Regional Rail for Metra: A supply-side model of operation and costs

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Abstract

Metra, the Chicago area commuter rail system serving Cook County and several of the area's "collar counties," has stated a goal to change to a regional rail model, with more frequent off-peak service as opposed to its current service centered around peak commuting times into and out of Chicago. While previous work has focused on the demand-side feasibility of regional rail service in terms of ridership [3], this paper considers the supply-side constraints and costs for Metra to run different scenarios of higher-frequency regional rail service on top of current hourly service to the ends of its lines during the off-peak midday times. Using regional rail operations where Metra runs higher-frequency regional rail service to and from certain stations along its lines, and with the total number of trainsets used in a scenario as a proxy for overall costs, this paper develops a model to determine the total number of trainsets required and efficiency in waiting time for different regional rail operating scenarios, both for route-level operation under current and improved travel and turnaround time conditions and pooled operation for Metra's Union Pacific, Milwaukee, and Metra Electric districts.

1 Introduction

1.1 Metra and Regional Rail

Metra outlined a goal to transition to regional rail-type service in its 2023-2027 strategic plan *My Metra Our Future*, which states that

> Metra is still committed to peak period service for downtown work trips, but we must also adapt to changes in rider behavior and demand. We plan to do this by moving toward a "regional rail" service model. Metra will provide service at more frequent intervals throughout the day for all trip types, and we will also explore targeted opportunities within the region to serve new, underserved ridership markets and destinations.

[1]. This shift is partially a reaction to post-pandemic trends in which traditional commuter rail demand has been hollowed out by increases in remote and hybrid work and therefore Metra's ridership has had difficulty recovering post-pandemic, and the reference to "new, underserved ridership markets and destinations" shows that Metra believes it can capture off-peak, i.e. mid-day ridership with better service between the morning and afternoon peaks.

1.2 Metra's current operating conditions

Metra operates 11 different routes across the Chicago area, with most of its service concentrated in the peak morning and evening times, as the following figure shows.

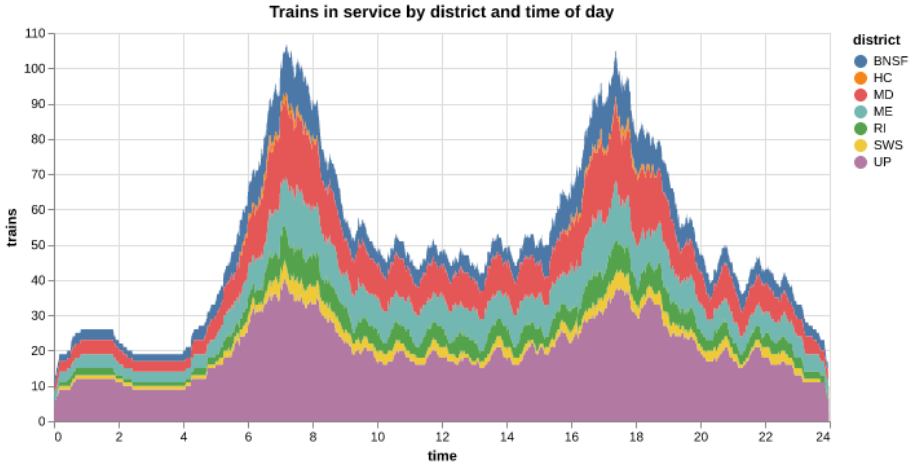


Figure 1: Current Metra trainsets in operation by time and district from Metra's GTFS static data

The following table shows, by line, the total number of stops, the distance and time to the end of the line from the central station, and the maximum number of trainsets in service on the line at any time throughout the day.

route	stations	central station	outer station	time to end	total distance	trains
BNSF	25	Union Station	Aurora	86	37.5	15
HC	6	Union Station	Joliet	66	40.0	2
ME	32	Millenium	University Park	69	31.5	17
ME-BI	26	Millenium	Blue Island	60	20.5	
ME-SC	18	Millenium	South Chicago	39	13.2	
MD-N	21	Union Station	Fox Lake	103	49.5	11
MD-W	21	Union Station	Big Timber	89	39.8	10
NCS	17	Union Station	Antioch	100	52.8	4
SWS	12	Union Station	Manhattan	80	4	6
RI	24	LaSalle	Joliet	92	40.0	11
UP-N	27	Ogilvie	Kenosha	105	51.5	13
UP-NW	20	Ogilvie	Woodstock	92	63.1	18
UP-W	18	Ogilvie	Elburn	88	43.6	12

1.3 Explanation of the Model

The model applies to a hypothetical midday operating scenario with hourly service to and from the end of the line and more frequent regional service to and from a "regional station" part of the way along the line. There is essentially an "overlay" of the more frequent regional service on top of the hourly service, though trains will be timed to ensure that, with a regional frequency of f_r trains per hour and a regional headway of $h_r = \frac{60}{f_r}$ minutes, long-distance trains depart from the central station on the hour and the next $f_r - 1$ trains to depart from the central station at intervals of h_r minutes are regional trains. This means there are essentially two "loops", one regional and one outer, through which trains run on the line.

