Running Time Analysis for Better Service and a Balanced Budget

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Impacts of Schedule Running Time

RUN NO.	DISP	CLASS	CARS	NOTE	Mdw Nb	35 Nb	17t hJN	T12 nb	T18 sb	T12 sb	17t hJS	35 Sb	Midway South Arr	Train Lv.	Crew Lv.
701	L	4	CIPC		0400	11	18	22	28	34	38	45	0455+ 4	0513 8	0524
702	L	4	CIPC		0415	26	33	37	43	49	53	00	0510+ 4	0524 8	0535
703	L	8	CIPC		0430	41	48	52	58	04	08	15	0526 8	0535 8	0545
704	L	8	CIPC		0445	56	03	07	13	19	23	30	0541 8	0550 8	0629
705	L	8	CIPC		0500	11	18	22	28	34	38	45	0556 8	0605 8	0642
706	L	8	CI		0513	24	31	35	41	47	51	58	0609 8	0620 8	0649
701	L	8			0524	35+	42+	46+	52+	58+	02+	09+	0620+ 8	0632 8	0639
702	L	8			0535	46+	53+	57+	03+	09+	13+	20+	0631+ 8	0646 8	0653
703	L	8	PS		0545	56+	03+	07+	13+	19+	23+	30+	0641+ 8	0653 8	0707
707	K	8	CI	a	0550	01+	08+	12+	To Kimball						
711	L	8	CIPS		0555	06+	13+	17+	23+	29+	33+	40+	0651+ 8	0707 8	0714
708	K	8	CIPS	a	0600	11+	18+	22+	To Kimball						
709	L	8	CI		0605	16+	23+	27+	34	40	44	51	0702 8	0714 8	0721
712	K	8	CIPS	a	0610	21+	28+	32+	To Kimball						
710	L	8	CIPS		0615	26+	33+	37+	44	50	54	01	0712 8	0728 8	0735
713	K	8	CI	a	0620	31+	38+	42+	To Kimball						
714	L	8	CIPS		0625	36+	44	48	54+	00+	04+	11+	0722+ 8	0735 8	0742
704	K	8	PC	a	0629	40+	48	52	To Kimball						
715	L	8	CI		0632	43+	51	55	01+	08	12	19	0730 8	0742 8	0749
701	L	8	PS		0639	50+	58	02	08+	15	19	26	0737 8	0749 8	0756
705	K	8	PC	a	0642	53+	01	05	To Kimball						
716	L	8	CI		0646	57+	05	09	15+	22	26	33	0744 8	0756 8	0803
706	K	8	PS	a	0649	00+	08	12	To Kimball						
702	L	8			0653	04+	12	16	22+	29	33	40	0751 8	0803 8	0810
717	L	8	CIPS		0700	11+	19	23	30	36+	40+	47+	0758+ 8	0810 8	0817
703	L	8			0707	18+	26	30	37	43+	47+	54+	0805+ 8	0817 8	0824
711	L	8			0714	25+	33	37	44	50+	54+	01+	0812+ 8	0824 8	0831
709	L	8	PS		0721	32+	40	44	51	57+	01+	08+	0819+ 8	0831 8	0838
707	K	8		b	From Kimball				0804	08	15		0826 8	LS 8	X0910
718	L	8	CI		0728	39+	47	51	58	05	09	16	0827 8	0838 8	0846
710	L	8			0735	46+	54	58	05	12	16	23	0834 8	0846 8	0854
708	K	8		b	From Kimball				0815	19	26		0837 8	LS 8	X0926+
714	L	8			0742	53+	01	05	12	19	23	30	0841 8	0854 8	0902
712	K	8		b	From Kimball				0825	29	36		0847 8	LS 8	CO
715	L	8			0749	00+	08	12+	19+	26+	30+	37+	0848+ 8	0902 8	0918
701	L	8			0756	07+	15	19+	26+	33+	37+	44+	0855+ 8	LS 8	X0952
713	K	8		b	From Kimball				0834+	38+	45+		0856+ 8	LS 8	CO
716	L	8			0803	14+	22	26+	33+	40+	44+	51+	0902+ 8	0910 8	0935
704	K	8		b	From Kimball				0843+	47+	54+		0905+ 8	LC 8	X1100
702	L	8			0810	21+	29	33+	40+	47+	51+	58+	0909+ 8	0918 8	X1009
705	K	8		b	From Kimball				0852+	56+	03+		0914+ 8	LC 8	X1108+
717	L	8			0817	28+	36	40+	47+	54+	58+	05+	0916+ 8	0926+ 8	0943+
706	K	8		b	From Kimball				0858+	02+	09+		0920+ 8	LS 8	X1017+
703	L	8			0824	35+	43	47+	54+	01+	05+	12+	0923+ 8	0935 8	X1043
711	L	8			0831	42+	50	54+	01+	08+	12+	19+	0930+ 8	0943+ 8	1000+
709	L	8			0838	49+	57	01+	08+	15+	19+	26+	0937+ 8	0952 8	X1026
718	L	8			0846	57+	05	09+	16+	23+	27+	34+	0945+ 8	1000+ 4	CO
710	L	8			0854	05+	13	17+	24+	31+	35+	42+	0953+ 8	1009 4	X1125+
714	L	8			0902	13+	21	25+	32	39	43	50	1001+ 8	LS 8	CO
707	L	8			0910	21+	29	33+	40	47	51	58	1009+ 8	1017+ 4	1034+
715	L	8			0918	29+	37	41+	48	55	59	06	1017+ 8	1026 4	CO
708	L	8			0926+	38	45+	50	56+	03+	07+	14+	1026 8	1034+ 4	1051+
716	L	8			0935	46+	54	58+	05	12	16	23	1034+ 8	1043 4	CO
717	L	8			0943+	55	02+	07	13+	20+	24+	31+	1043 8	1051+ 4	CO
701	L	8			0952	03+	11	15+	22	29	33	40	1051+ 8	1100 4	1117
711	L	4			1000+	12	19+	24	30	37	41	48	1059+ 4	1108+ 4	CO
702	L	4			1009	20+	28	32+	38+	45+	49+	56+	1108 4	1117 4	1134
706	L	4			1017+	29	36+	41	47	54	58	05	1116+ 4	1125+ 4	1142+

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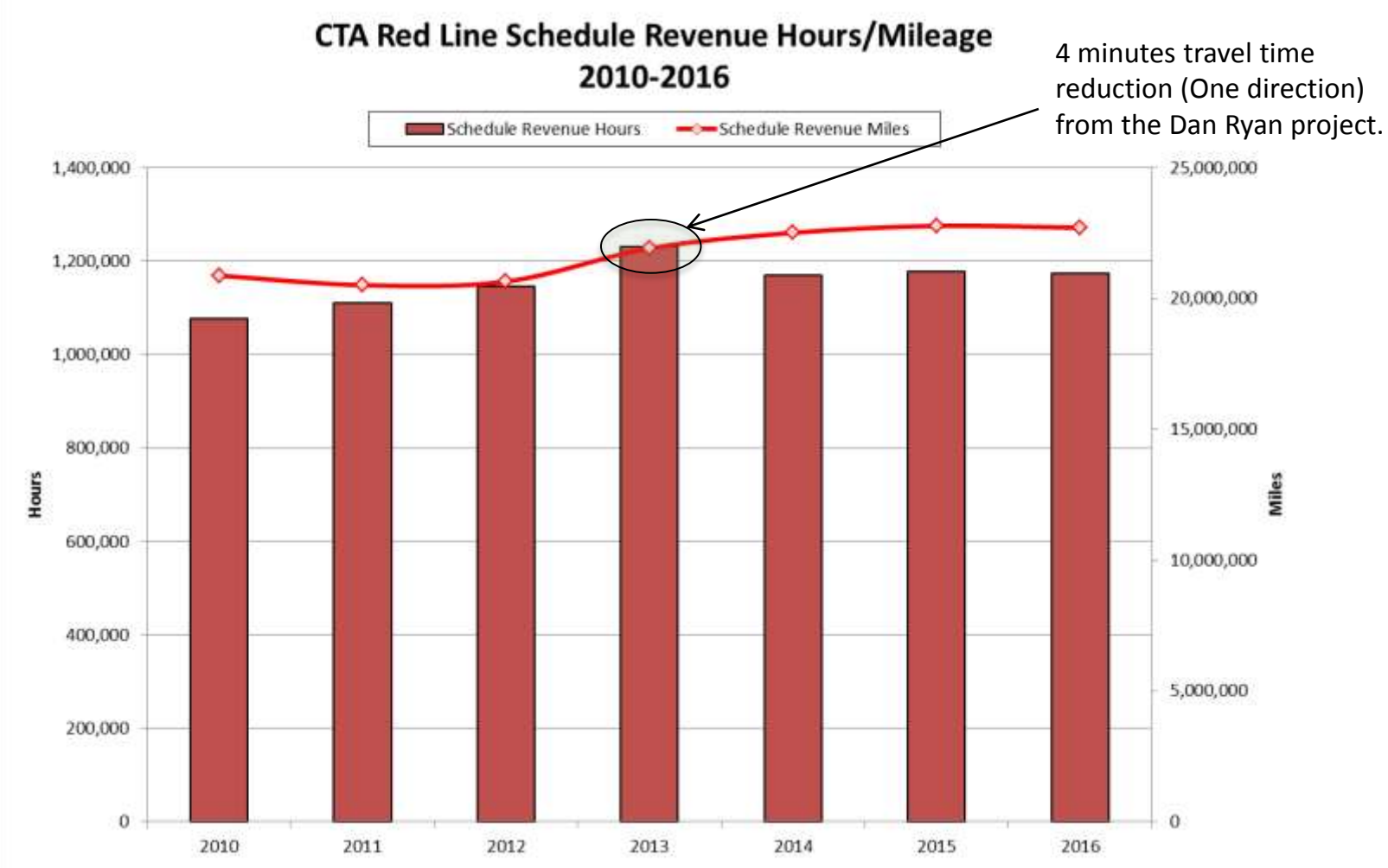
Budget

Budget and Efficiency
Inspection and Maintenance Cost

Train Wheel Flat Spot photo by Wikipedia

Revenue hour is one of the basic elements for forming an operating budget in the transit industry.

