Appendix B
CTA Transit Data Supporting Documentation

Memorandum

Date: *May 14, 2015*

Subject: *Red-Purple Bypass Project*
Chicago Transit Authority (CTA) Transit Data Supporting Documentation

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Contents

This memo provides a summary of CTA transit data that was utilized in identifying the needs for the Red-Purple Bypass Project.

CTA. 2013a. Passenger Trips through Clark Junction

CTA routinely tracks "train loads" – the number of passengers on trains at a specific location – by utilizing station entry data to model where people travel on the rail system, and thus how many people are on trains at a given location. This model is called the CTA Origin-Destination Model. This model is calibrated and validated with field observations by CTA personnel and third party passenger surveys.

Utilizing this CTA Origin-Destination Model, CTA is able to review the loads on all trains leaving stations prior to the junction where the Red, Purple, and Brown lines converge (known as "Clark Junction") and calculate how many people are on the train crossing through Clark Junction. **Table 1** below shows the average weekday loading by direction for all three lines that travel through Clark Junction.

Table 1: Passenger Trips through Clark Junction Compared to System Ridership

Line	Direction	Leaving Station	April 2013 Average Weekday Loading
Red	SB	Addison	39,712
Purple	SB	Howard	7,097
Brown	SB	Southport	25,495
Red	NB	Belmont	41,085
Purple	NB	Belmont	5,740
Brown	NB	Belmont	25,456
TOTAL	NB+SB	Through Clark Junction	144,585
Total System Wide Average Weekday Station Entries			604,653
Percent of System Wide Passenger Trips travel through Clark Junction			24%

Notes: Data on average loading at stations is provided by the CTA Origin-Destination Model, using April 2013 data. System wide ridership data is provided from CTA 2013 April Ridership Report using daily rail station entries by rail line branch. CTA ridership data is available publically here: http://www.transitchicago.com/ridership/

When considering only Red and Purple line trips combined, note that over 93,634 passengers are passing through Clark Junction on Red and Purple line trains each weekday, which represents approximately 30.1 million trips annually. The annual trip calculation assumes an annualization factor of 324 days (weekdays to annual ridership).

CTA. 2013b. Existing Peak Ridership Demand

CTA provides transit service based on the ridership demand for each line. During the peak period in particular, CTA determines how much service to supply based on how many people are using the service. If CTA cannot provide enough service, trains become overcrowded as the demand for services remains. This section describes how CTA and other transit agencies study ridership demand in order to determine service levels.

Peak Load Point:

For rail transit, the passenger demand used for determining service is called the "peak loading point." The peak loading point is the location on the rail line where the number of riders on trains is at its highest point along the line (i.e. the location where trains are most crowded). Loading on trains is related to boardings at stations, but takes into consideration the fact that

riders board the train along the entire line. This translates to trains becoming more crowded as it approaches the central business district.

On the Red Line, the AM peak load point is generally between the Clark/Division and the Chicago/State stations. This indicates that people in the morning are boarding the Red Line between Howard (end of the Red Line) and Clark/Division stations and begin exiting the train for work/school at Chicago/State.

On the Brown and Purple lines, the AM peak load point is generally between the Sedgwick and Chicago/Franklin stations. The number of trains scheduled for each train line is determined so that people are not left at platforms due to overcrowded trains at the peak load point. To serve a peak load point, train service must travel from the terminal (Howard for the Red Line and Kimball for the Brown Line) with enough service to address that peak load point.

Peak Hour:

In transportation, whether for automobile travel or public transit, a "peak hour" is often used to examine demand and capacity. The need to use "peak hour" stems from one fact: a large percentage of the population has a work/school day starting at the same time. This translates to a great amount of people traveling at the same time. Most employees and students have little flexibility in selecting their start time and therefore need to travel in the peak hour between their residence and place of employment or education. In transportation planning terminology, travel demand is rather inelastic. People do not travel in the peak of rush hour by choice; it is a requirement of their livelihood.

