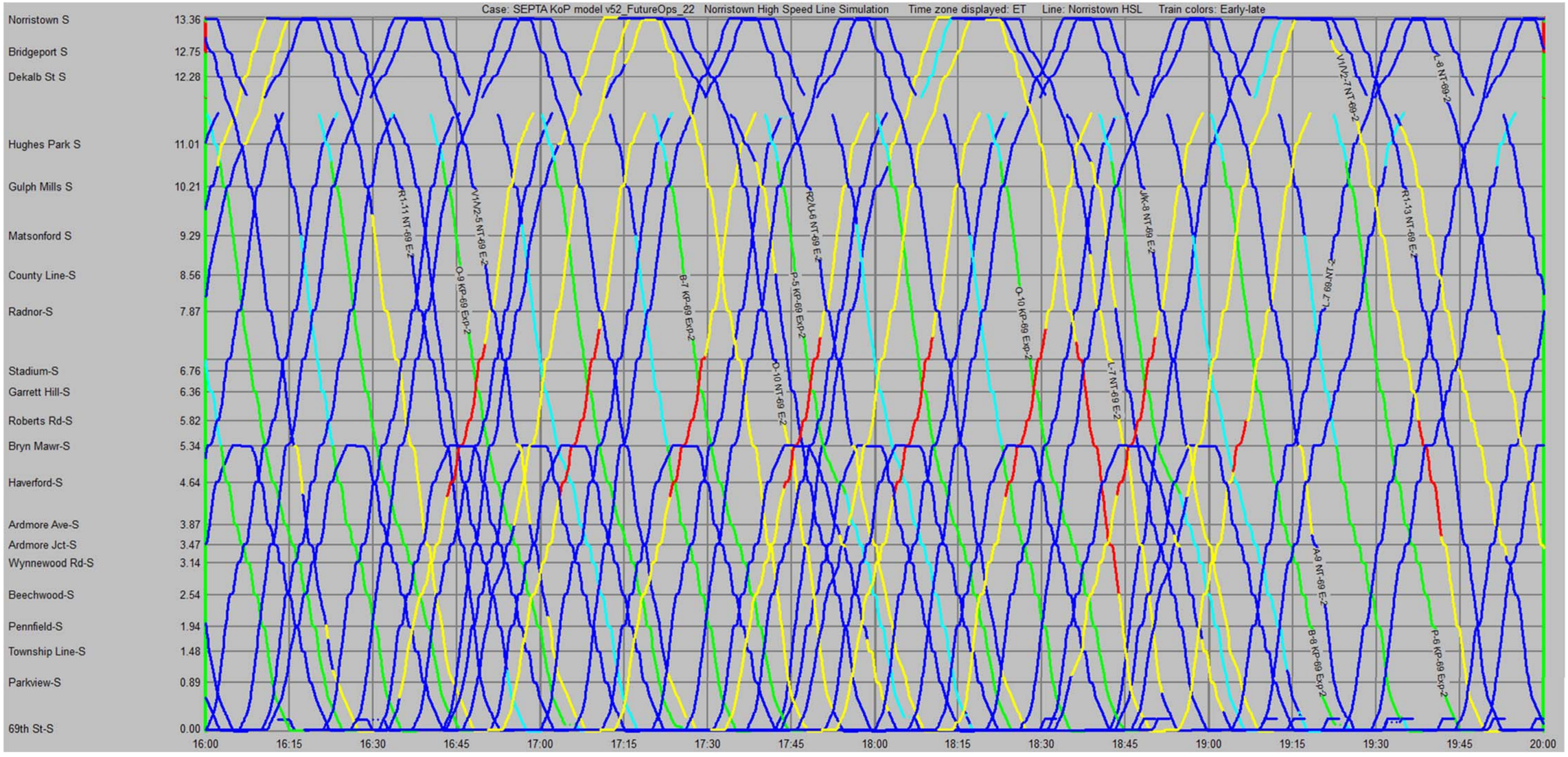

Figure 36 – Future Case String Chart – NHLS – 1600h – 2000h

LEGEND:

- Early (1 minute early or more)
- On Time (between 1 min. early and 3 min. late)
- Late (between 3 min. late and 6 min. late)
- Very Late (more than 6 min. late)