With this model of operation and the point-to-point and turnaround times held fixed, the two main decision variables are the **regional frequency** f_r and the **regional station** s_r, and the output is the **number of trainsets** T required for operation with the given regional frequency and regional station. Because each trainset has hourly operating and labor costs associated with it, the number of trainsets is a proxy for cost.

Previous work on Metra's potential for regional rail operation has focused on the demand (ridership) side of its market by analyzing ridership trends on boarding and alighting surveys and formulating regional rail scores by stop (Walsh, 2024). This study, however, aims to provide a framework for understanding the supply side of Metra's market, particularly the costs in terms of trainsets required by potential regional rail operating scenario.

2 Methods

2.1 Data

2.1.1 Possible regional turnaround stations

For each route, a station was considered a viable regional turnaround station if it was not the route's central or end station and it had a crossover between it and the next station on the line, as determined from track charts along Metra's lines.

2.1.2 Times

The most important data required for constructing the model are the point-to-point and regional turnaround times. The point-to-point times were found by taking the modes of all trips' times between subsequent stations on a line, and the regional turnaround times were estimated from the times between when one scheduled trip would reach the end of and another scheduled trip would begin from a given station.

From turnaround times, we found that decent placeholder values were 5-minute turnaround times for the central stations, 15-minute turnaround times for the regional stations, and 20-minute turnaround times for the outer stations.

In addition to the 5-minute turnaround time for the central stations, we also included 5 minutes of "buffer time" on account of, per Metra's 2025 on-time statistics, approximately 95 percent of trips arriving within 5 minutes of their scheduled time [2]. This increases the turnaround time at the central stations to 10 minutes to somewhat deal with this uncertainty.

The time out to a station (or regional time, t_r) was considered the cumulative sum of the point-to-point times between subsequent stations prior to that station. The time to the outer station from a regional station t_o was found from the same method.

2.2 Modeling with an hourly cycle

The model considers a repeating hourly cycle by line beginning with a long-distance train departing from the central station. The model does not consider how many times this cycle would repeat during the midday or how to set up trains before and after the cycle, only the cycle itself and the trains that run within the cycle.

2.3 Clock-faced scheduling

This model does not consider trains capable of departing immediately after completing a turnaround at the central and outer station, but instead has trips adhering to **clock-faced scheduling**. This has different implications for trains turning around at the central and regional stations:

- Trains turning around at the central station will need to wait until $t_{departure} \equiv 0 \pmod{h_r}$ to depart. In the model, trains will finish their turnarounds at the central station at some time $\pmod{h_r}$ and will need to wait t_{wc} minutes before departing.
- Trains turning around at the outer station will need to wait until they can depart in order to arrive inbound at the regional station at the same time as a long-distance train would have were it turning around at the regional station. In the model, trains will finish their turnarounds at the outer station at some time $\pmod{60}$ and will need to wait t_wo before departing.

The waiting time across all trains over the course of the cycle, $t_w = t_{wo} + h_r t_{wc}$ is the **excess downtime** of a scenario, when trains are waiting and not either travelling or turning around. Closely related is the **efficiency** of a scenario, $eff = 1 - \frac{t_w}{60T}$.

2.3.1 Finding waiting times

Long distance trains will return to the regional station inbound at $t \equiv t_r + 2t_o + t_{to}t_{wo} \pmod{60}$, and a long distance train, which leaves at $t \equiv 0 \pmod{60}$, would have departed from the regional station inbound at $t \equiv t_r + t_{tr}$ were it a regional train. This means

$$t_r + 2t_o + t_{to} + t_{wo} \equiv t_r + t_{tr} \pmod{60},$$

and therefore that

$$t_{wo} \equiv t_{tr} - t_{to} - 2t_o \pmod{60}$$

Regional trains will have returned to and finished turning around at the central station at $t \equiv t_{rr} \pmod{h_r}$, where $t_{rr} = 2t_r + t_{tr} + t_{tc}$ is the regional roundtrip time. Therefore, in order to depart at $t \equiv 0 \pmod{h_r}$,

$$t_{wc} = h_r - t_{rr} \pmod{h_r}$$

2.4 Finding total trainsets required

To find the total number of trains required in a scenario we consider two sections of operation, the **regional section** consisting of trains operating up to and back from the regional station and turning around at the central station and also trains up to t_{tr} minutes past the regional station (long-distance trains that pass the regional station are counted within the regional section as the equivalent of a regional train turning around at the regional station) and the **outer section** consisting of trains operating from t_{tr} minutes past the regional station outbound to the outer station, trains turning around at the outer station, and trains inbound from the outer station up to the regional station. The total number of trainsets required for a scenario is then found with

$$T = \frac{t_{rr} + t_{wc}}{h_r} + \frac{2t_o + t_{to} - t_{tr} + t_{wo}}{60},$$

Which **will** be an integer value on account of the derivation of t_{wc} and t_{wo}.

2.5 Interworking of trainsets by district

Metra's three districts (the UP district consisting of the three UP lines, the Milwaukee District consisting of the two MD lines and the North Central Service, and the Metra electric district which, while technically one line, can have its main, Blue Island, and South Chicago branches treated as separate lines) each allow interworking of their respective trainsets at the central station, meaning that trainsets arriving at a district's central station from one of its lines can depart on a different of that district's lines. This interworking, or **pooled operation** brings the potential to reduce central station waiting times and total trainsets required across a district.

