4.0 TRAFFIC OPERATIONS AND SAFETY

This study evaluated existing street network traffic operations to establish a baseline for comparison. In addition, two alternatives for a short-term post conversion scenario were evaluated that considered both a 3-lane concept with center TWLTL (Scenario 2A) and a 2-lane concept (Scenario 2B) for the analyzed street corridors. Finally, a long-term post conversion scenario with a larger two-way conversion footprint that included P, Q, 16th, and 17th streets was evaluated. The four scenarios are referred to throughout this document as the following:

- Scenario 1 – No action existing street
- Scenario 2A – Short-Term time horizon, Group 1 and Group 2 corridors, 3-lane concept
- Scenario 2B – Short-Term time horizon, Group 1 and Group 2 corridors, 2-lane concept
- Scenario 3 – Long-Term time horizon, Group 1, Group 2, and Group 3 corridors

4.1 Scenario 1 (No Build) Traffic Operations

Based on existing traffic volumes and travel patterns, all signalized intersections were evaluated for signalization warrants. The *Manual on Uniform Traffic Control Devices, 2009 Edition (MUTCD)* provides nine signal warrants for evaluation of intersection signalization. The preliminary need for signalization was based on the Eight-Hour Vehicular Volume (Warrant 1) and the Peak Hour Volume (Warrant 3) contained in the MUTCD. One warrant contained in the MUTCD is based on the Coordinated Signal System (Warrant 6). This is a traffic progression check on one-way streets to aid in platooning vehicles.

All intersections in this analysis meet these MUTCD guidelines; however, locations that do not meet other traffic criteria are a helpful comparison to identify corridors that may be converted to two-way operations. Maintaining bi-directional platooning on two-way streets may be more difficult with closer spaced signalized intersections when compared to one-way streets. Other MUTCD signal warrants include reviews of pedestrians, crash experience, and at-grade railroad crossings. These traffic signal warrants were either not applicable or not expected to be satisfied at any location in the study area. The signal warrant evaluation is summarized with detailed analysis results in **Appendix B.**

The results of the traffic signal warrant evaluation indicate that 22 existing signalized intersections could be evaluated further for traffic signal removal:

11th Street	12th Street	13th Street	14th Street	Centennial Mall	16th Street	17th Street
• Q Street	• Q Street	• Q Street	• P Street	• P Street	• P Street	• Q Street
• P Street	• P Street	• P Street	• N Street	• N Street	• N Street	• N Street
• N Street	• N Street	• N Street	• M Street	• M Street		
• M Street	• M Street	• M Street				

Capacity analyses were performed for the existing study intersections utilizing the existing lane configurations and traffic control. For analysis purposes, no changes to intersection traffic control were assumed despite the results of the signal warrant evaluation. Analyses were conducted using Synchro, Version 11.0 which is based on the Highway Capacity Manual, 6th Edition delay methodologies. For simplicity, the amount of control delay is equated to a grade or Level of Service (LOS) based on thresholds of driver acceptance. The amount of delay is assigned a letter grade A through F, LOS A represents little or no delay and LOS F represents a very high delay. **Table 4** shows the delays associated with each LOS grade for signalized and unsignalized intersections, respectively.

Table 4. Intersection Level of Service Criteria

Level-of-Service	Average Control Delay (seconds)	
	Signalized	Unsignalized
A	≤ 10	≤ 10
B	> 10-20	> 10-15
C	> 20-35	> 15-25
D	> 35-55	> 25-35
E	> 55-80	> 35-50
F	> 80	> 50

Highway Capacity Manual (HCM, 6th Ed.)

Current downtown signal timing plans were utilized which were updated in Fall 2019 as part of Green Light Lincoln – Phase 3. All signalized intersections currently operate at LOS D or better in both peak hours. Several individual movements operate at LOS E or LOS F and are summarized in **Table 5**.

Table 5. Movement LOS

Intersection	Movement	LOS (AM/PM)
9th St and L St	WBT/L	(C/E)
9th St and M St	EBT/R	(C/E)
9th St and N St	EBR	(D/E)
9th St and O St	EBR	(E/F)
10th St and Q St	WBR	(B/E)
Centennial Mall and O St	SB	(D/E)
Centennial Mall and O St	NB	(D/E)

Although most individual movements operate at acceptable levels of service, queues between intersections can exceed a block length, which can cause gridlock-like conditions on side streets during peak periods. Notable corridors include 9th, 10th, and O streets and certain lanes carrying priority movements in and out of parking facilities. Most of these conditions occur for only a few signal cycle lengths and coincide with employment operation hours, large events, and at facilities with singular points of entry/exit.

Field observations and user experience do not always coincide with modeled LOS. Recent construction projects with overlapping timelines have caused observable differences in queues and delays including the downtown water main replacement project (2018-2019), the new State of Nebraska office space/garage near 17th and K streets (2019-2020), the Lied Place residence (2020), and many other projects that cause temporary lane closures and/or detours. These projects do create challenges in reporting how the transportation network appears to operate at any given time and how it is represented in the model. Specific movements, intersections, or streets may have observable deficiencies, but it can be difficult to untangle them from certain construction activities versus general capacity limitations and irregular events. The Scenario 1 capacity analysis summary is illustrated in **Figure 12** and **Figure 13**. Capacity analysis reports can be found in **Appendix C**.