Table 2 shows the number of trains required in the morning (AM) peak hour, from 7:30 am – 8:30 am, to serve all the current customers on the trains.

Table 2: AM Peak Hour Southbound Loading and Required Trains

Line	Peak Loading	Train Car Length	People per Car	Trains/Hour Required
Red SB	10,194	8	75	17
Brown SB	10,230	8	75	17
Purple SB	2,757	6	75	6
TOTAL	23,181	varies	75	40

Notes: Loading at stations from Origin-Destination Model, Origin-Destination Model, and using April 2013 data. 75th percentile loading at the peak load point from 7:30 am – 8:30 am. In this scenario, 25% of weekdays would be considered "crowded," or have an average loading over 75 passengers per car.

In December of 2012, CTA implemented the *Plan to Reduce Crowding* to target the heaviest loads on the CTA rail system. The maximum rail car loading standard for the peak period was previously set at 90 passengers per car. CTA found that this 90 passenger standard was unachievable and resulted in routine periods during both the AM and PM peak period when

trains left customers behind on platforms. For the Red and Brown lines, these were daily occurrences.

CTA lowered the peak of the peak schedule goal to approximately 75 passengers per car by adding frequency. To maintain the 75 passengers per car standard, CTA has added additional trains in the peak to the Red, Purple, and Brown line with each new regular rail schedule since December 2012.

Nonetheless, CTA is unable to meet the 75 passengers per car standard during the peak due to the high demand and growth in this corridor. As a result, crowding and passengers being left behind are regular operating occurrences. A photo series (shown in **Figures 1** through **3**) was taken on Wednesday, December 4, 2013 and represents a typical morning commute at Addison station.

Figure 1: Addison Series 1 of 3 – Train at capacity, customers trying to board

Figure 2: Addison Series 2 of 3 – Customers unable to board train already at capacity

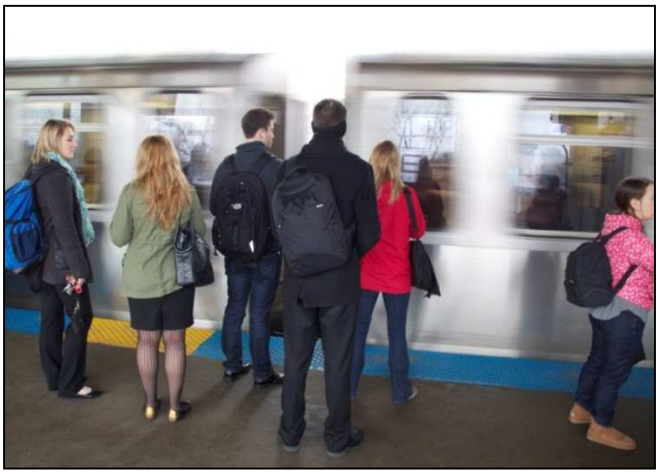

Figure 3: Addison Series 3 of 3 – Customers unable to board, waiting for next train

CTA. 2014a. 'L' Train Route & Individual Station Schedules/Timetables

Information was gathered from CTA official rail schedules available here:

http://www.transitchicago.com/travel_information/allrailschedules.aspx.

Accessed on November 6, 2014.

CTA. 2014b. Historic North Side Ridership Growth

CTA analyzed three scenarios for growth projections based on past ridership trends from 2000 through 2014. Under even the most conservative projections, demand at Clark Junction is predicted to exceed capacity within the next 5 years. Peak-period demand has grown by almost 40 percent since 2008. At this rate, by 2016, service demands will exceed Clark Junction capacity in the peak direction. As a direct result, train delays at the junction will continue to worsen, affecting service reliability on all three lines. **Figure 4** compares the current and projected demand for the RPM corridor to the capacity at Clark Junction assuming low, medium and high growth projections rates. These projections were developed using standard planning procedures.