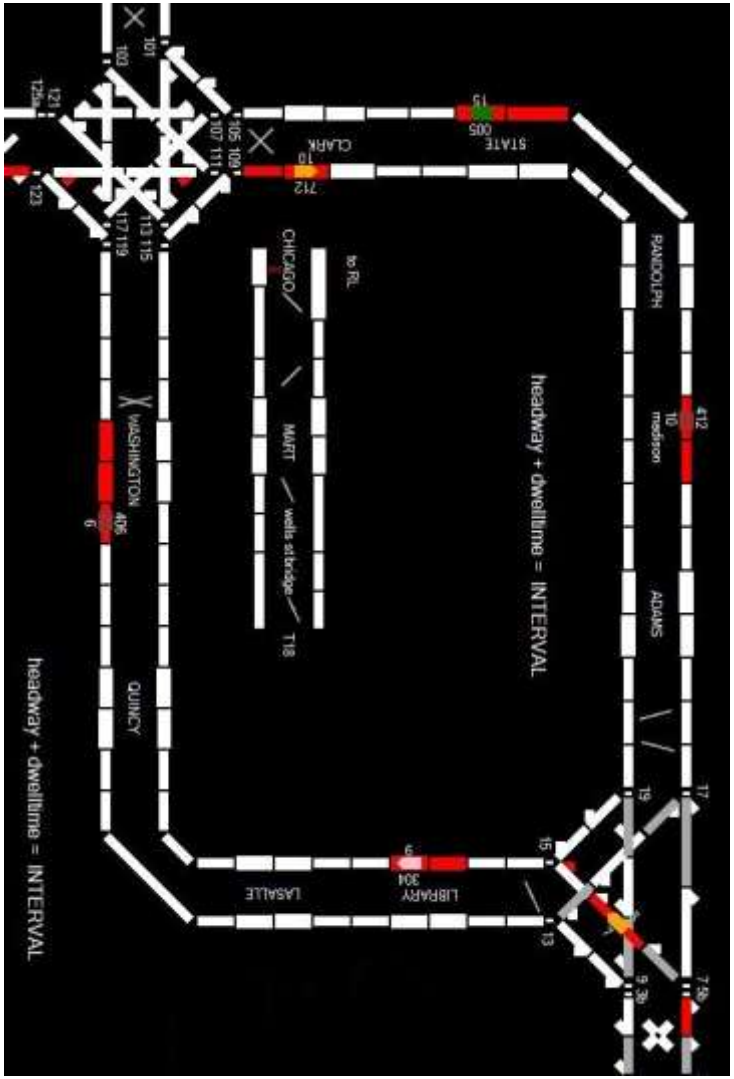
Budget and Efficiency



Running time reduction from the Dan Ryan Reconstruction have achieved revenue hour savings despite revenue mileage (service) had gone up.

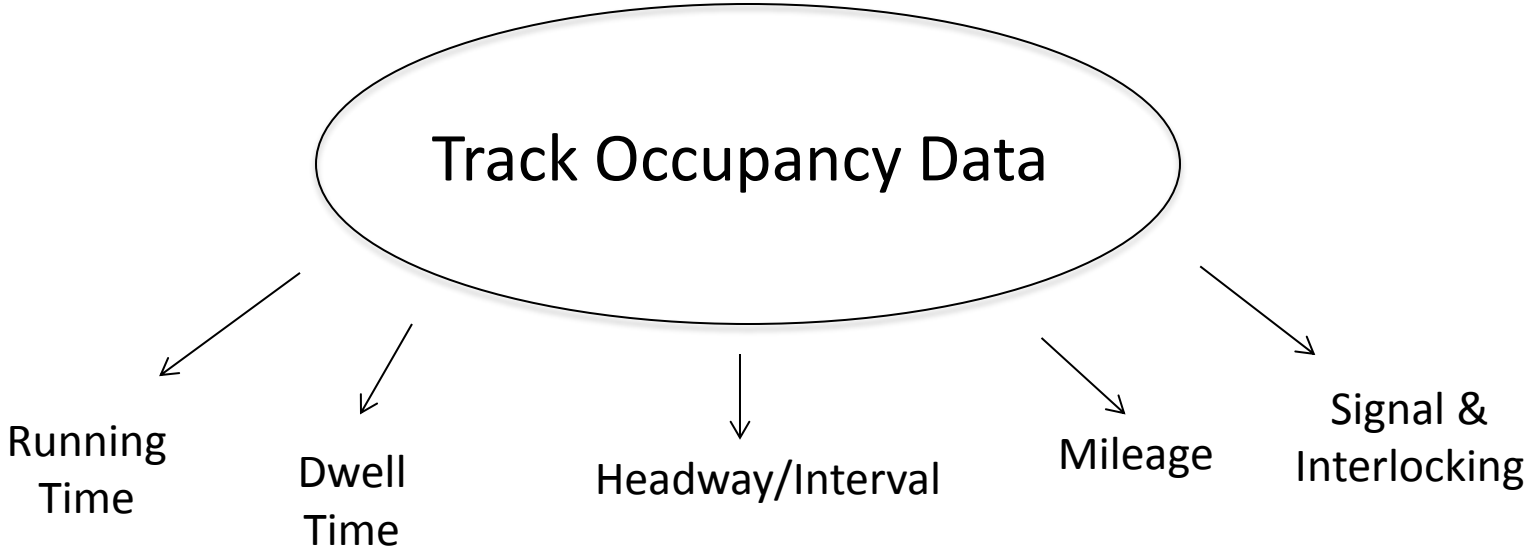
Data Collection

Quictrak



Supervisory control and data acquisition (SCADA)

Methodology



Data Transformation Model

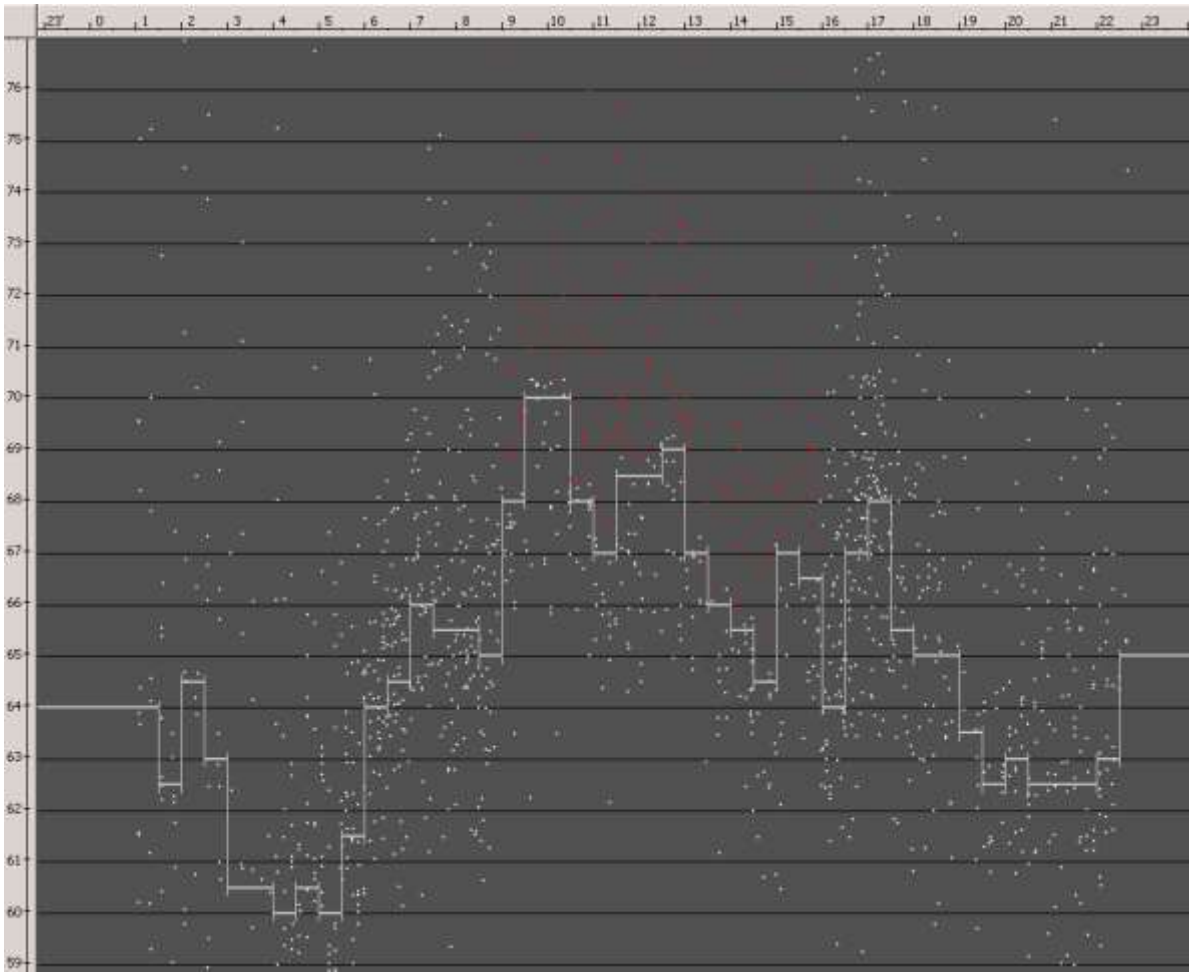
1. Eliminate garbage data (Example: faulty track circuit)
2. Format timestamp and datatype
3. “Line-up” data rows (Oracle Analytical Functions: Lead/Lag)
4. Relate tables to organize train data by route, direction, and sequence

Running Time Analysis

GIRO Hastus ATP Tool (From French: Analyse des Temps de Parcours)

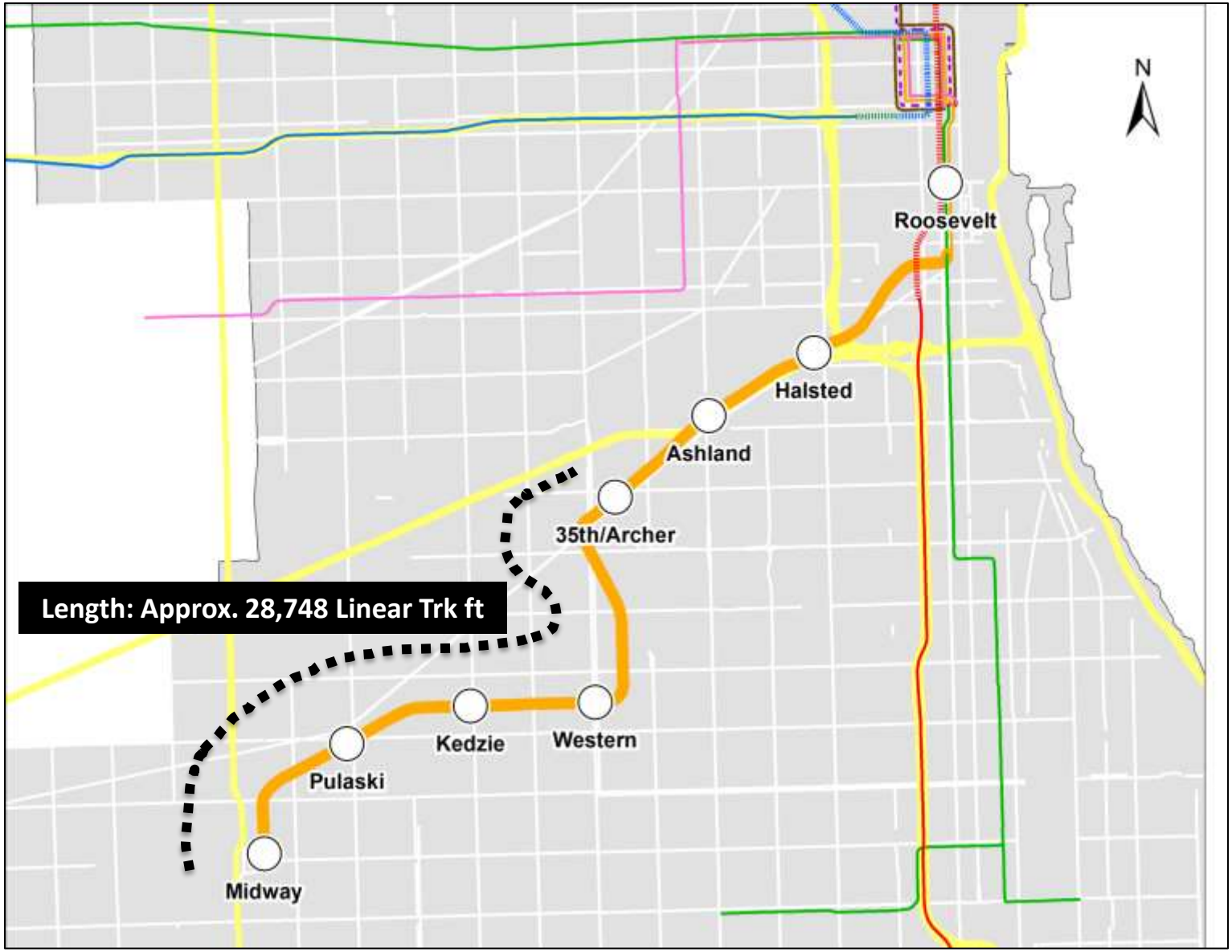
CTA Red Line NB (95th to Howard)