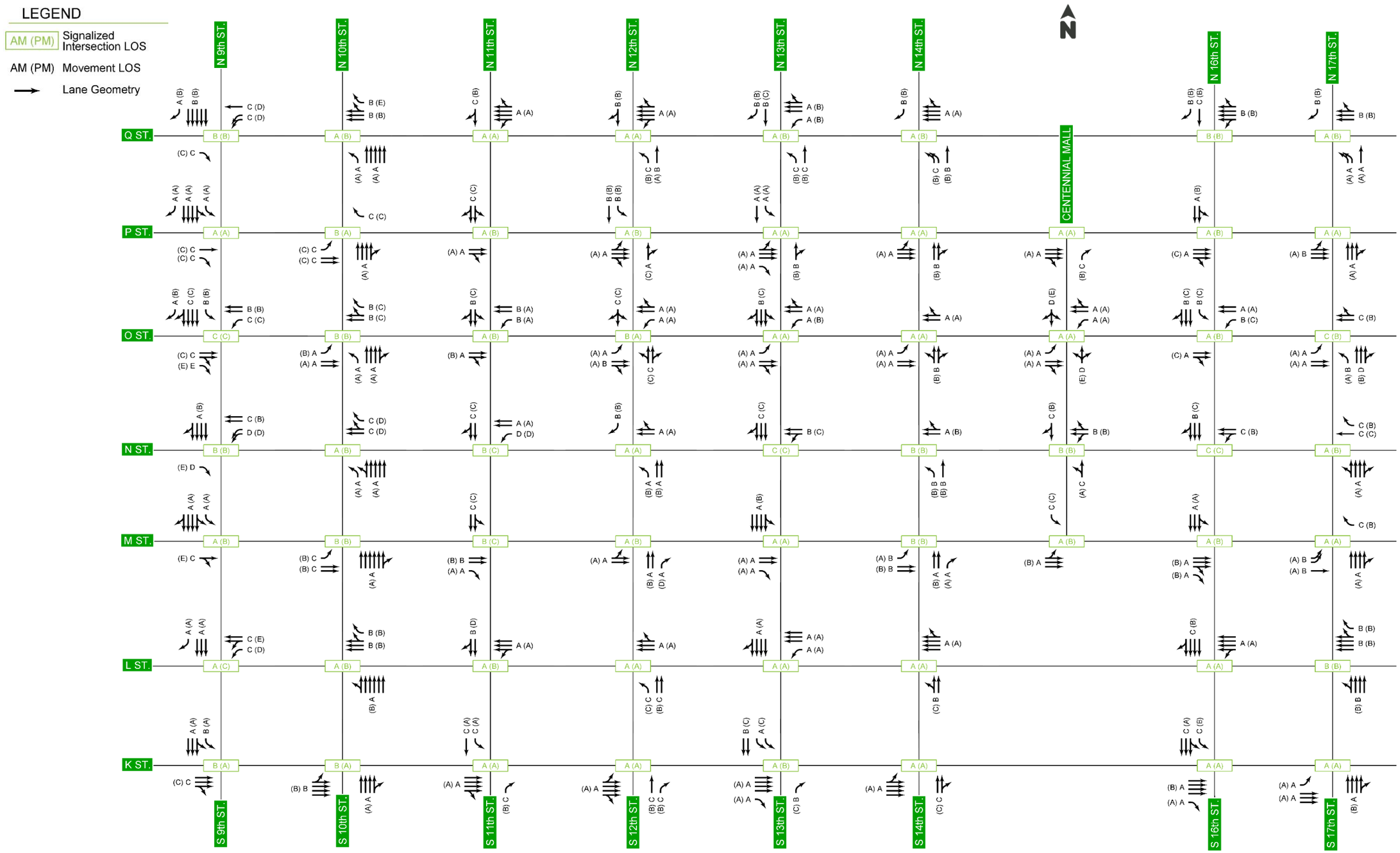

Figure 12. Scenario 1 Capacity Analysis (North)