Operating under the same cyclic model with the same regional frequency by line but with 5-minute gaps between when lines' long-distance trains depart, the objective of pooled operation is to reduce the total excess downtime at the central station.

3 Results and Analysis

Example base and modified single-route scenario results for the UP-N line and pooled scenario results for the UP district with services up to Winnetka on the UP-N, Barrington on the UP-NW, and College Ave. on the UP-W lines are considered here. The appendix includes the full base and modified scenario results for all lines and overviews of trainsets required and efficiency between possible pooling and non-pooling scenarios for the three districts.

3.1 Constraint on number of trainsets

As seen from the table in the introduction, each route had a maximum number of trainsets (i.e. trips) running on it at any time in the day. For each route, this "peak maximum" was scaled by to get a "mid-day maximum" to account for the likely reduced number of trainsets during the mid-day, and to provide an estimated constraint on the number of trainsets that could be used on a line in any scenario

3.2 Base and modified scenario trainsets required for UP-N

The following heatmaps show the number of trainsets required for scenarios with the given regional frequency on the x-axis and regional turnaround station on the y-axis. Cells shaded in grey represent scenarios that use more trainsets than the defined mid-day capacity constraint.

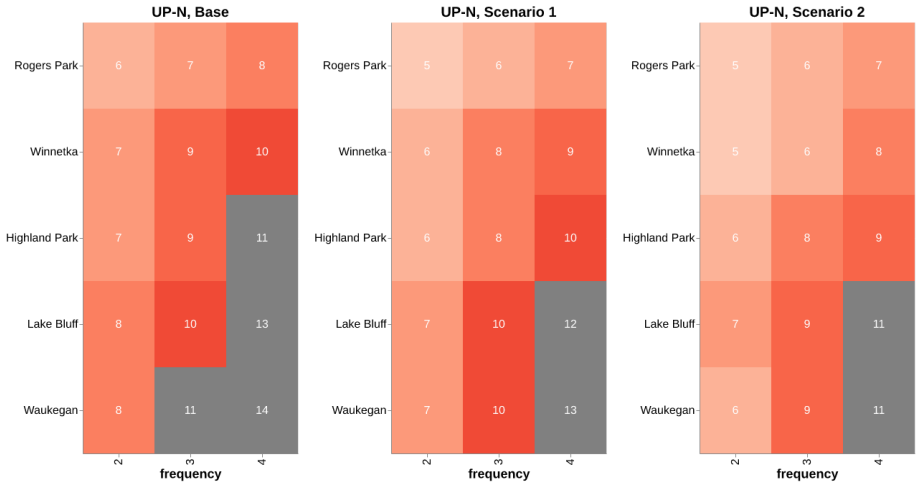


Figure 2: Trainsets required by regional station, regional frequency, and operating conditions scenario for the Union Pacific North Line.

The charts show that even with the base level point-to-point and turnaround times as in the leftmost heatmap, the majority of the regional scenarios are still feasible, though the higher two frequencies (especially 4 trains per hour) begin to make the constraint more binding. Notably, Winnetka, where certain UP-N trains turn around from outbound to inbound service in present operation, is a feasible turnaround station for all three frequencies.

The modified operating conditions increase the number of scenarios available in both the middle and right heatmap, though both fail to extend the 15-minute headway service past Highland Park, suggesting that certain stations along the lines (such as Highland Park for the UP-N) can serve as sensible limitations for regional service with both current and somewhat improved conditions.

An idiosyncracy seen in the rightmost heatmap (and in many of the heatmaps in the appendices) is that running regional service with a 30-minute headway to Lake Bluff requires more trainsets than for Waukegan. One reason this arises is due to Waukegan, which is only 12 minutes past Lake Bluff in the right heatmap's scenario, having an outer waiting time of 20.2 minutes compared to Lake Bluff's 56.2 minutes and a central waiting time of 3.8 minutes compared to Lake Bluff's 27.8 minutes. This shows that waiting times can have enough of an impact on the model to recuce the number of trainsets required even at a further-out station, and points to waiting times' importance in reducing the number of trainsets needed.

3.3 Example pooling scenarios for the UP district

We consider an example pooling configuration on the UP lines with regional stations of Winnetka on UP-N, Barrington on UP-NW, and College Avenue on UP-W.

Using the single-route model for each route will require a total of 22 trains with a 30-minute headway, 28 trains with a 20-minute headway, and 34 trains with a 15-minute headway. The total hourly central station waiting times across all three lines are 146 minutes for the 30-minute headway, 129 minutes for the 20-minute headway, and 112 minutes for the 15-minute headway.

An example optimal pooling arragement for the 30-minute headway is to have trains departing at a 0-minute offset from UP-N, a 5-minute offset for UP-NW, and a 10-minute offset for UP-W, with trains returning from UP-N departing from UP-W, trains returning from UP-NW departing from UP-N, and returning from UP-W departing from UP-NW. The following graphs compare the base and example pooling scenario for how trainsets are interworked.