Running Time



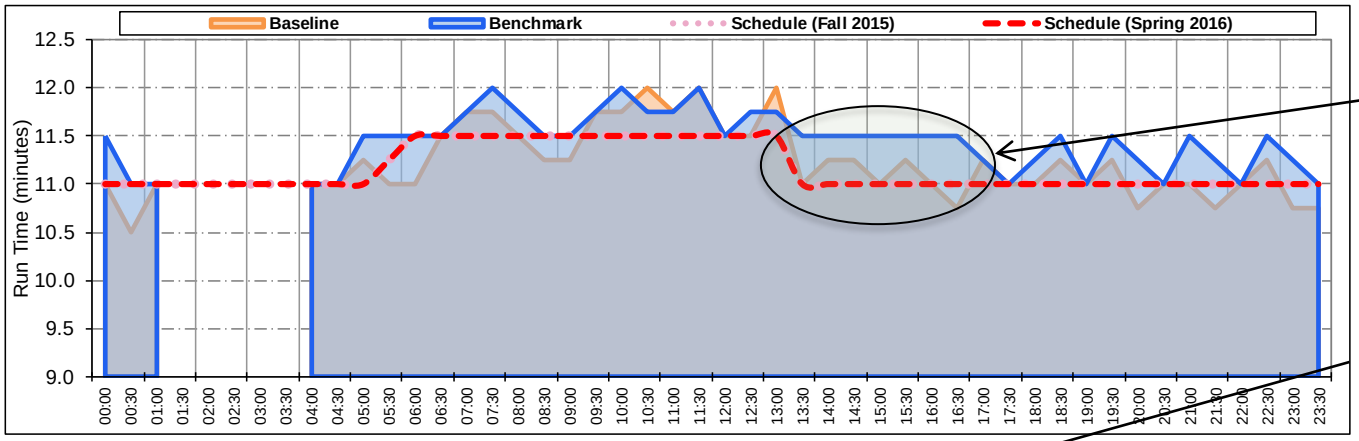
Time

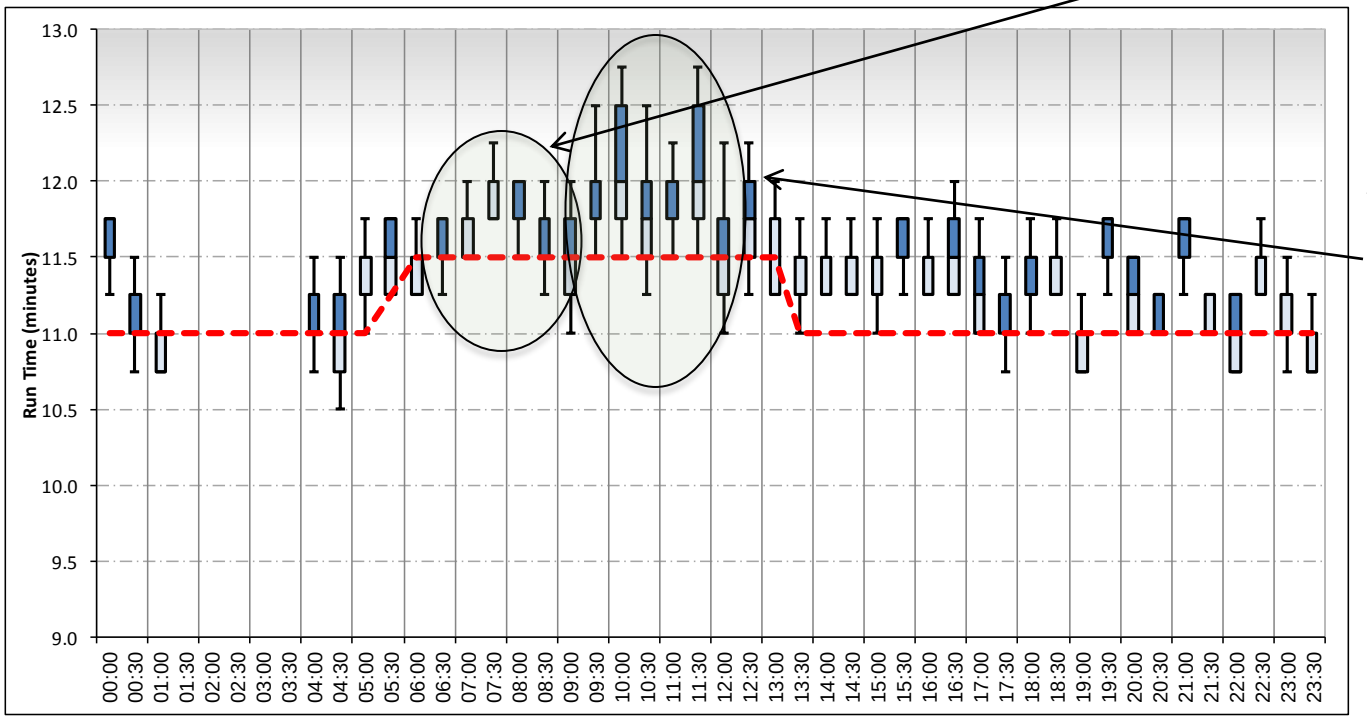
Orange Line: Midway to 35th/Archer



Orange Line: Midway to 35th/Archer

Orange Line	Baseline	=	WKD	Sched K-06	10/1/2015	--	10/28/2015
Midway to 35th/Archer	Benchmark	=	WKD	Sched K-07	3/21/2016	--	4/29/2016





Increased Runtime?

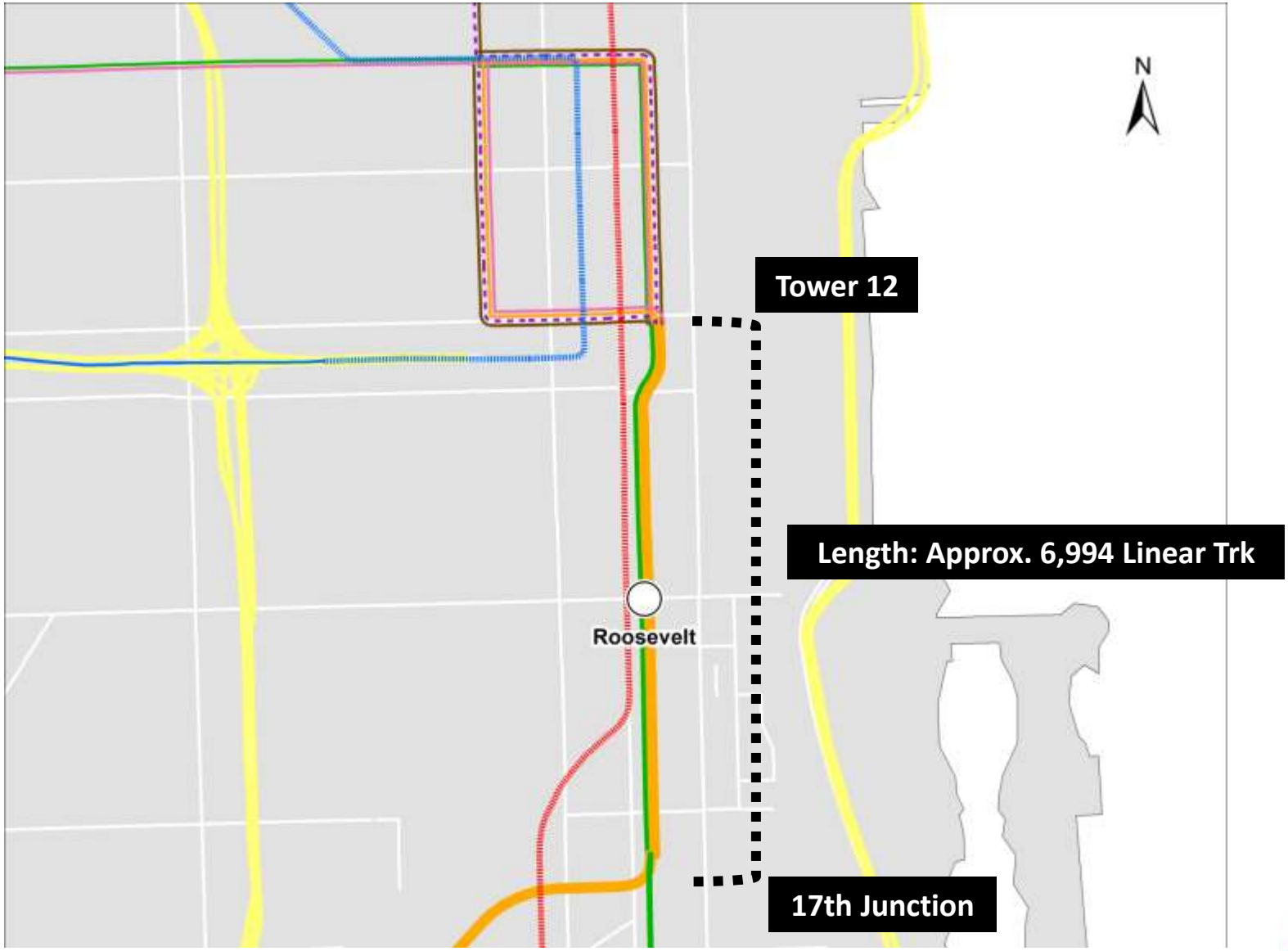
AM Peak (0600-0900)