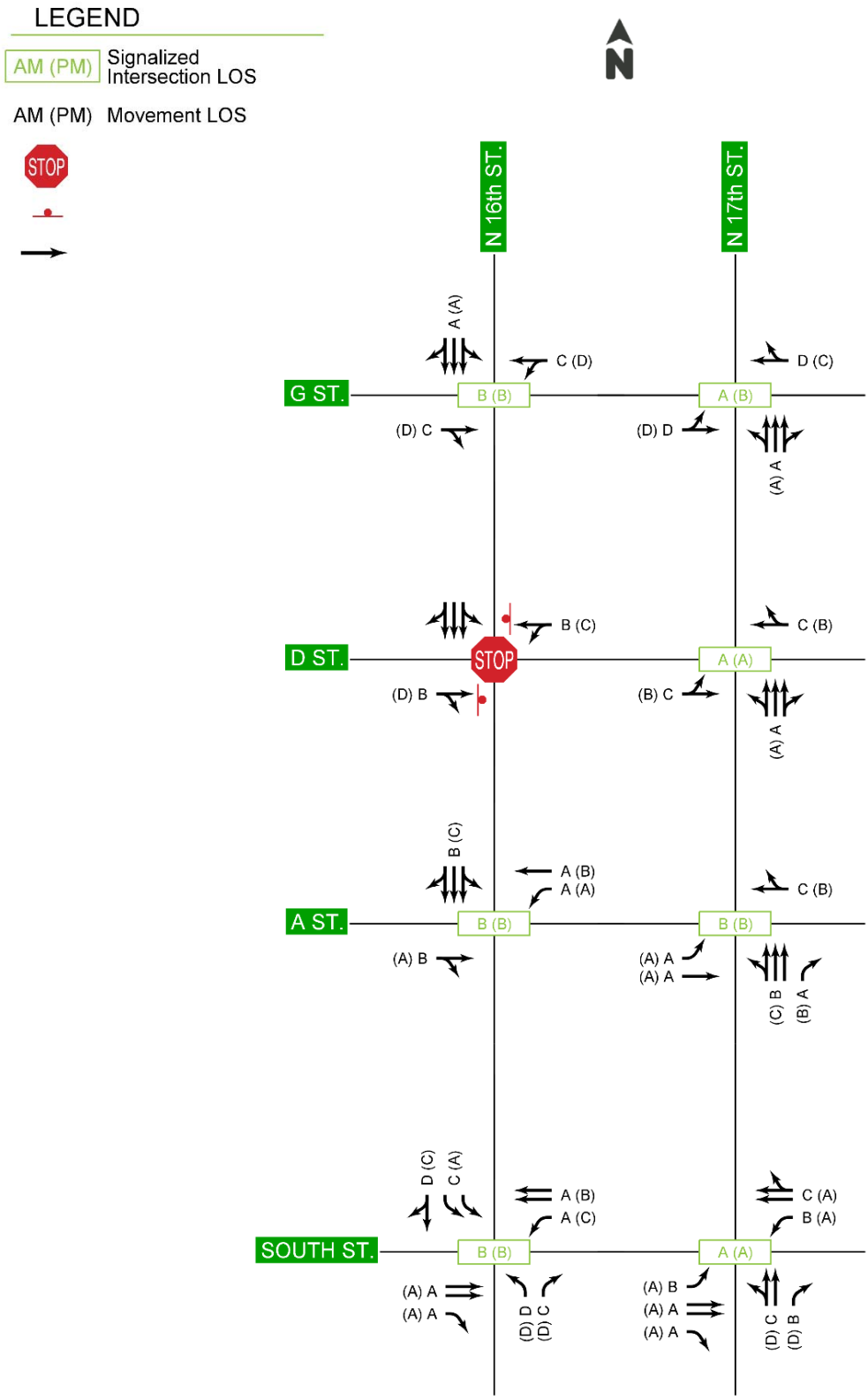

Figure 13. Scenario 1 Capacity Analysis (South)

4.2 Two-Way Volume Development

Two unique two-way volume datasets were developed for analysis in this study. These datasets correlate to the short-term and long-term two-way conversion buildout scenarios described earlier in this report. Scenario 2 traffic volumes consider a two-way conversion of 11th, 12th, 13th, 14th, M, and N streets in downtown Lincoln. Scenario 3 is an expansion of Scenario 2 where 16th, 17th, P, and Q streets are also converted to two-way operations.

Vehicle traffic from one-way pairs was split evenly in both directions (11th and 12th streets, 13th and 14th streets, and M and N streets). Knowing that destinations do not change, just the path availability, the volumes were altered to account for parking garage ingress/egress points. These access points were used to determine existing demand, the gap between intersection volumes, and rerouting based on new two-way operation paths available. Altering volumes was weighted toward taking the shortest path from the higher volume streets (9th, 10th, K, L, and O streets) to the destination/origin. Directional split of traffic at adjacent intersections was also considered when adjusting volumes. The directional split indicates where ingress/egress trips are likely to enter/exit the network area. Scenario 2 projected two-way volumes are illustrated in **Figure 14**.

The traffic volume projection methodology used for Scenario 3 adhered to what was followed with Scenario 2 with the one-way pair vehicular traffic split evenly between two-way pairs and adjusted for specific characteristics. Additionally, 16th Street volumes were adjusted on the south end to account for the through connection terminating at South Street at Bryan Medical Center West Campus. Even though Scenario 3 is expected to be converted in a 5–10 year timeframe, no growth in volume was assumed for the projected two-way volumes. Scenario 3 projected two-way volumes are illustrated in **Figure 15** and **Figure 16**.

4.3 Scenario 2 (Short-Term) Traffic Evaluations

After looking into multiple two-way high-level design concepts, it was decided to evaluate traffic operations for two unique alternatives of Scenario 2 conversions. Scenario 2A provides 3-lanes for vehicular traffic with a center TWLTL. Scenario 2A is expected to utilize more street width for vehicular capacity at the expense of parking availability. All corridors were analyzed for 3-lanes even if other constraints would physically make them not possible.

Scenario 2B provides one lane for vehicular traffic in each direction. This option decreases the vehicular capacity of each street but allows for more parking capacity and safer pedestrian treatments. Both options can be constructed with or without pedestrian nodes, but Scenario 2B would be able to decrease the pedestrian crossing distance by the width of one driving lane on each approach if the node were to be constructed.