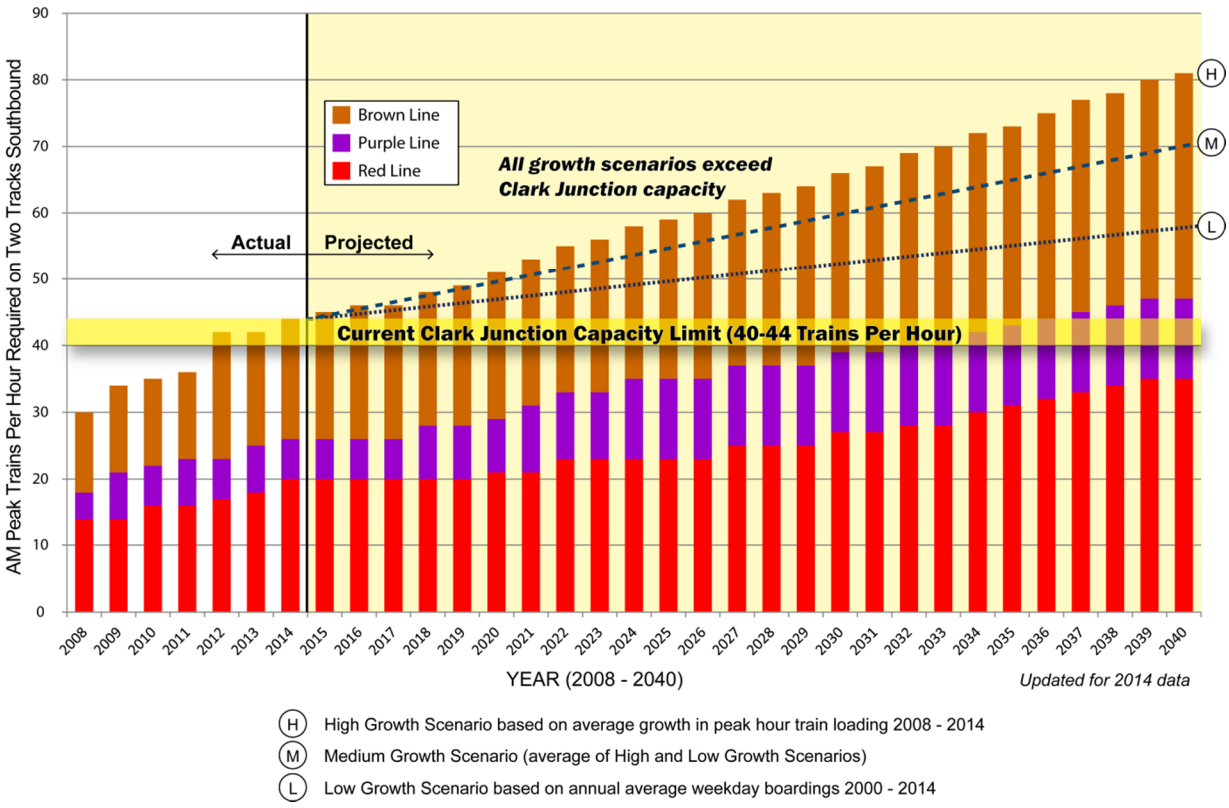

Figure 4: Clark Junction Projected Train Demand and Capacity Constraints

Tables 3 and **4** provide annual weekday boards for the Low and High Growth scenarios.

The Low Growth scenario analyzed CTA rail branch level station entries using available data from 2000 to 2014. The average annual growth percentage was applied to the existing peak loading to arrive at number of trains required in the future, considering a standard loading of 75 passengers per car, 8 car trains on the Red and Brown lines, and 6 car trains on the Purple Line.