- 7 Org-Brn trains
- Ridership
- Dwell Time

AM Peak Late Shoulder (0900-1230)

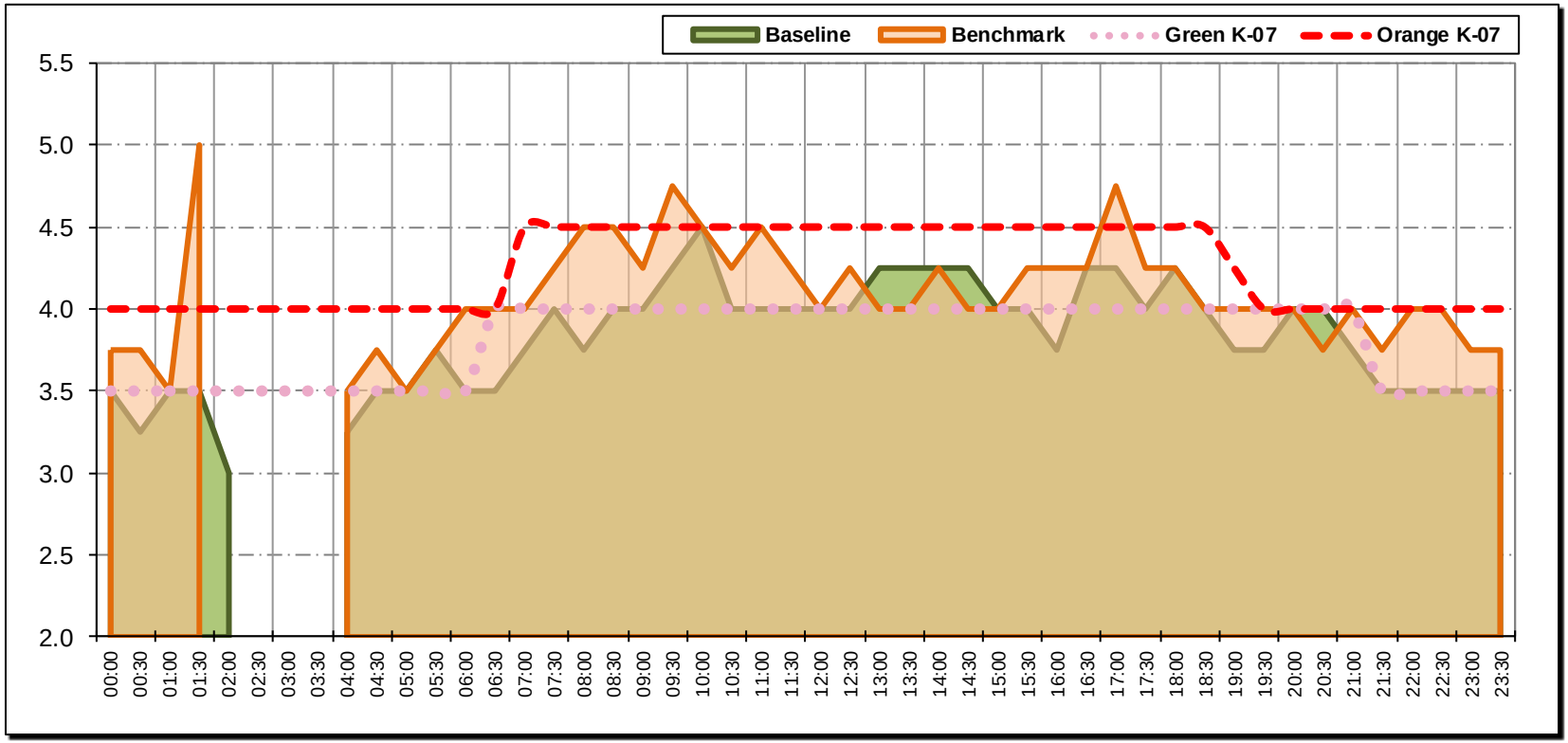
- Construction
- Track Inspection
- Signal Maintenance
- Lunch Break at noon

Orange Line: 17th Junction to Tower 12



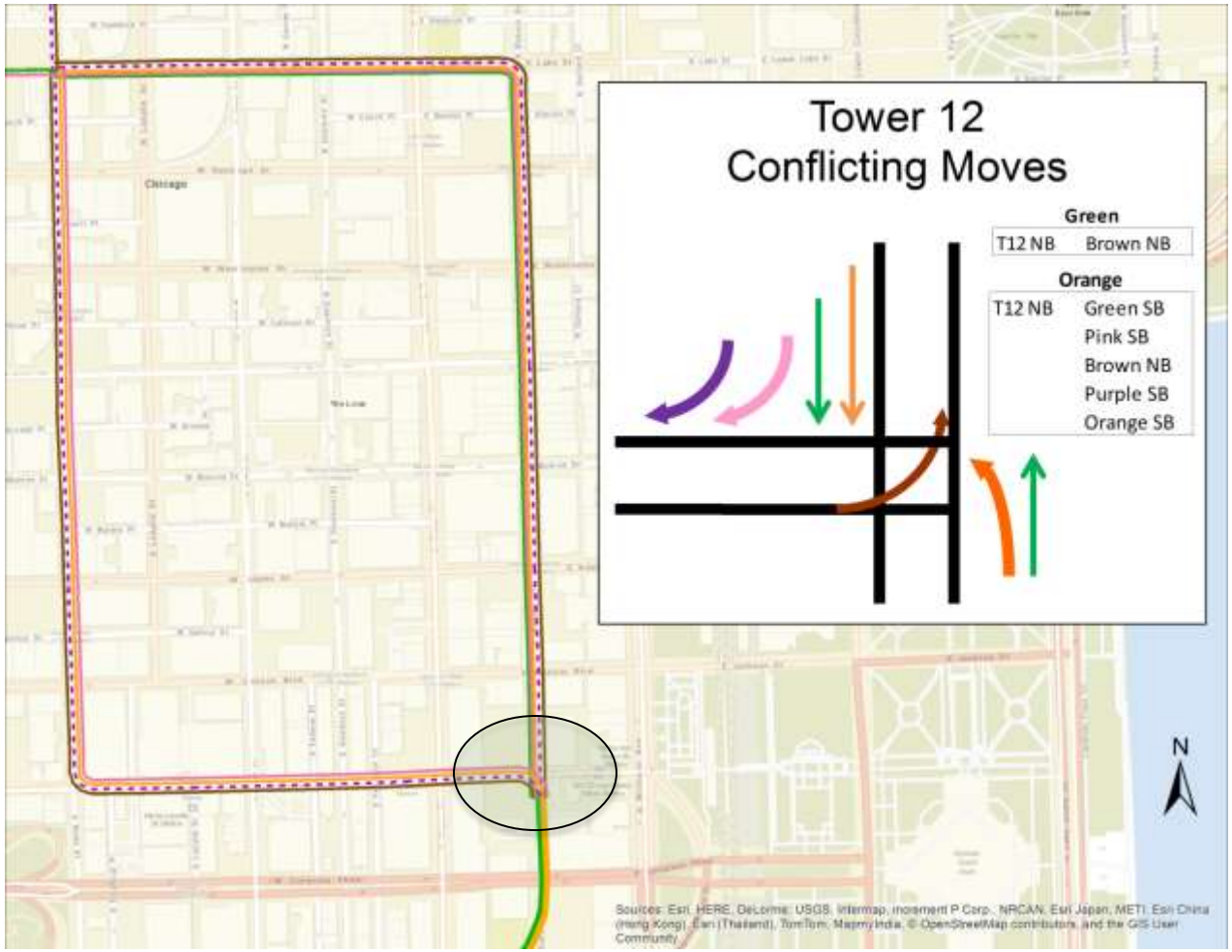
Orange Line: 17th Junction to Tower 12

Orange Line / Green Line	Baseline	=	WKD	Green	3/21/2016	--	4/29/2016
17th Junction to Tower 12	Benchmark	=	WKD	Orange	3/21/2016	--	4/29/2016



The Orange Line and the Green Line share the same tracks from 17th Junction to Tower 12. Interestingly, the Orange Line requires more travel time than the Green Line.

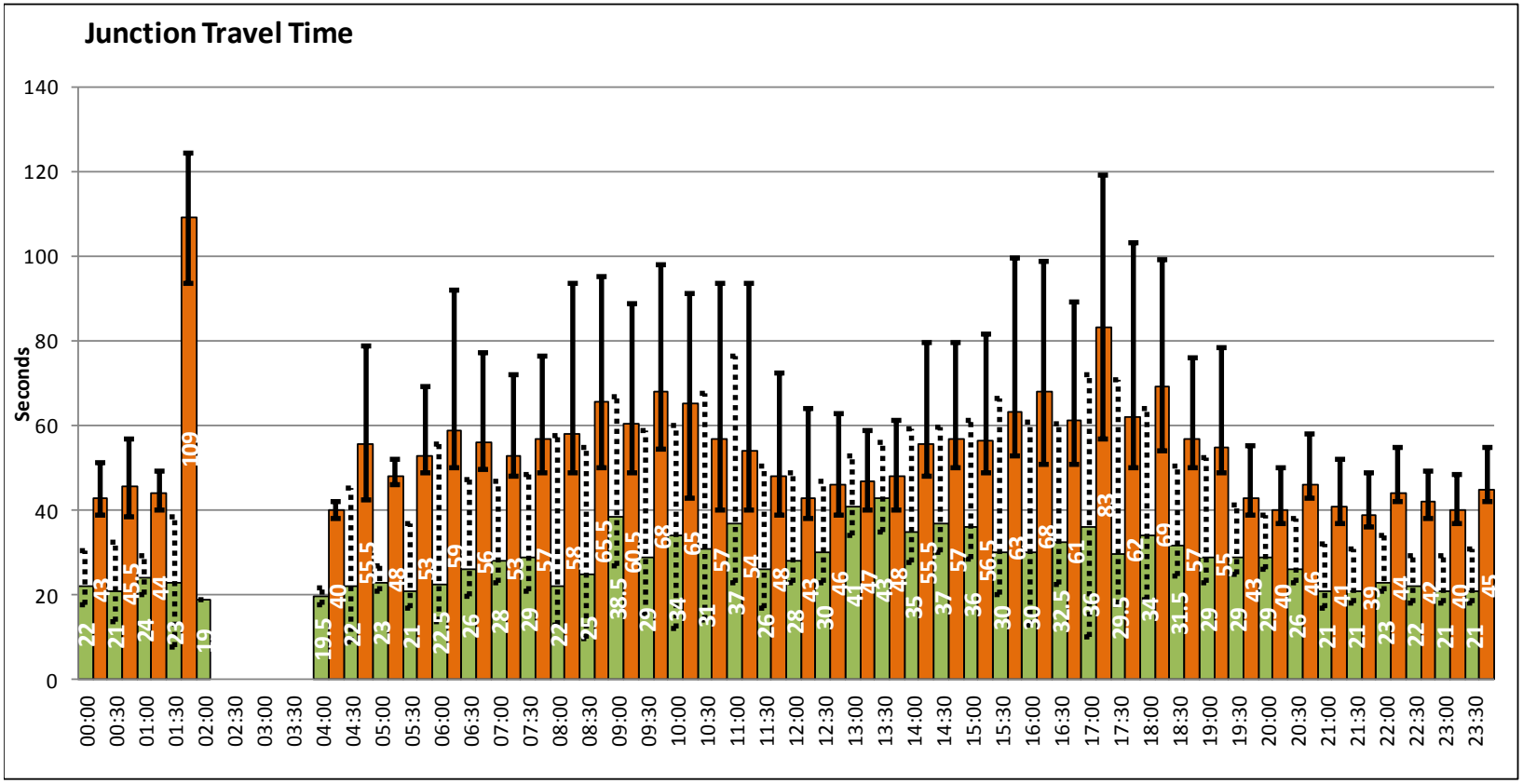
Orange Line Vs Green Line



At Tower 12, the NB Orange Line has five “conflicting moves” whereas the NB Green Line will only conflict with the Brown Line. The Orange Line also requires a cross-over move while the Green Line will simply get a straight line-up.