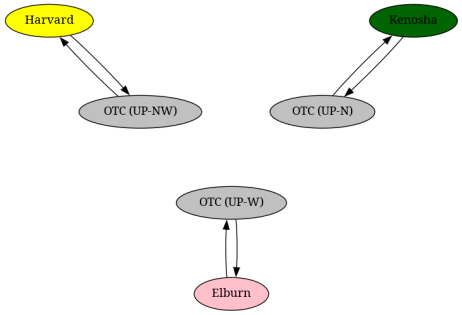


Figure 3: The base interchanging scenario on the UP lines, with each line operating with its own trains and no interchanging at the central station.

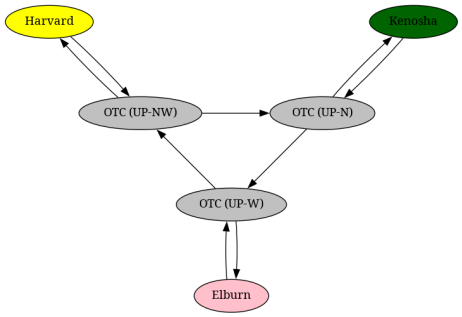


Figure 4: An example pooled interchanging scneario on the UP lines, where lines exchange trains as shown.

For each of the three regional frequencies, the following table shows how the optimal pooling scenarios compared to the base scenarios in number of trainsets required and efficiency.

Frequency	Trains	Base trains	Efficiency ratio	Train ratio
2	20	22	1.100	0.910
3	27	28	1.040	0.960
4	33	34	1.030	0.970

The highest proportional increase in efficiency and reduction in trains required between the base and pooling scenarios was seen with the 30-minute headway service, likely on account of the higher central station waiting times encountered with a longer headway. The following table, which shows the averages of the trainset and efficiency ratios across all the possible pooling scenarios compared to the corresponding base scenarios and grouped by frequency, showing a similar trend.

Frequency	Efficiency ratio (mean)	Train ratio (mean)
4	1.027	0.983
3	1.041	0.961
2	1.061	0.943

Figure 5: Mean efficiency and train ratios between pooling and base scenarios grouped by frequency in the Union Pacific District.

4 Discussion

4.1 Model limitations

The main limitation of the model is its inability to deal with uncertainty in train arrival times, especially how trains accumulate late time as they travel along their trip and how delays can propagate through the system. While we had the five-minute buffer added to the central station turnaround time to reflect a realistic time interval for when trains would arrive beyond the scheduled time, this time was merely a reflection of arrival time distributions across Metra's 2025 arrival data, not taking into accoutn the aforementioned delay accumulation and propagation. Using realtime data collected over a span of time from Metra's realtime GTFS data feed would allow finding more exact arrival time uncertainties and how delay accumulation and propagation could affect arrival times.

For considering scenarios in which Metra uses trainsets with improved speed and/or acceleration, more thorough calculations using distances and curvature on tracks between station can provide better estimates of modified point-to-point and turnaround times times compared to our simply scaling these times

by respective factors.

4.2 Incorporating demand-side data and considerations for mid-day regional operation

While the previous demand-side work on Metra showed how conducive different stations along routes were to increased ridership from higher-frequency regional service, this study provides a supply-side model of Metra's operating costs and limitations for different scenarios of regional service. Future work that incorporated both a supply-side model like this one and demand-side data and characteristics could essentially serve as a "complete"model from which Metra would understand both the costs and potential for increased ridership and revenue from these different scenarios and find optimal scenarios accordingly.

An important consideration for implementing mid-day regional service is the increased amount of trainsets needed during the midday and thus the reduced capacity for maintenance during that time, meaning that Metra would need to move much of its maintenance that would have formerly taken place during the midday to the overnight times.

5 Appendix

5.1 Base trainsets required by regional station and frequency

5.1.1 BNSF

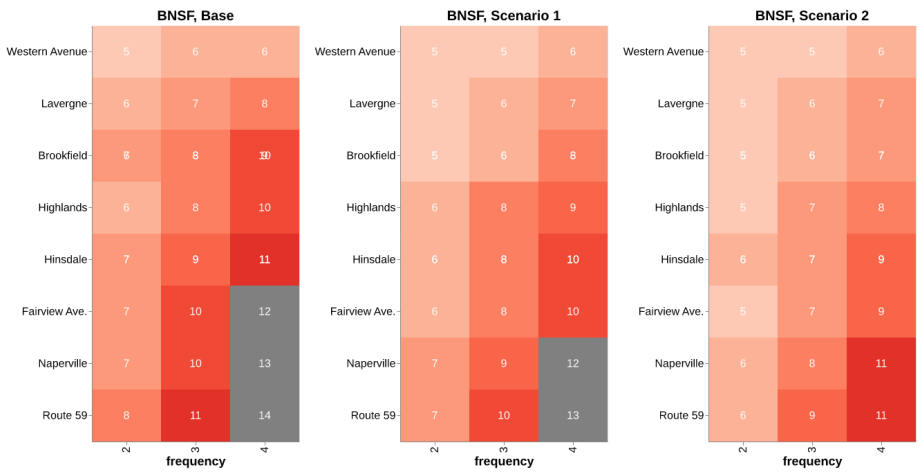


Figure 6: Trainsets required by regional station, regional frequency, and operating conditions scenario for the BNSF Line.