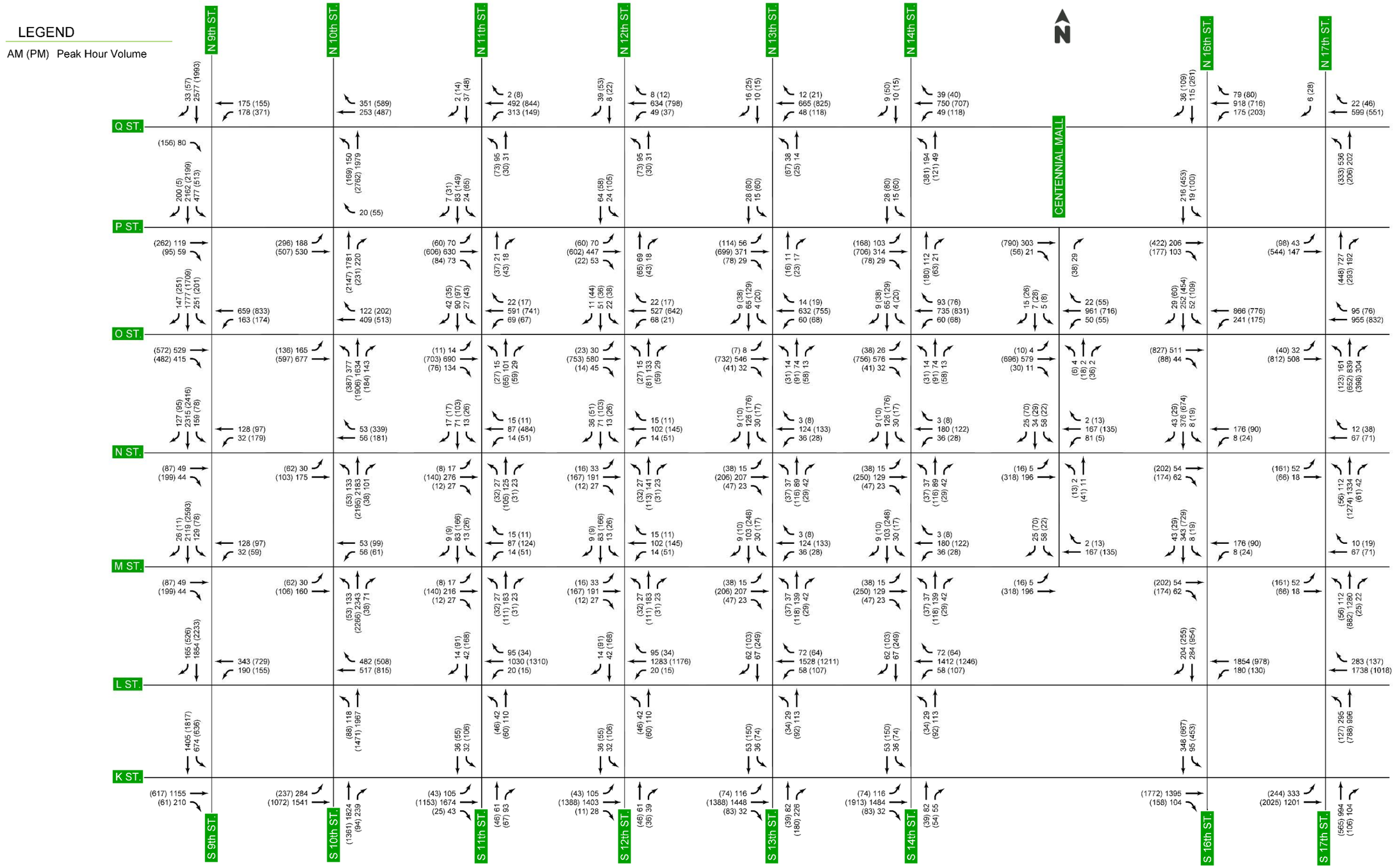

Figure 14. Scenario 2 Projected Two-Way Volumes

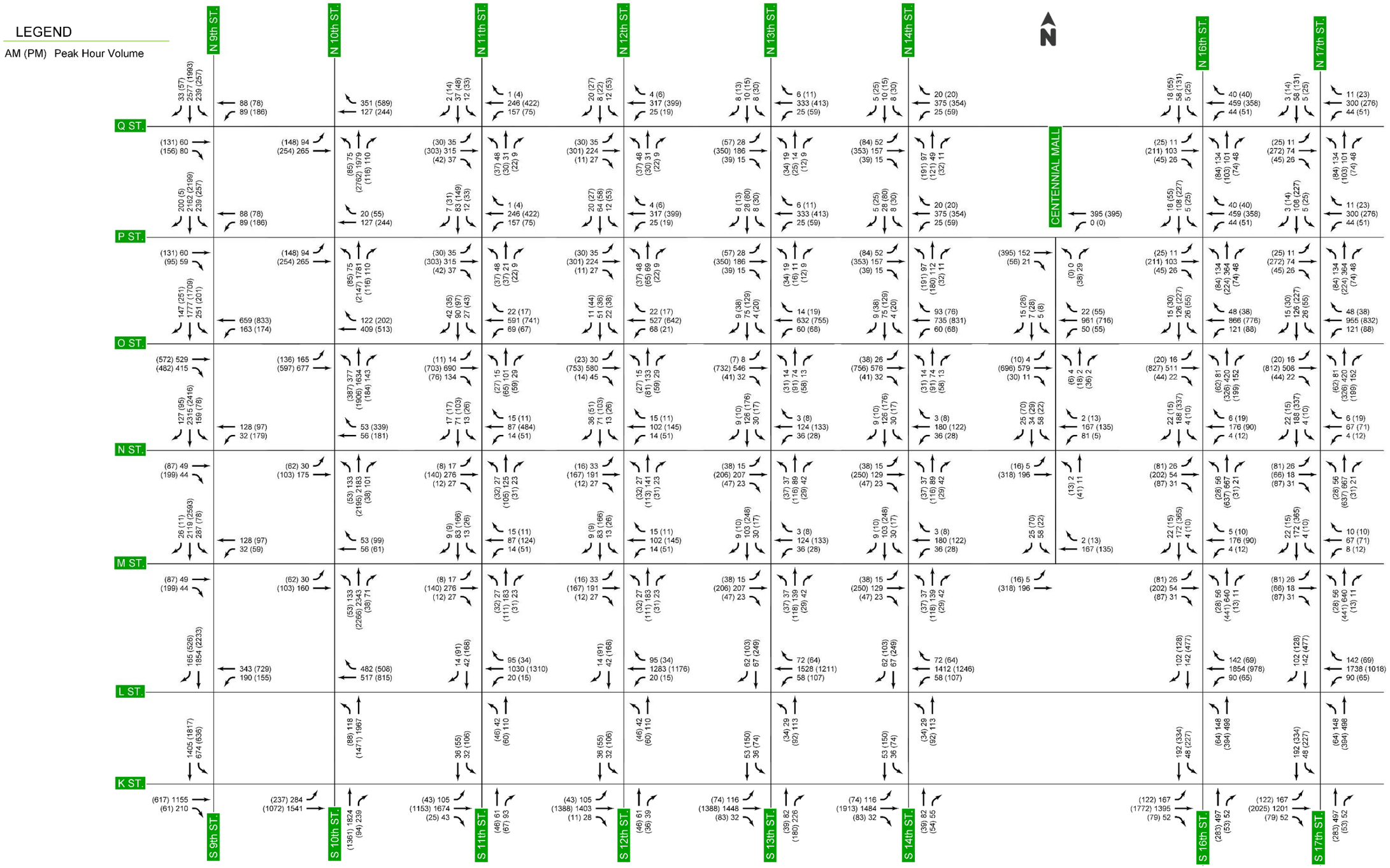