Table 3: Average Annual Weekday Boardings for Low Growth Scenario

Year	North Red	Brown	Purple	Combined
2000	95,431	44,228	8,955	148,614
2001	93,712	41,848	8,614	144,174
2002	95,673	41,749	8,764	146,186
2003	92,551	41,457	8,656	142,664
2004	89,601	38,850	8,046	136,497
2005	98,380	43,460	8,519	150,359
2006	96,960	41,288	8,494	146,742
2007	90,593	35,879	8,270	134,742
2008	95,375	39,879	8,868	144,122
2009	96,087	46,142	8,586	150,815
2010	115,435	53,068	9,843	178,346
2011	121,222	57,121	10,105	188,448
2012	123,229	60,398	10,249	193,876
2013	124,287	61,626	10,026	195,939
2014	138,028	66,583	10,817	215,428
			Average Percent Growth Per Year:	3.21%

Notes: Data from CTA Annual Ridership Reports, available online at:
http://www.transitchicago.com/ridership

The High Growth scenario analyzed CTA loading data for the periods possible (2008 – 2014). The High Growth scenario assumed that the same growth rate percentage from the previous 6 years (8 percent annual average) continued into the future to arrive at the projected number of trains required in the future, considering a standard loading of 75 passengers per car, 8 car trains on the Red and Brown lines, and 6 car trains on the Purple Line.

Table 4: Average Annual Weekday Peak Hour Loading for High Growth Scenario

Year	AM Peak Hour in Peak Direction 7:30 am - 8:30 am - Southbound				PM Peak Hour in Peak Direction (4:30 pm to 5:30 pm) - Northbound				AM + PM Peak Hours
	Red	Brown	Purple	AM SB Total	Red	Brown	Purple	PM NB Total	
2008	7,643	5,817	884	14,343	8,036	4,189	1,555	13,780	28,123
2009	8,733	7,699	2,432	18,863	7,694	5,358	2,971	16,023	34,887
2010	9,130	7,936	2,238	19,304	8,200	5,727	2,815	16,742	36,046
2011	8,806	9,014	2,355	20,175	7,692	5,867	3,316	16,876	37,051
2012	9,276	9,419	2,546	21,240	8,301	6,276	3,576	18,153	39,393
2013	10,027	9,457	2,510	21,993	9,303	6,032	3,264	18,599	40,592
2014*	*10,254*	*9,672*	*2567*	*22,493*	*9,514*	*6,169*	*3,338*	*19,022*	*41,515*
Average Annual Growth			AM: 9%				PM: 6%		AVG: 8%

Notes: Loading at peak loading location during peak hour is provided from the Origin-Destination Model, utilizing April monthly weekday averages. 2014 estimated by applying the 2013 to 2014 boarding growth rate of 2.27% to the 2013 loading numbers.

The Medium Growth scenario utilized an average of the High Growth scenario and the Low Growth scenario (approximately 5.6%) to arrive at the projected number of trains required in the future, considering a standard loading of 75 per car, 8 car trains on the Red and Brown lines, and 6 car trains on the Purple Line.

CTA. 2014c. Peak Period Trip Data

CTA changes rail schedules approximately two-three times per year.

Table 5 shows the number of Peak Period trips on each line for each schedule. CTA has had to add peak period trains to tat least one of the three lines that operate through Clark Junction, the Red, Purple and Brown lines in every schedule since the "Plan to Reduce Crowding" began in December 2012. More information on the *Plan to Reduce Crowding* can be found here:

http://www.transitchicago.com/news_initiatives/projects/decrowding.aspx

Table 5: Number of peak trips by line and direction from April 2012 to November 2014

Line	Peak	April 2012	December 2012	October 2013	May 2014	November 2014	INCREASE 4/2012 - 11/2014
Brown	AM	41	45	46	47	47	6
	PM	39	40	40	40	41	2
Purple	AM	19	20	20	20	20	1
	PM	21	22	22	22	23	2
Red NB	AM	38	39	39	39	40	2
	PM	46	50	50	50	52	6
Red SB	AM	47	50	50	50	52	5
	PM	38	40	40	40	40	2
TOTAL	AM	145	154	155	156	159	14
	PM	144	152	152	152	156	12

Notes: AM Peak is defined as 6:00 am – 10:00 am. PM Peak is defined as 3:00 pm – 7:00 pm. Dates correspond to when new schedules went into effect. Does not include May 2013 schedule, as the Red Line South Reconstruction project required substantial changes to how CTA could operate Red Line service, as the South Red Line Branch (Dan Ryan Branch from Cermak/Chinatown to 95th/Dan Ryan) was out of service for 5 months of construction.