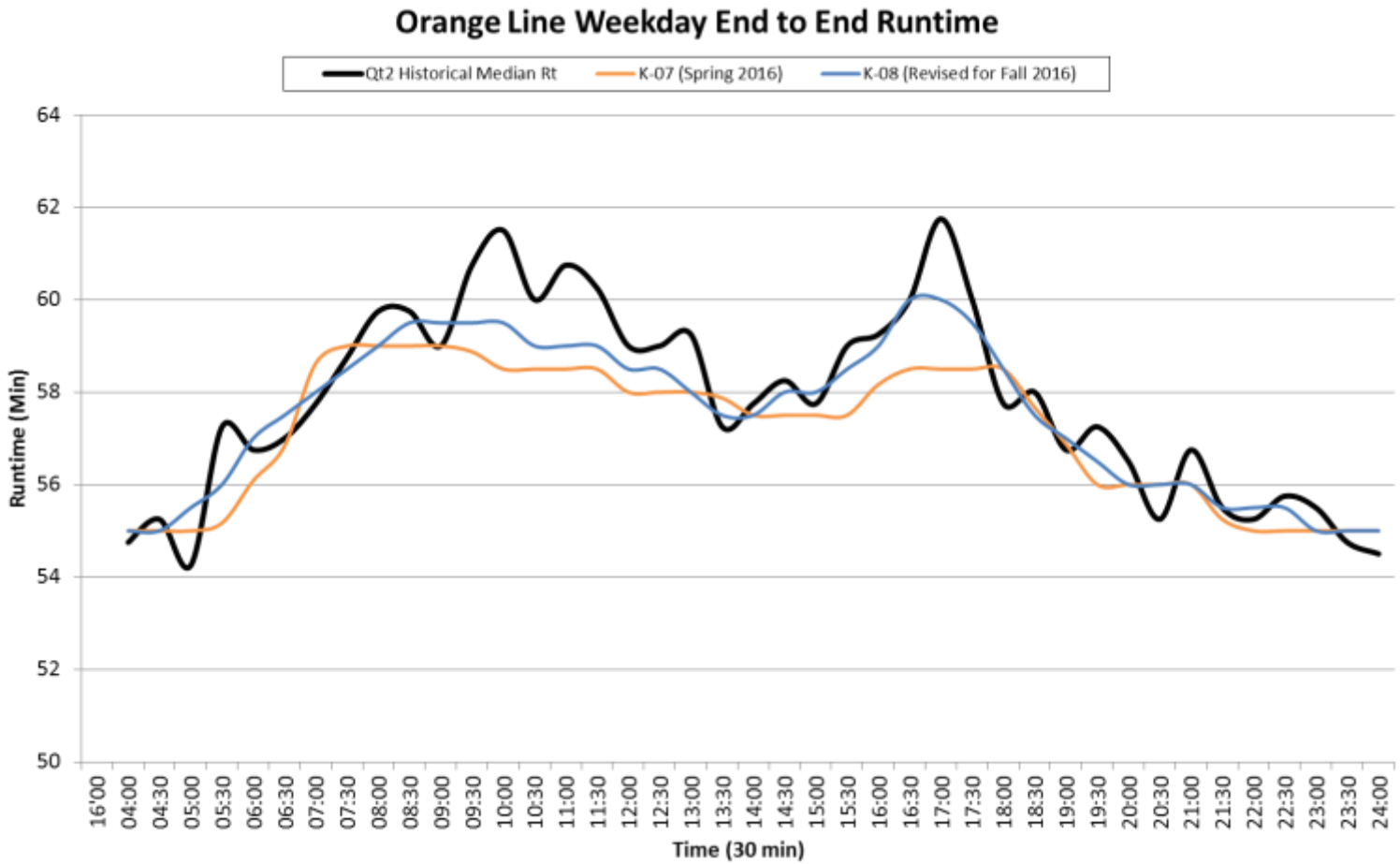
Orange Line Vs Green Line

Orange Line / Green Line	Baseline	=	WKD	Green	3/21/2016	--	4/29/2016
Tower 12 Travel Time	Benchmark	=	WKD	Orange	3/21/2016	--	4/29/2016



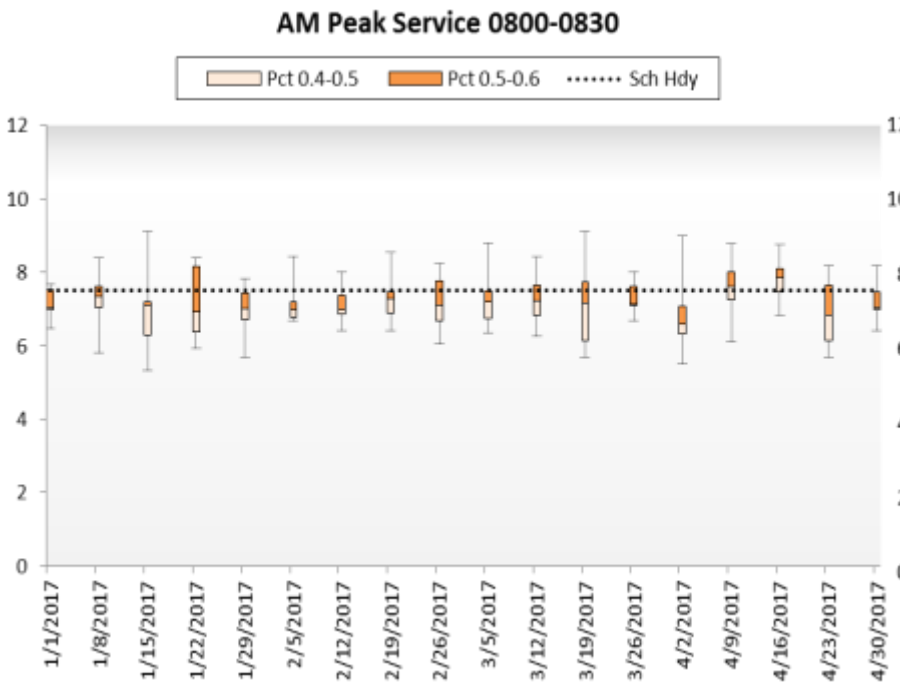
Compared to the Green Line, Junction travel time data clearly indicated the Orange Line requires more travel time to enter and clear at Tower 12.

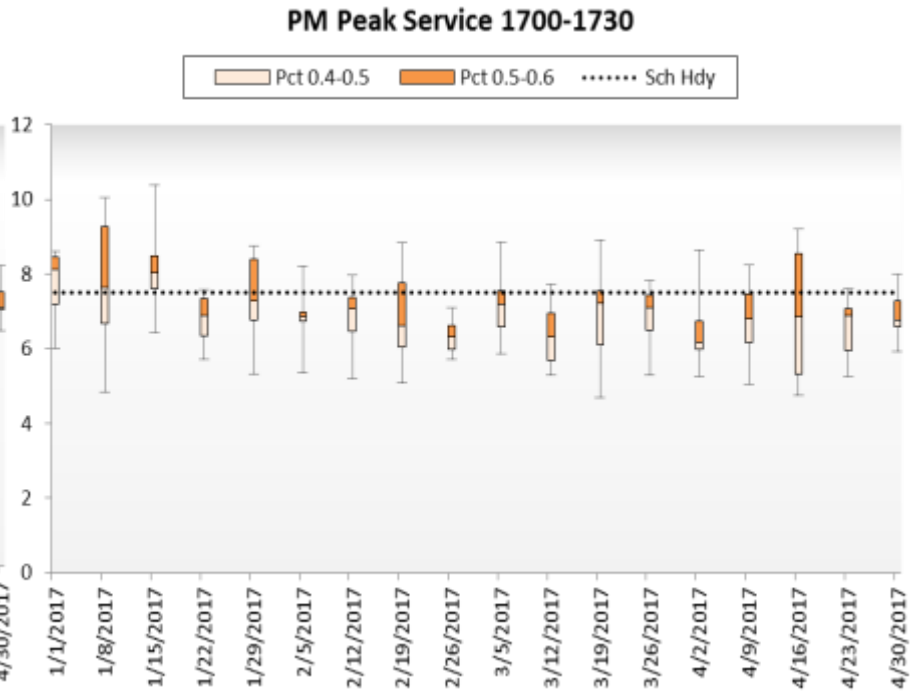
Orange Line – Total Runtime (Midway to Midway)



- CTA rail running time has high "variability" during the late AM peak shoulder due to personnel on the Right-of-way and terminal congestion from yard moves.
- PM peak of the peak running time is generally the greatest due to excessive dwell time and loop congestion.