Figure 15. Scenario 3 Projected Two-Way Volumes (North)

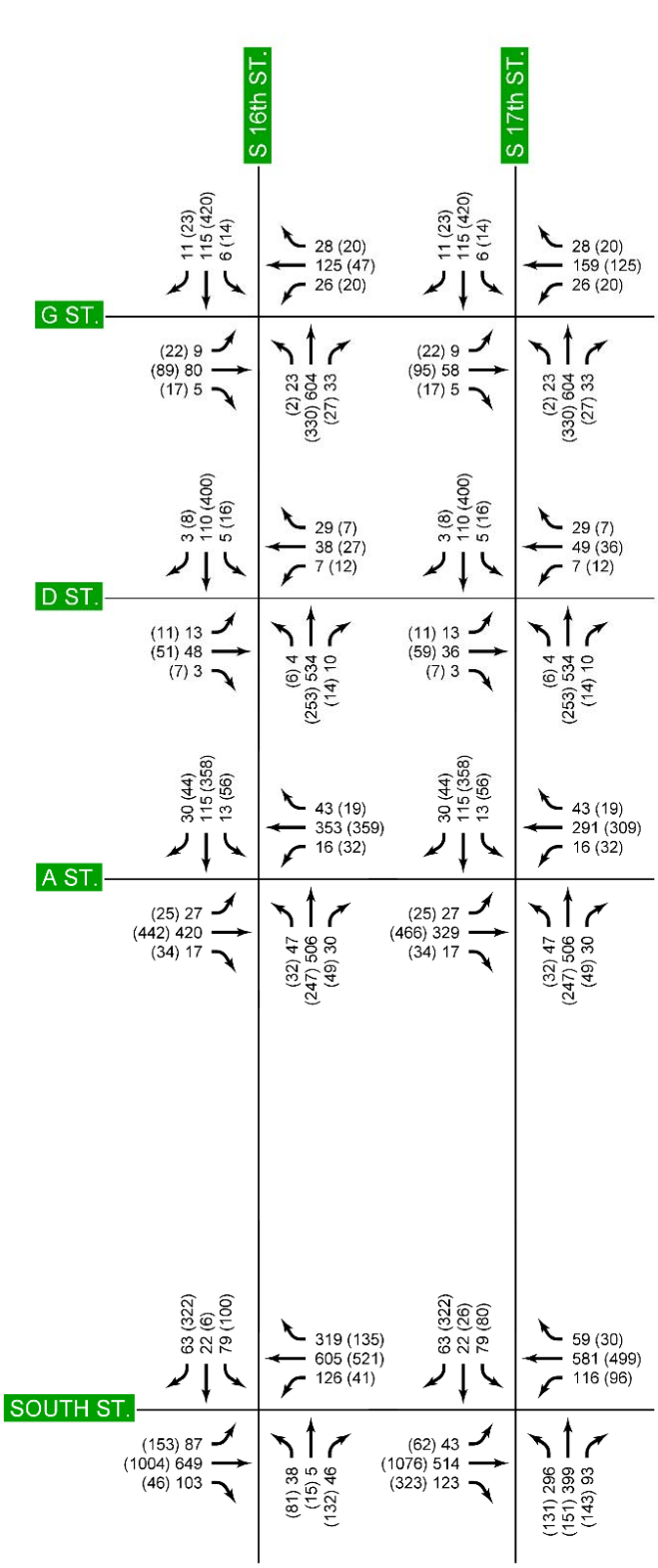

Figure 16. Scenario 3 Projected Two-Way Volumes (South)