CTA. 2014d. QuicTrak Circuit Data

Using QuicTrak data, which is the data utilized to implement the CTA "Train Tracker" program, CTA was able to determine the time it takes trains to travel through the Clark Junction area. QuicTrack utilizes the track circuit system to identify trains that are within a circuit. The way the CTA signal system works, only one train can occupy a circuit at a given time. By tracking a single train through multiple circuits, CTA can estimate the total travel time between circuits.

CTA identified a circuit prior to the Clark Junction and again after Clark Junction for each line and direction to capture the travel time between these circuits. The travel time is variable due to the flat junction configuration. To calculate delay events, CTA used a conservative approach, and set a limit that was 20-30 seconds greater than the minimum time trains took to maneuver this junction.

Table 6 shows the results of this analysis, where over 39 percent of all trips are delayed by the flat junction, even utilizing this conservative approach. This equates to over 67,300 delayed trips and totaling 448 train-hours of delay in a single year.

Table 6: Train Trips impeded by the at-grade crossing and delay

Line	Direction	Total Trips	Delayed Trips	Percent Delayed	Minimum time (sec)	Time Considered Delayed (sec)	Maximum Time (sec)
Purple	SB	12,417	5,315	43%	22	50	294
Red	SB	56,118	27,272	49%	31	63	299
Red	NB	50,187	15,421	31%	42	68	298
Brown	NB	43,921	17,683	40%	51	73	298
Purple	NB	10,399	1,611	15%	51	83	298
TOTAL		173,041	67,302	39%			

CTA. 2014e. December 2014 Ridership Report

Table 7 provides data on the North Red and Purple Line station entries compared to systemwide entries. Year to Date North Red and Purple line station boardings from the December 2014 Ridership Report were used to represent 2014 annual totals.

Table 7: North Red and Purple Line station entries compared to Systemwide

Branch	Year to Date Station Entries	Percent of System wide Station Entries
Red Line - North Side Total	42,837,599	22%
Purple Line - Evanston Total	3,311,197	2%
North Red and Purple Combined	46,148,796	24%
System Wide	194,826,885	100%

Notes: December 2014 Ridership Report Accessed at:
http://www.transitchicago.com/ridership
Accessed on March 10, 2015.

CTA. 2014g. TCRP Capacity Calculations for Clark Junction

Train capacity was calculated from *TCRP Report 165, Transit Capacity and Quality of Service Manual, Third Edition*. This is the accepted transit capacity manual across all of North America. Formulas can be found in Chapter 8 related to rail capacity. The information below only serves to supply inputs into the formulas. The rail capacity background, theory, and formulas are all available by accessing the full *TCRP Report 165 Transit Capacity and Quality of Service Manual, Third Edition, Chapter 8,* available here: http://www.trb.org/main/blurbs/169437.aspx

The calculation of line capacity, or the number of trains per hour on a single track, requires the following information:

Table 8: Inputs utilized to calculate train capacity at Clark Junction

Element	Input
Train Length (nominal)	8 cars x 50 feet/car = 400 feet
Initial Service Acceleration Rate	2.79 feet/sec^2
Service Deceleration Rate	2.79 feet/sec^2
Line Speed (Mainline)	25 mph (maximum through switches and curves)
Switch Throw and Lock Time	6 seconds
Operating Margin	42 seconds (based on actual = 2 x standard deviation of controlling dwell time)
Brown Line Train Speed through Clark Junction signal block (entering the junction until clearing track 1)	15 mph average, 20 mph maximum (Note: using the range from average to maximum provides a capacity range)
Reaction and Braking Times	5 seconds (used in Line Headway calculations)
Brown Line Train Time through Clark Junction signal block	49 seconds average, 40 seconds minimum (Note: using the range from average to minimum was used to provide a check on the capacity range)