Orange Line – Roosevelt Station AM Peak Service Vs PM Peak Service



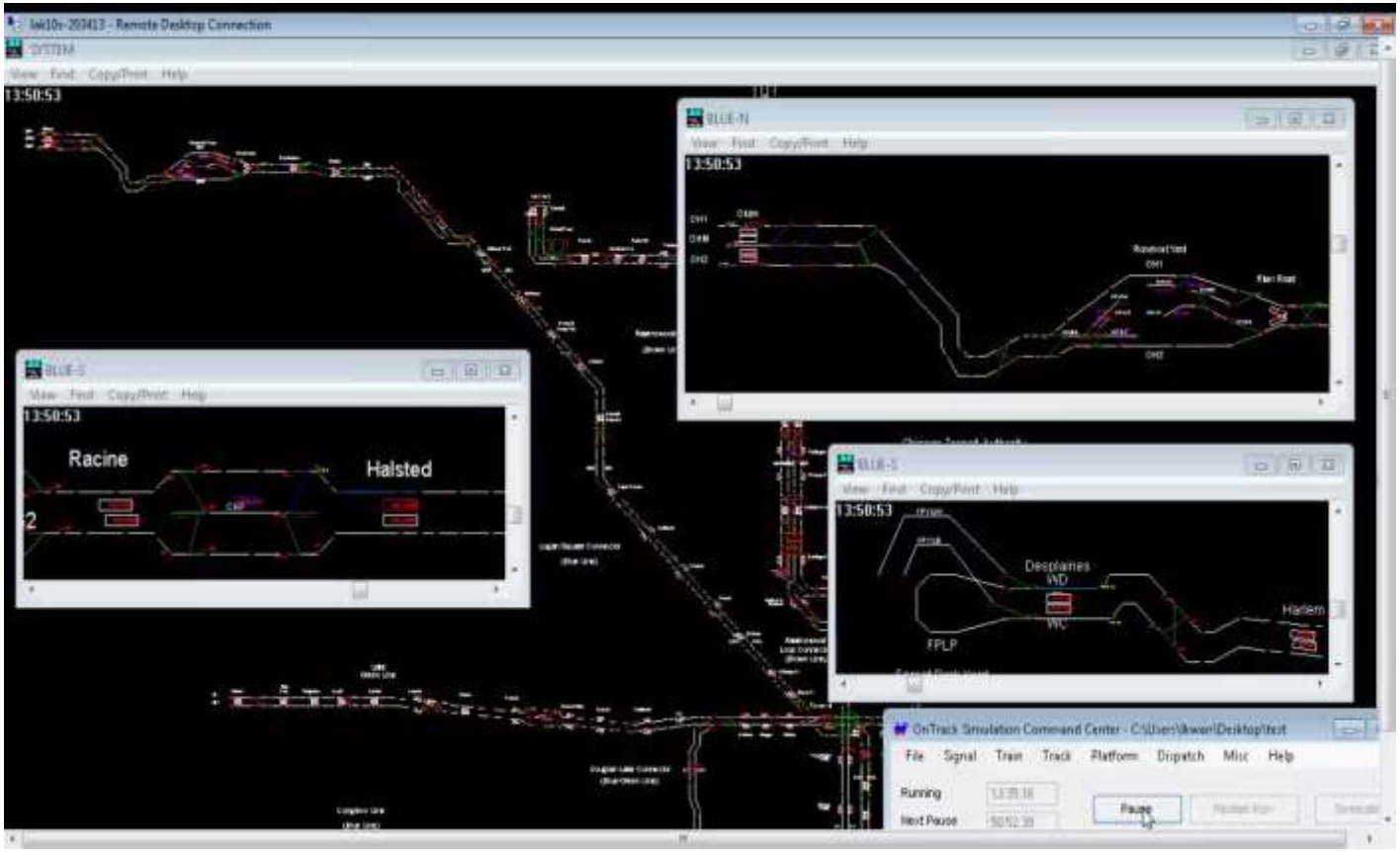


Orange Line PM peak service is less reliable than AM peak provided that PM headway distribution fluctuate more than the AM distribution.

- Excessive concentration of ridership at 1700
- Excessive PM Peak dwell time
- Loop Congestion
- Direction of flow (AM Inbound, PM Outbound)

Simulation

So far all the analysis is base on historical data. What about potential or anticipated changes in the future?



What if we completely eliminate all the slow zones on the Blue Line Congress branch?

Simulation
Blue Line Congress Branch (NB)

In this Speed & Distance graph, the Yellow Line represents the speed of a simulated train operating on the Congress branch without any Slow Zone. The Blue Line represents the speed of a simulated train operating on the current Congress Branch with 30,233 ft of Slow Zones.

Simulation
Blue Line Congress Branch (SB)

The simulated train under the “Slow Zone free” Congress branch achieved much faster operating speeds when compared to the simulated train under the current Congress branch with 30,233 ft of Slow Zones.

Simulation
Blue Line Congress Branch

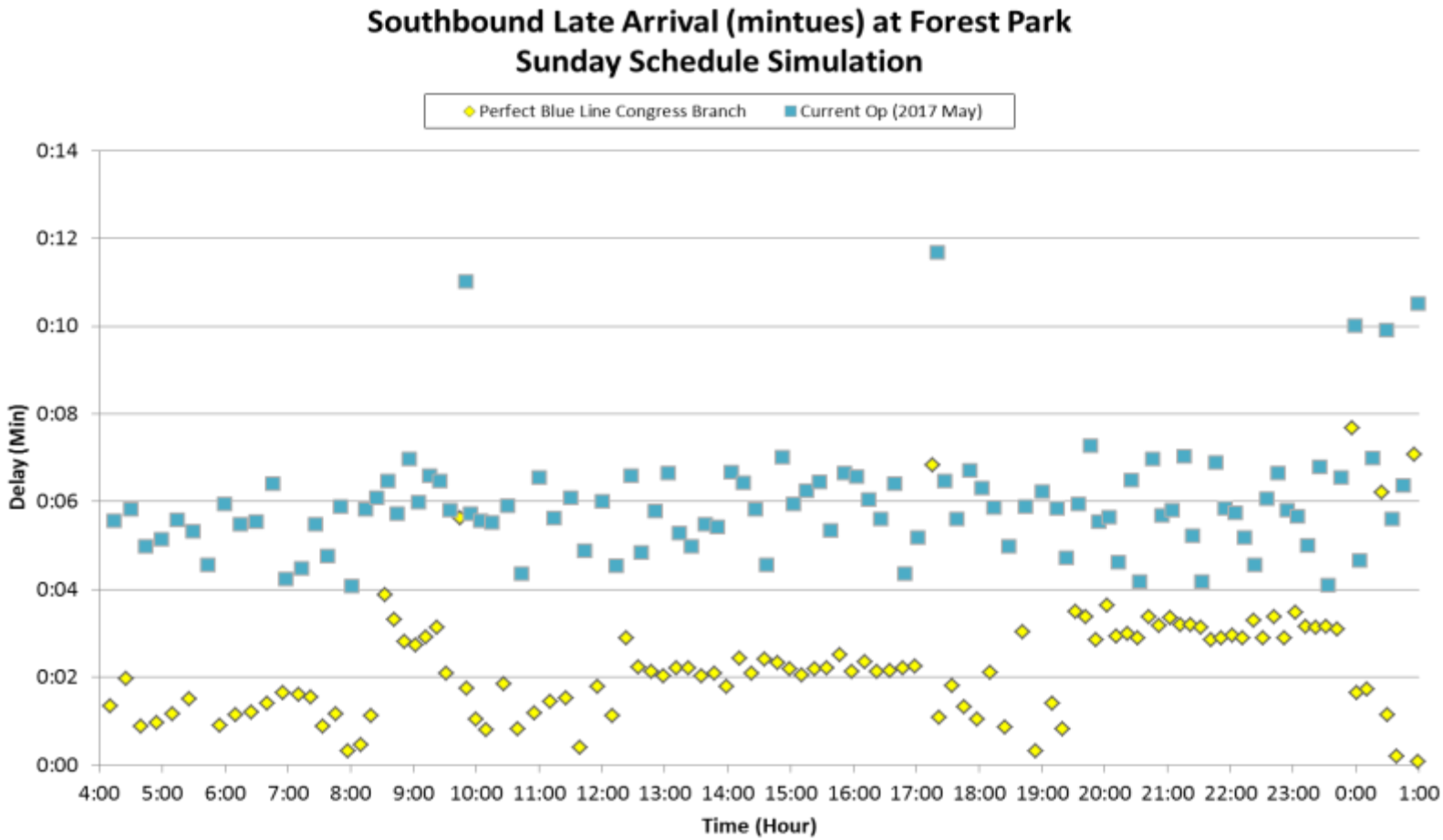
Direction	Scenario	Blue-Congress Branch Station (NB)											Total
		DESP-CNC	HAR-CNC	OAK-CNC	AUS-CNC	CIC-CNC	PUL-CNC	KED-CNC	WST-CNC	MEDC-CNC	RAC-CNC	HAL-CNC	
NB	Perfect	2:59:44	3:01:21	3:03:02	3:04:40	3:07:39	3:09:38	3:11:38	3:13:37	3:15:19	3:17:00	3:18:26	0:18:42
	Current	2:59:44	3:01:22	3:03:08	3:05:17	3:08:47	3:10:46	3:13:20	3:15:51	3:17:56	3:19:46	3:21:19	0:21:35
Time Saving			0:00:01	0:00:05	0:00:31	0:00:31	0:00:00	0:00:34	0:00:32	0:00:23	0:00:09	0:00:07	0:02:53

Direction	Scenario	Blue-Congress Branch Station (SB)											Total
		HAL-CND	RAC-CND	MEDC-CND	WST-CND	KED-CND	PUL-CND	CIC-CND	AUS-CND	OAK-CND	HAR-CND	DESP-CND	
SB	Perfect	3:49:41	3:51:04	3:52:43	3:54:23	3:56:19	3:58:14	4:00:07	4:03:10	4:04:50	4:06:35	4:08:27	0:18:46
	Current	3:50:10	3:51:37	3:53:16	3:55:07	3:58:23	4:00:48	4:03:04	4:07:12	4:08:52	4:11:19	4:13:11	0:23:01
Time Saving			0:00:04	0:00:00	0:00:11	0:01:20	0:00:30	0:00:23	0:01:05	0:00:00	0:00:42	0:00:00	0:04:15

Blue Line Congress Branch NB: 0:02:53 travel time savings
Blue Line Congress Branch SB: 0:04:15 travel time savings
Greatest travel time reduction between Western SB – Kedzie SB and Cicero SB – Austin SB