5.1.2 Heritage Corridor

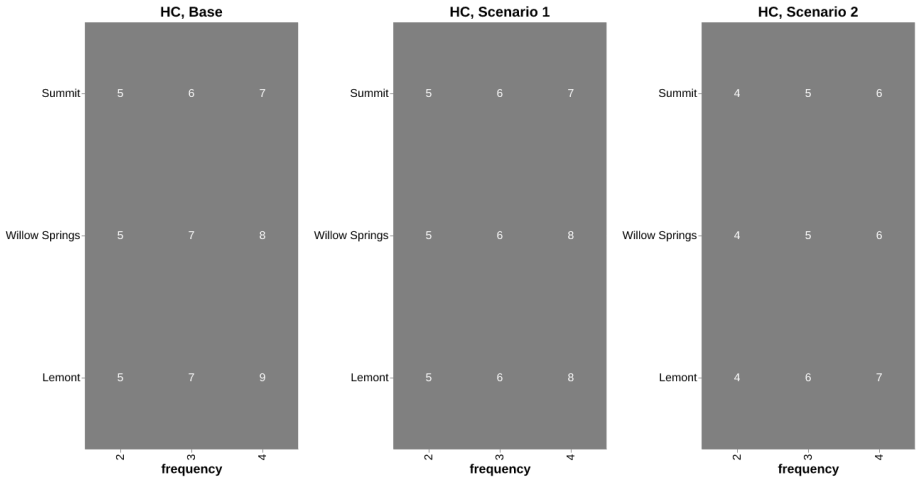


Figure 7: Trainsets required by regional station, regional frequency, and operating conditions scenario for the Heritage Corridor. The Heritage Corridor is one of the three lines for which no regional scenario is feasible under current conditions.

5.1.3 Metra Electric

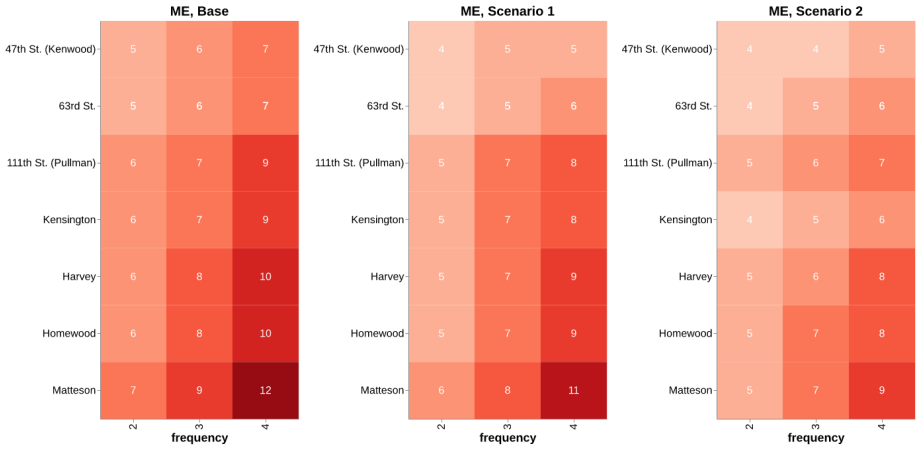


Figure 8: Trainsets required by regional station, regional frequency, and operating conditions scenario for the Metra Electric.

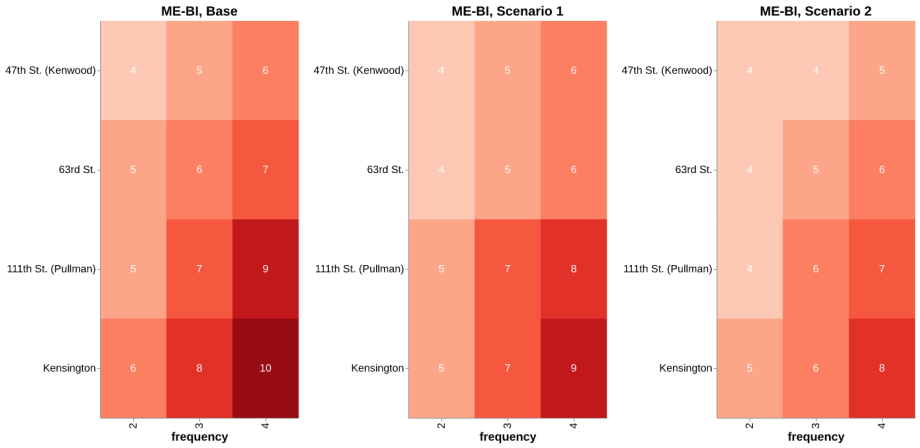


Figure 9: Trainsets required by regional station, regional frequency, and operating conditions scenario for the Metra Electric Blue Island Branch.