Using the methodology in the capacity manual, the range of capacity at Clark Junction calculates to **20** to **22** trains per hour per track. Capacity is a function of tolerable delay. At the lower range, fewer delay events will occur. At the higher range, reoccurring delay is likely. Because train arrival times at Clark Junction vary, some trains are delayed waiting on signal clearance while other trains pass through the junction without a red (stop) signal. The capacity range has been verified by observing actual throughput at Clark Junction.

CTA. 2014h. Red-Purple Bypass Area Speed Restrictions

The conflicts at Clark Junction also impact speed, as trains need to come to a full stop while waiting for other trains to pass. This junction is a product of the original design for the Ravenswood Branch that was constructed in 1907 and represents antiquated infrastructure. Clark Junction is an extremely unusual junction in rail transit, as there is a flat junction where one train must cross three other tracks. Generally at a flat junction, a train only has to cross one other track to access a branch. In addition, "general guidance in rail transit design is that junctions should be grade separated for headways below 150 to 180 s[1]" or 3 minutes between trains. Currently the Brown and Purple lines combine to have headways below 3 minutes during the peak and the Red Line's headway is very close to that same limit. The complex nature of this

[1] TCRP Transit Capacity and Quality of Service Manual, Third Edition. Chapter 8/Rail Transit Capacity, p. 8-61

particular junction which includes three lines on multiple tracks, leads to even more opportunity for interference, capacity constraints, and reliability issues.

Red and Purple Line trains that could be traveling at a steady 25 mph need to come to a complete stop any time a Brown Line needs to pass. Trains operate at slower speeds through this section of track regardless of actual train conflicts, as the signaling system is complicated by the need to keep these conflicts in mind, often slowing trains unnecessarily because of routings already set for previous passing trains.

In addition to the slow train speeds due to conflicts, the section of track just north of Clark Junction includes two speed restricted curves that limit trains to 25 mph. While this section is a short distance, CTA trains could accelerate to 47 mph in normal operation if these speed restricted curves were to be realigned for faster speeds. **Figure 5** shows how current speeds are restricted due to train conflicts requiring trains to stop at red signals and tight curves that create geometric speed restrictions.