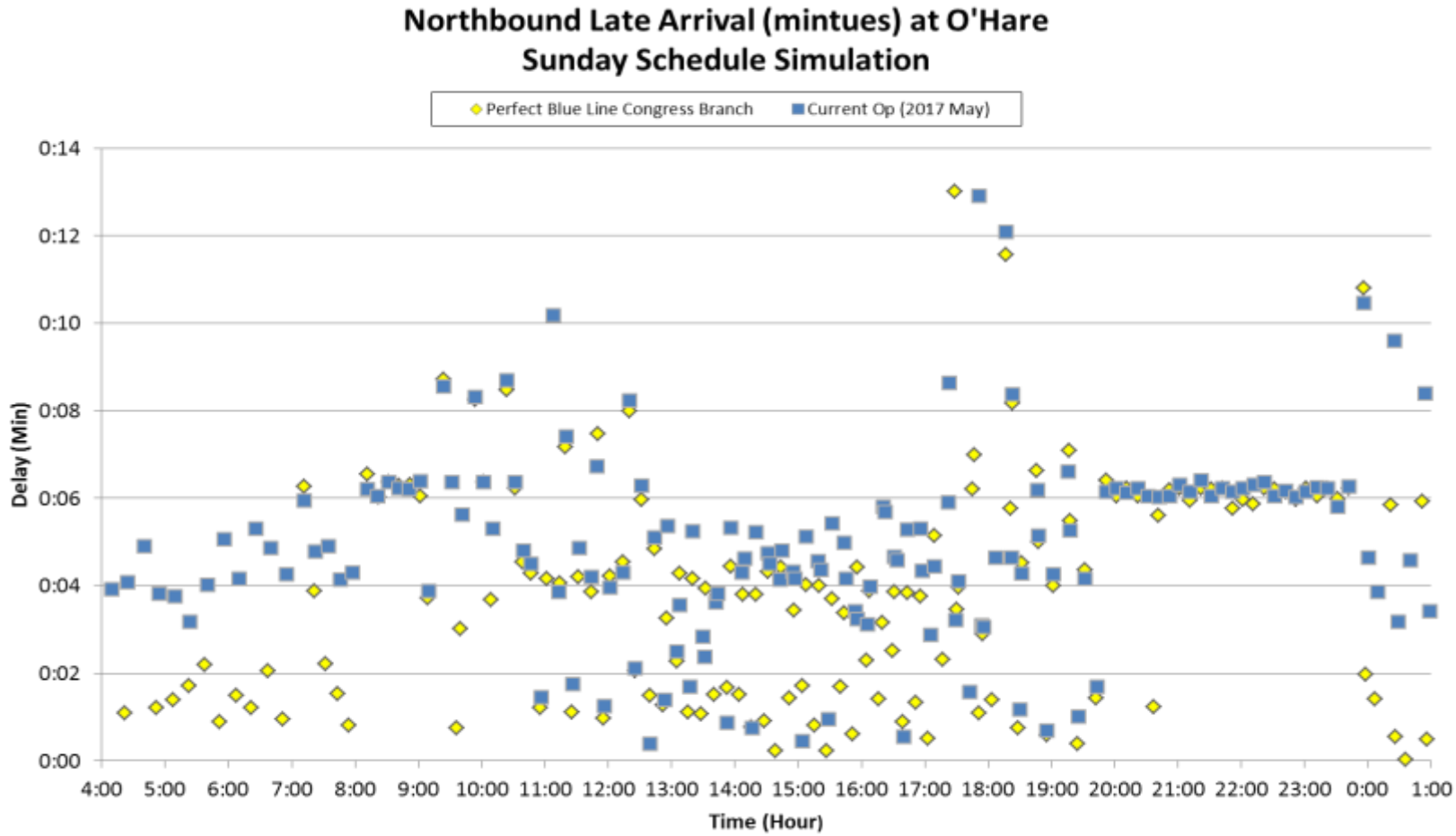
A robust data model and simulation allow CTA to evaluate different scenarios to prioritize track work and capital investments.

Simulation
Blue Line Forest Park Terminal



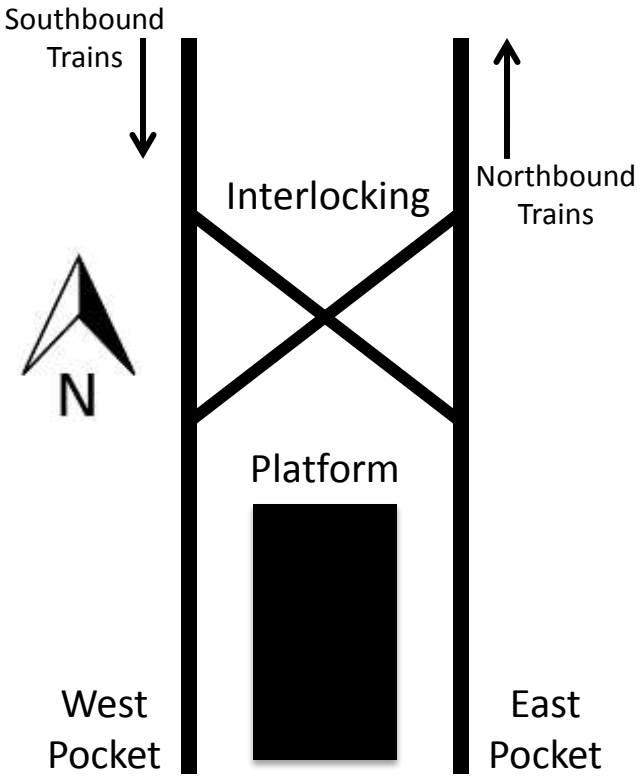
The blue dots represent Southbound terminal delays under current track condition and the yellow dots illustrate terminal delays if the Congress branch is Slow Zone free. Forest Park terminal will be more resilient to random delays if we eliminate all the Slow Zones on the Blue Line Congress branch.

Simulation
Blue Line O'Hare Terminal



O'Hare terminal achieved less significant improvements due to less Northbound travel time reduction.

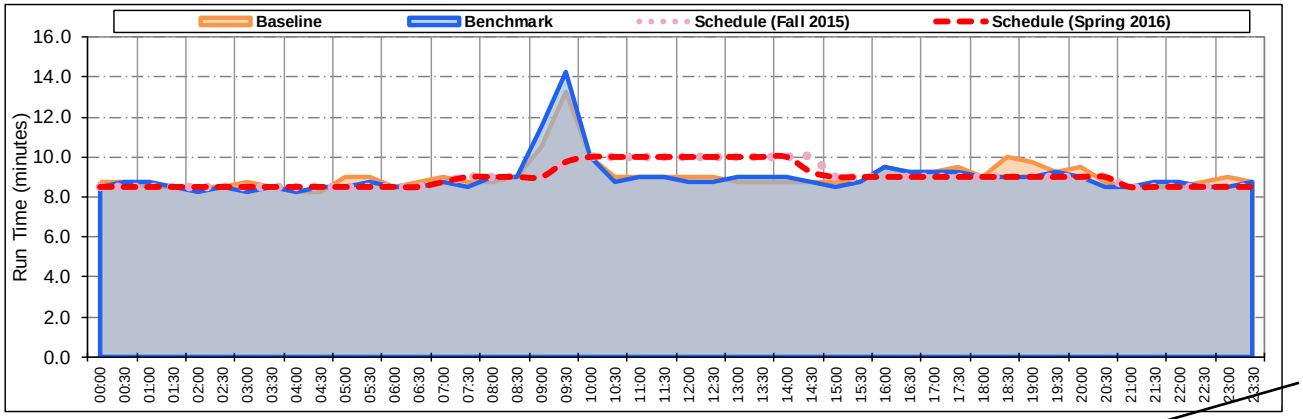
Optional Discussion - Terminal Congestion Red Line 95th Terminal

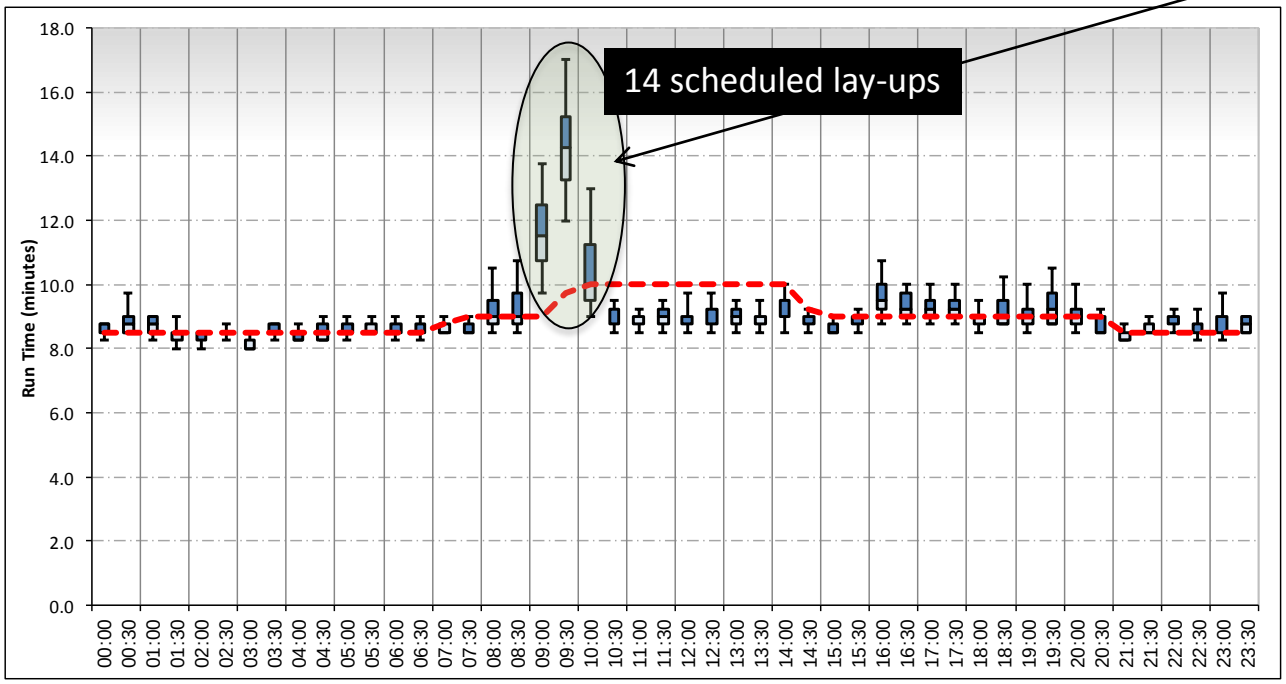


Red Line 95th Station is known for having terminal congestion between 0900 and 1000 because of an imbalanced inbound and outbound headway. Given that 95th Station has two pockets for stub operation, the theoretical maximum train recovery time would be five minutes and thirty seconds with a three minutes headway. These limitations and random delays pose significant challenges for train crews to move trains in and out of 95th terminal.