Based on the projected Scenario 2 two-way traffic volumes, all existing signalized intersections were again evaluated for signalization warrants. It is important to note that several signals were maintained for capacity analysis purposes despite falling short of satisfying signal warrants. Signals were assumed at these locations based on safety concerns.

Two-way stop control was not considered appropriate for high density development and significant presence of pedestrians. Driver's perception of uncontrolled approaches on two-way stop-controlled intersections may create a false sense of mobility that could negatively impact other uses (pedestrians, bicyclists, parking movements, and turning movements/slowing or stopped in the traveling lane). Multilane approaches could have instances where vehicles would be stopped side by side on the same approach. The adjacent vehicles will block portions of the driver's vision and could create situations where one vehicle may obstruct the ability of the driver to view possible conflicts.

Vehicles on the same approach may also create confusion. For instance, if two vehicles are stopped side by side, a left-turning vehicle may advance through their movement. The vehicle adjacent to the left-turning vehicle may assume they can proceed straight through the intersection as well and may not see a pedestrian crossing the opposite crosswalk approaching from the drivers obstructed view. Vehicles stopped side by side, may also "fight" for clear sight lines by creeping further into the intersection to observe beyond the adjacent vehicle. Vehicles lose the ability to see conflicts and may start to creep further into the intersection. This creates a "battle" for sight lines and pose additional safety risks to cross traffic.

All-way stop control would have the same issues with side by side vehicles as two-way stop control. Since all vehicles must stop, severity of crashes would likely decrease, but sight line issues would not be fixed. All-way stop control also relies more on driver and pedestrian negotiation of shared space. Side by side vehicles double the number of potential drivers who may be participating in this space negotiation. Having side by side stopped vehicles limits the driver's ability to negotiate with other drivers at the intersection and could create more false starts proceeding into the intersection only to stop quickly when they perceive an issue.

Scenario 2B creates the possibility of removing traffic signals without creating sight distance issues when two vehicles are stopped side by side on the same approach. Scenario 2B was analyzed with some all-way stop controlled intersections along the M and N streets corridor (intersections where both streets no longer operate as one-ways). Multiple intersections in the Haymarket area currently use single-lane approach all-way stop control and would not be unfamiliar for users around the downtown area. Only peak hour two-way volumes were projected, so only peak hour signal warrants were analyzed. This signal warrant evaluation and traffic control assumptions for Scenario 2A and 2B is summarized, with detailed analysis results, in **Appendix D.**

Under Scenario 2A, intersections are expected to operate at LOS D except for 11th and N streets. The westbound approach and intersection are expected to operate at LOS F in the PM peak hour. These operations can be attributed in part to the Center Park Garage egress points from the facility onto N Street between 11th and 12th streets. Operations rely heavily on the ability of the 9th and 10th streets pair to serve traffic leaving the immediate downtown area. Scenario 2A, from an intersection operations standpoint, generally replaces the available capacity that was seen under Scenario 1. Since many intersections in the Scenario 2 conversions do not meet volume thresholds for signalization, a signalized intersection would be expected to provide sufficient operational capacity during peak demand. The tradeoff is that during off peak periods, drivers may experience higher delays at a signalized intersection than a stop-controlled intersection. A summary of Scenario 2A capacity analysis results are illustrated in **Figure 17**.

Under Scenario 2B, intersections are expected to operate at similar LOS as Scenario 2A. The single lane westbound approach at 11th and N streets operate at LOS F in the PM peak hour and leaving unserved demand during peak use. All other approaches analyzed at all-way stop controlled intersections are expected to operate at LOS C or better in peak hours. Compared to Scenario 2A, the average delay is overall similar but is generally higher for signalized intersections. At an intersection level, the single lane approaches at signalized intersections are not ideal. Although capacity analysis shows average operations being acceptable, individual experiences may differ greatly for everyday users during similar time periods. When left-turning traffic is not separated into their own lane, they block all progression in a particular direction until the opposing demand is served and pedestrian conflicts no longer remain. When these vehicles are at or near the front of the queue, they can create periods of unserved demand on their approach for varying amounts of time. Reliability of trips often plays a role in user experience and one lane approaches at signalized intersections would be expected to reduce the reliability of user's experience.

The intersection of 9th and N streets does have a considerable change in LOS from Scenario 2A to Scenario 2B. Without exclusive turn lanes, east-west vehicular traffic cannot be served while bicycles, with exclusive green time, utilize the cycle track. As a result, the AM peak hour operates at LOS F. Queues would also exceed the available space between the adjacent intersection. This would greatly affect the operations of multiple adjacent intersections and all signalized intersections along the 9th Street corridor leading up to the 9th and N streets intersection. For this reason, N Street was assumed as 3-lanes between 9th and 10th streets in all concepts.