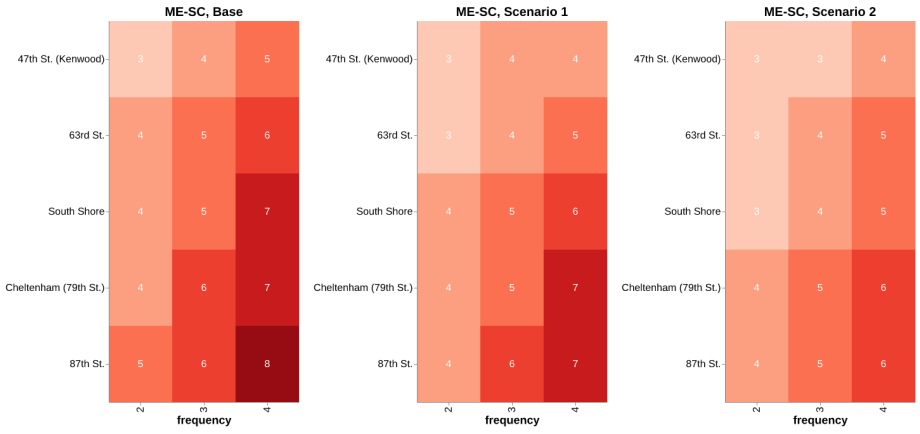


Figure 10: Trainsets required by regional station, regional frequency, and operating conditions scenario for the Metra Electric South Chicago Branch.

5.1.4 Milwaukee District

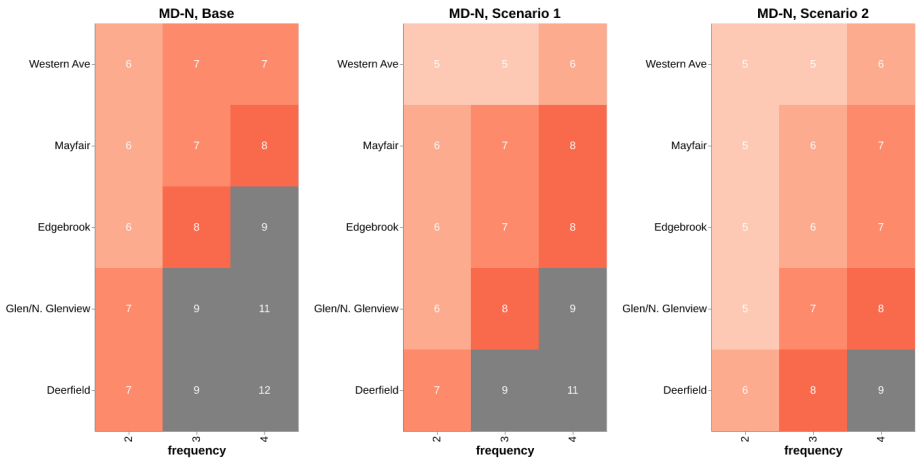


Figure 11: Trainsets required by regional station, regional frequency, and operating conditions scenario for the Milwaukee District North Line.

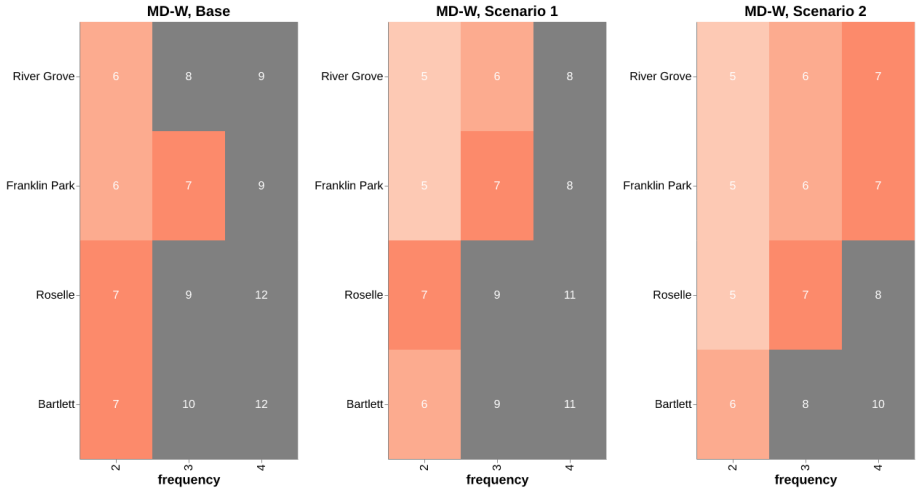


Figure 12: Trainsets required by regional station, regional frequency, and operating conditions scenario for the Milwaukee District West Line.

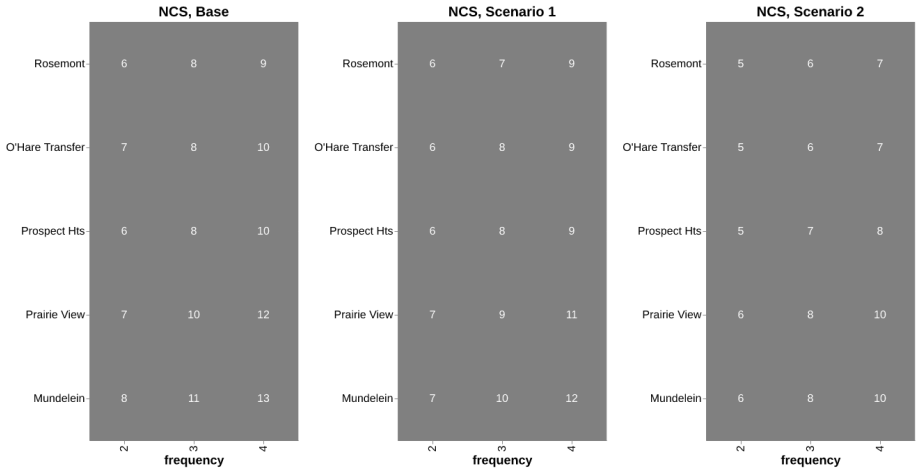


Figure 13: Trainsets required by regional station, regional frequency, and operating conditions scenario for the North Central Service Line. The NCS is one of the three lines for which no regional scenario is feasible under the current conditions.