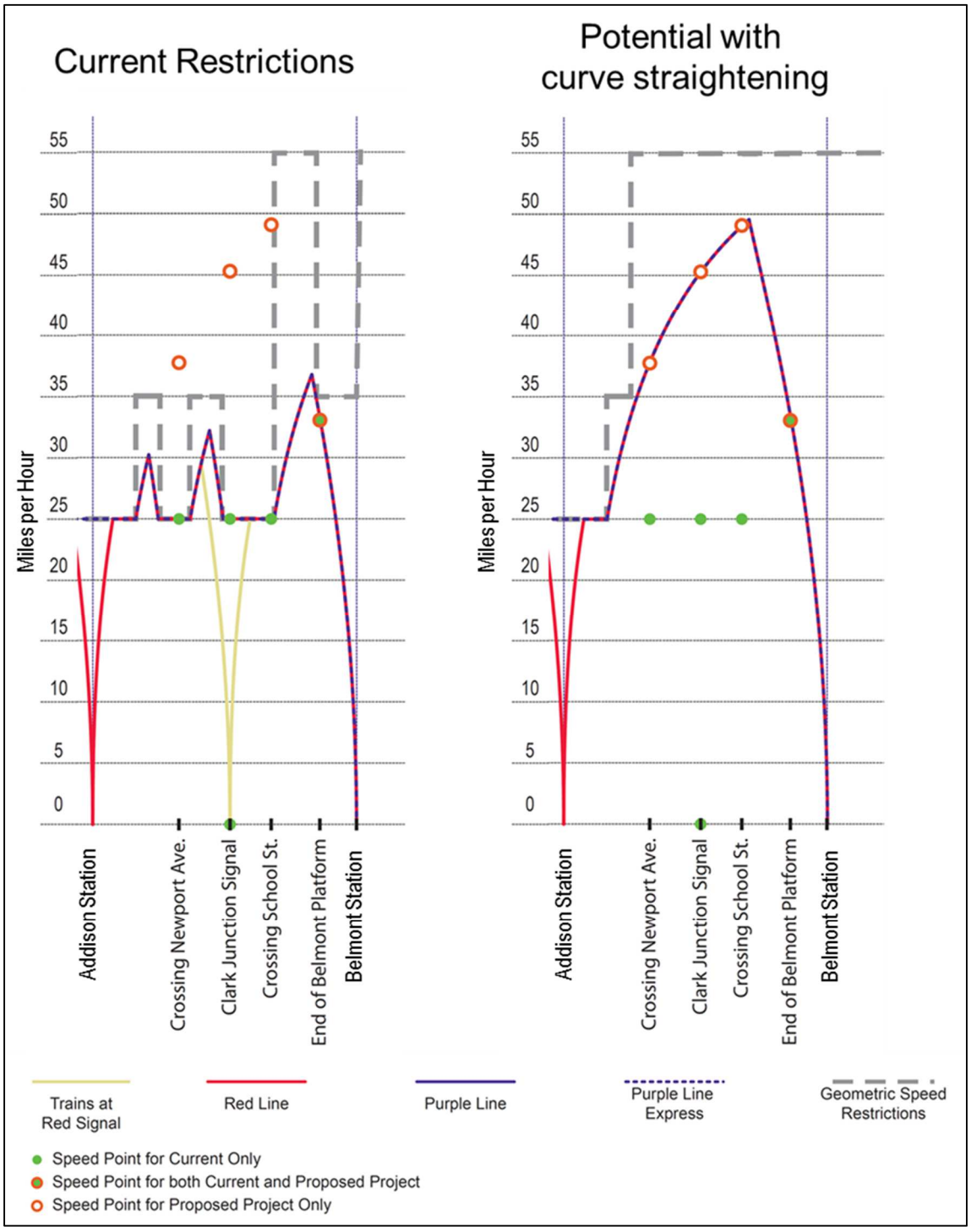

Figure 5: Trains speeds possible with and without signal and curve restrictions

Utilizing a rail simulation model, CTA was able to estimate the travel time savings for Red and Purple Line trains between Addison and Belmont stations. This section of track includes the speed improvements that result from straightening the curves and removing the flat junction. By simulating the travel time after the project is complete and comparing this travel time to existing, we are better able to estimate the average travel time savings. **Table 9** shows the modeled travel time based on existing restrictions, and the projected travel time after the project and a weighted averaged using the number of peak trips. This analysis shows that for an average peak trip on Red and Purple lines, passengers would save over a minute (1 minute, 16 seconds). This travel times savings applied to the annual trips traveling through this section (over 30 million) leads to 636,000 hours of travel time savings, or over 1/2 million hours annually.

Table 9: Peak Period Travel time between Addison and Belmont (Red and Purple Line)

Line	Direction	Peak Period	Travel Time with Existing Constraints	Travel Time with Project	Difference	Peak Period Trips
Red	SB	AM	0:02:48	0:01:13	0:01:35	52
Purple	SB	AM	0:01:54	0:00:53	0:01:01	20
Red	NB	PM	0:02:19	0:01:13	0:01:06	52
Purple	NB	PM	0:02:00	0:00:53	0:01:07	23
Weighted Average			0:02:23	0:01:07	0:01:16	147

Notes: Data from simulation model, considering peak period travel time in the peak direction. Peak period trips from the November 2014 CTA rail schedule. The above travel time does not include the dwell time at stations, only the time traveling.