In addition, Pinnacle Bank Arena event traffic operations would be greatly limited by a 2-lane section from 9th to 10th streets on N Street. Various event management tactics could be used to make 2-lane sections work for events on N Street, but a 3-lane section would allow more options (e.g., reversible lanes) to handle event demands. A summary of the Scenario 2B capacity analysis results are illustrated in **Figure 18**. Scenario 2A and 2B capacity analysis reports can be found in **Appendix E**.

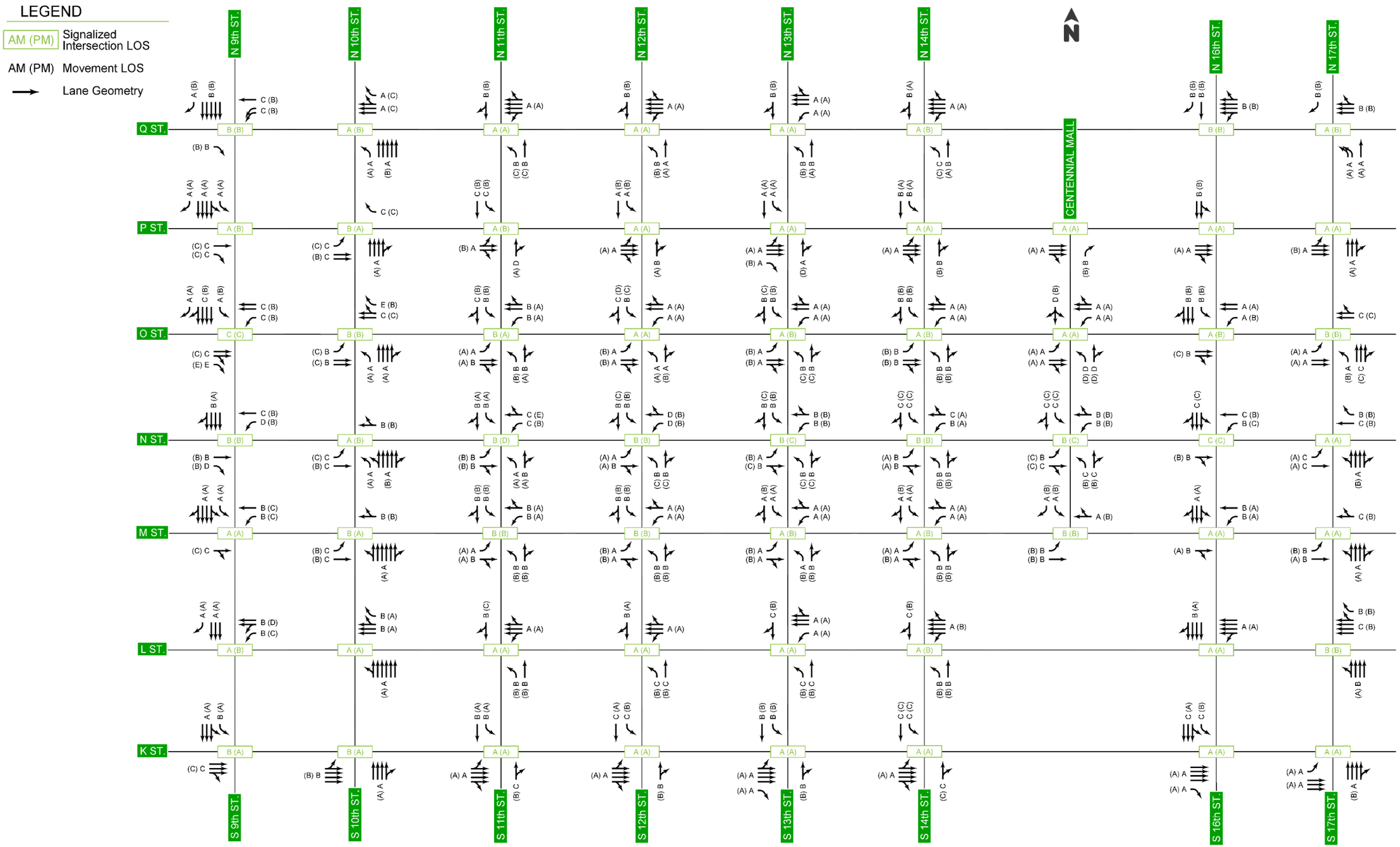

Figure 17. Scenario 2A Capacity Analysis

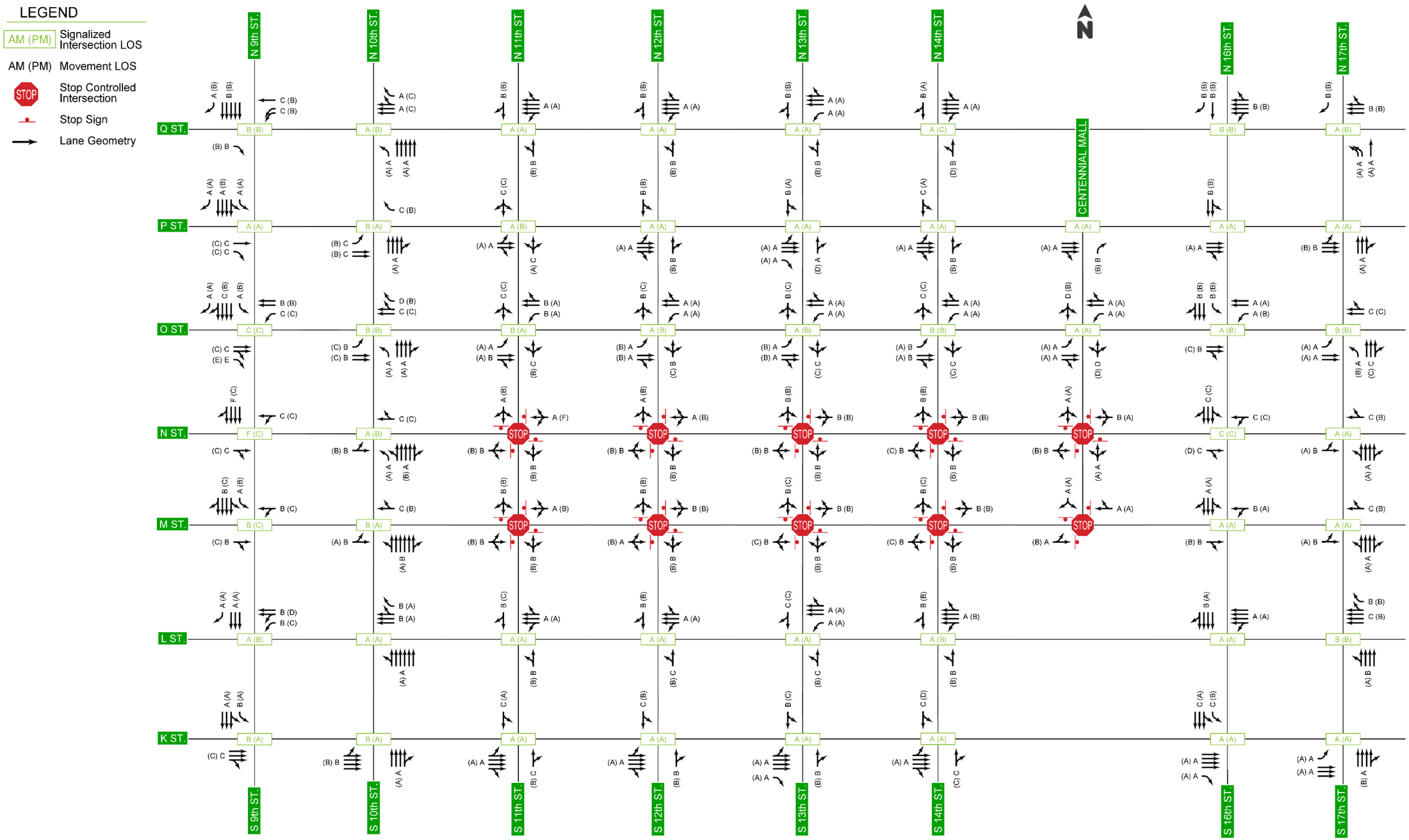

Figure 18. Scenario 2B Capacity Analysis

4.4 Scenario 3 (Long-Term) Traffic Operations

Scenario 3 adds long-term two-way conversion of P, Q, 16th, and 17th streets corridors to the street corridors analyzed in Scenario 2. Capacity analysis of two-way operations with a 2-lane section yields unacceptable delays and queues. Models indicate that queues would exceed the distance between intersections. Under Scenario 1 conditions, Q, P, 16th, and 17th streets have three or four lanes of capacity in one direction. Reducing all four corridors down to 2-lanes, one in each direction, would eliminate enough capacity that peak operations would not operate at acceptable LOS. Under existing conditions, drivers have more than sufficient capacity and the induced demand from these conditions exceeds the peak hour capacity of a 2-lane facility. To address these findings, only a 3-lane section was carried forward for further analysis. Traffic volumes should be monitored after conversion of Scenario 2 to confirm that these assumptions remain valid.