5.1.5 Rock Island

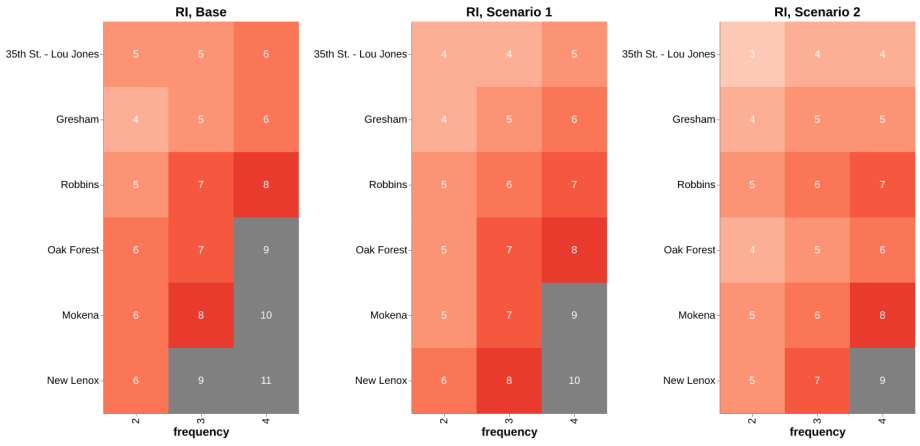


Figure 14: Trainsets required by regional station, regional frequency, and operating conditions scenario for the Rock Island Main Branch.

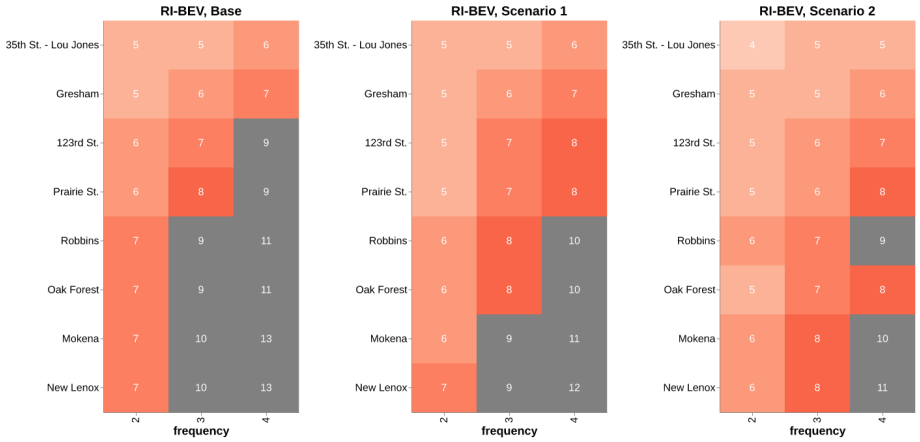


Figure 15: Trainsets required by regional station, regional frequency, and operating conditions scenario for the Rock Island Beverly Branch.

5.1.6 Southwest Service

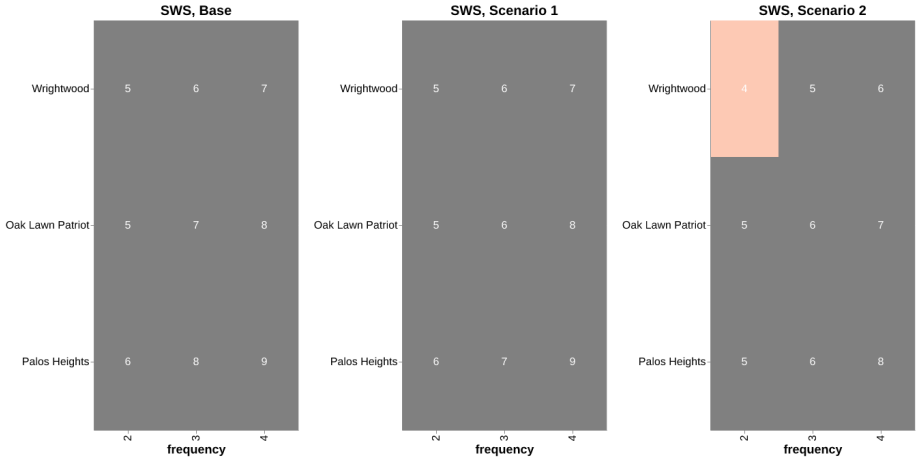


Figure 16: Trainsets required by regional station, regional frequency, and operating conditions scenario for the Southwest Service Line. The SWS is one of the three lines for which no regional scenario is feasible under the current conditions.

5.1.7 Union Pacific District

For the Union Pacific North line's required trainsets, see Figure 2.