Optional Discussion - Terminal Congestion Red Line 95th Terminal

Red Line SB 63rd Station - 95th Station	Baseline Benchmark	= WKD = WKD	Sched K-06 Sched K-07	10/1/2015 -- 10/28/2015 3/21/2016 -- 4/29/2016

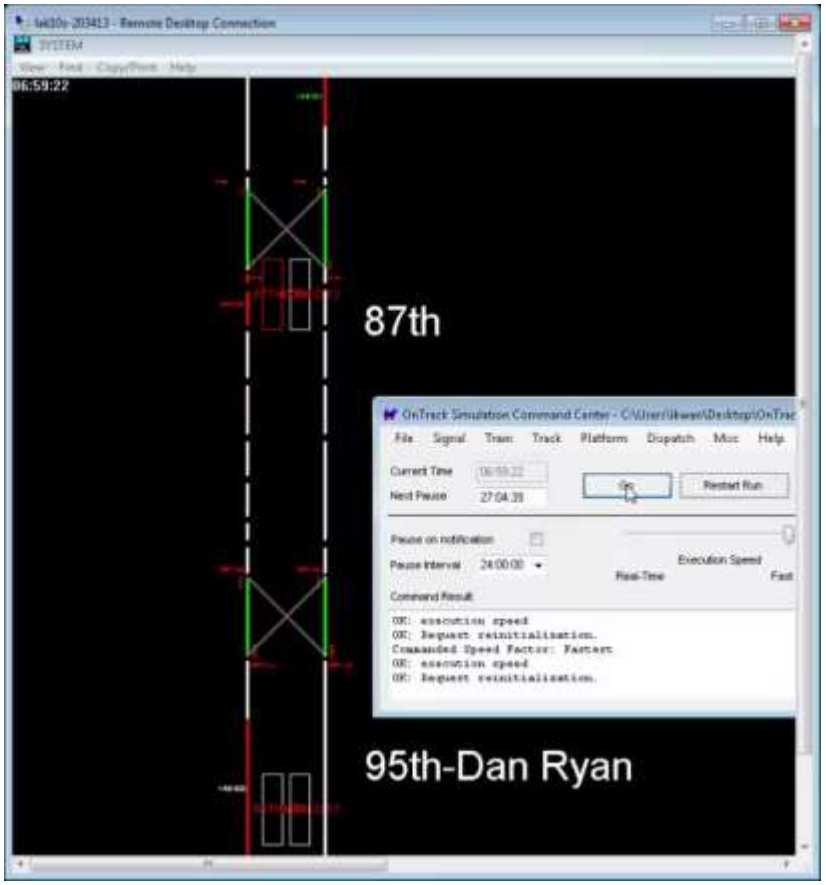




Crews removing 14 in-service trains after AM peak causing runtime variability.

Optional Discussion - Terminal Congestion Red Line 95th Terminal Simulation

Arrival SB		Departure NB
8:00:00		8:08:00
8:05:30		8:14:00
8:09:30	Out-of-srv	
8:13:30		8:20:00
8:17:30		8:26:00
8:21:30	Out-of-srv	
8:25:00		8:32:00
8:28:30	Out-of-srv	
8:32:00		8:38:00
8:35:30	Out-of-srv	
8:39:00		8:44:00
8:42:00	Out-of-srv	
8:45:00		8:50:00
8:48:00	Out-of-srv	
8:51:00		8:56:00
8:54:00	Out-of-srv	
8:57:00		9:02:00
9:00:00	Out-of-srv	
9:03:00		9:08:00
9:05:30	Out-of-srv	
9:08:30		9:14:00
9:11:00	Out-of-srv	
9:14:30		9:20:00
9:17:00	Out-of-srv	
9:20:00		9:26:00
9:22:30	Out-of-srv	
9:25:00		9:32:00
9:28:00	Out-of-srv	
9:32:00		9:38:00
9:36:00		9:44:00
9:41:00		9:50:00
9:46:30		9:56:00
9:51:30	Out-of-srv	



CTA Train crews must perform the following to lay-up trains:

- Prepares cars for storage
- Check all cars of trains to ensure no customers remain on board
- Close doors and windows
- Secures all Safety chains and springs
- Trims Motorcabs
- Turn off interior/exterior lights
- Leaves A/C turned on
- Secures trains against rolling

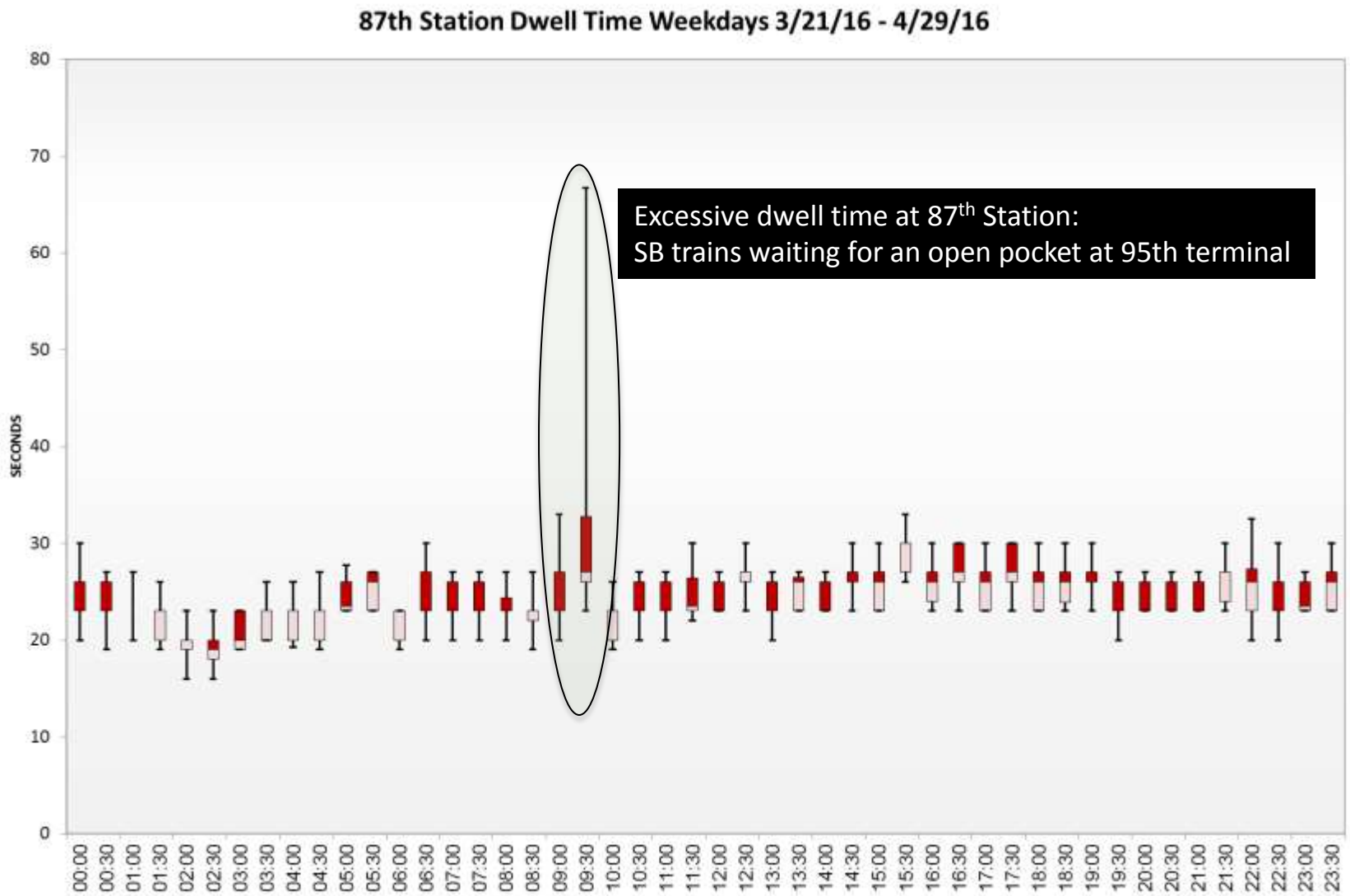
In this situation, adding more schedule running time would not mitigate terminal congestion but worsen the problem by inserting more trains to the terminal.

Potential Solution #1
Utilize Service Restoration technique(s). Example: Gapping – When a train has been delayed approaching a terminal, a supervisor or another certified employee can operate a train to a predetermined station to “trade” train with the delayed operator.

Potential Solution #2
Space out the layups by adjusting the inbound and outbound headway

Potential Solution #3
Infrastructure improvement

Optional Discussion - Terminal Congestion



Summary

- Running time is central to the formation of service and operating budget in the transit industry.

- Running time analysis is the combination of arts and science base on data analysis, operation knowledge, and scheduling concepts.

- A robust data model can collect and summarize service performance, running time, dwell time, vehicle mileage, and junction performance. These data is useful in monitoring service quality and operation cost.

- Simulation is an important tool to quantify what-if-scenarios for providing recommendations in corrective procedures and capital investments.

Appendix I
Scheduling Basics

$$\frac{Running\ Time + Recovery\ Time}{Headway} = Number\ of\ Vehicles/Train\ Cars$$

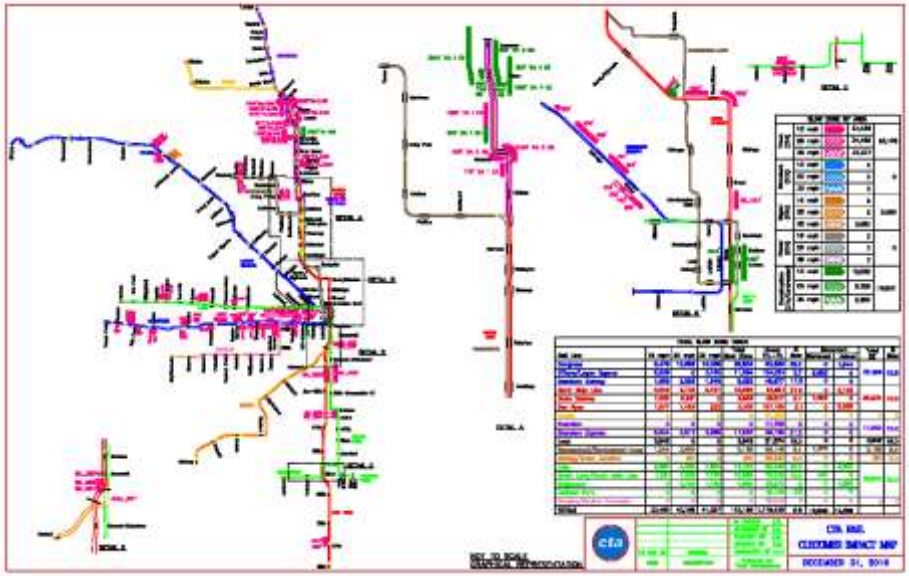
*Formula by TCRP report 30

Example: Red Line

Running Time	=	120	121
Recovery Time	=	12	12
Cycle Time	=	132	133
Headway	=	3	3
Number of trains	=	44	44.3
Number of cars	=	352	360

Running time is critical to the formation of service and operating budget in the transit industry. Insufficient running time might lead to the underestimation of vehicle requirement, causing headway irregularity and unreliable service. Too much running time will lead to the overestimation of fleet size and crew requirement, resulting train bunching and an inefficient operating budget.

Appendix II
Factors affecting Rail Running Time



- Slow Zones
- Personnel on the Right-of-way
  - Construction Activities
  - Track Inspection
  - Signal Maintenance
- Ridership/Dwell Time
- Loop/Terminal Congestion

- Rail car Series
- Car Length
- Operator Experience
- Operation Philosophy
- Service Restoration Techniques