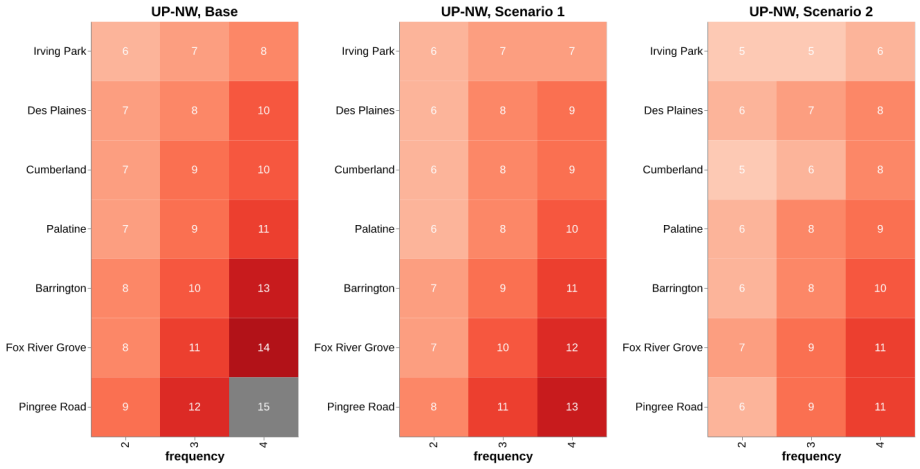


Figure 17: Trainsets required by regional station, regional frequency, and operating conditions scenario for the Union Pacific Northwest Line.

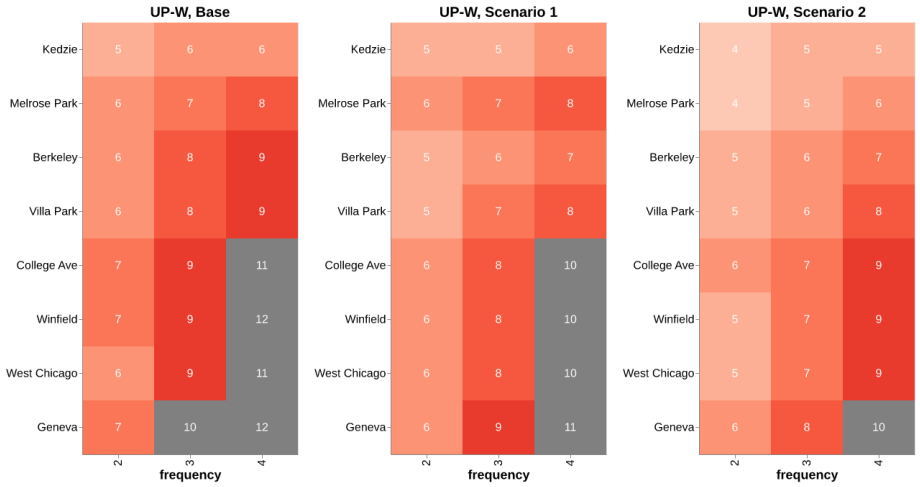


Figure 18: Trainsets required by regional station, regional frequency, and operating conditions scenario for the Union Pacific West Line.

5.2 Impact of pooling on trainsets required and efficiency

5.2.1 Metra Electric

Frequency	Efficiency ratio (mean)	Trainset ratio (mean)
2	1.083	0.925
3	1.045	0.958
4	1.053	0.956

Figure 19: Mean efficiency and train ratios between pooling and base scenarios grouped by frequency in the Metra Electric District. While, like for the Union Pacific District, pooling has a higher impact on reducing trainsets and increasing efficiency for the 30-minute headway service, it has somewhat less of an impact on both for the 20-minute headway than the 15-minute headway services.

5.2.2 Milwaukee District

Frequency	Efficiency ratio (mean)	Trainset ratio (mean)
2	1.034	0.968
3	1.035	0.967
4	1.024	0.985

Figure 20: Mean efficiency and train ratios between pooling and base scenarios grouped by frequency in the Milwaukee District. The Milwaukee District differs from both the Union Pacific and Metra Electric Districts in that pooling has a somewhat higher impact on reducing trainsets and increasing efficiency for the 30-minute than the 20-minute headway service, while the 30- and 20-minute headway services have similarly lower trainset ratios and higher efficiency ratios than the 15-minute service.

5.2.3 Union Pacific District

For the impact of pooling on trainsets and efficiency for the Union Pacific District, see Figure 5.

References

[1] Metra. *My Metra, Our Future*. Feb. 2023. URL: https://assets.metra.com/s3fs-public/2024-11/My_Metra_Our_Future.pdf?VersionId=yq0YPkr0ogEFNrS8wPw1HLbUcx_sOuGW (visited on 09/20/2026).

[2] Metra. *On-Time Performance December 2025*. Dec. 2025. URL: https://assets.metra.com/s3fs-public/2026-01/On-Time-Performance-Report-December-2026.pdf?VersionId=G8hEJxhmg.896M2_gwxw7qIg61uKKNVg (visited on 09/20/2026).

[3] Stephen Walsh and Ian Savage. “Feasibility of a Regional Rail Model for Chicago’s Metra”. May 2024.