Based on the projected Scenario 3 two-way traffic volumes, all existing signalized intersections were again evaluated for signalization warrants. It is important to note that several signals were maintained for capacity analysis purposes despite falling short of satisfying signal warrants. Although signal warrants are not expected to be warranted based on volumes, many streets operations suffer under stop-controlled intersections. In a downtown environment, if one street fails to operate at a sufficient LOS, adjacent intersections can become affected and cause jams that cause compounding delays. For these reasons, signalization was assumed for all existing signalized intersections on Q, P, 16th, and 17th streets. This signal warrant evaluation and traffic control assumptions for Scenario 3 is summarized with detailed analysis results in **Appendix F.**

No existing turning movement count data was available for 27th and Q streets (unsignalized intersection). If P Street is converted to two-way operations, the signalized intersection of 27th and P streets should be removed due to the proximity of 27th and O streets. AMP practices may convert this intersection to right-in, right-out (RIRO) and would likely be unable to provide storage capacity for a northbound left-turn movement.

Scenario 3 corridor intersections are expected to operate at similar LOS as existing conditions. The intersection of 16th and N streets operate at LOS E in the AM hour. Some individual movements are expected to operate at LOS E or LOS F. This is due to the decrease in the number of through lanes. Scenario 3 capacity analysis is illustrated in **Figure 19** and **Figure 20**. Scenario 3 capacity analysis reports can be found in **Appendix G**.

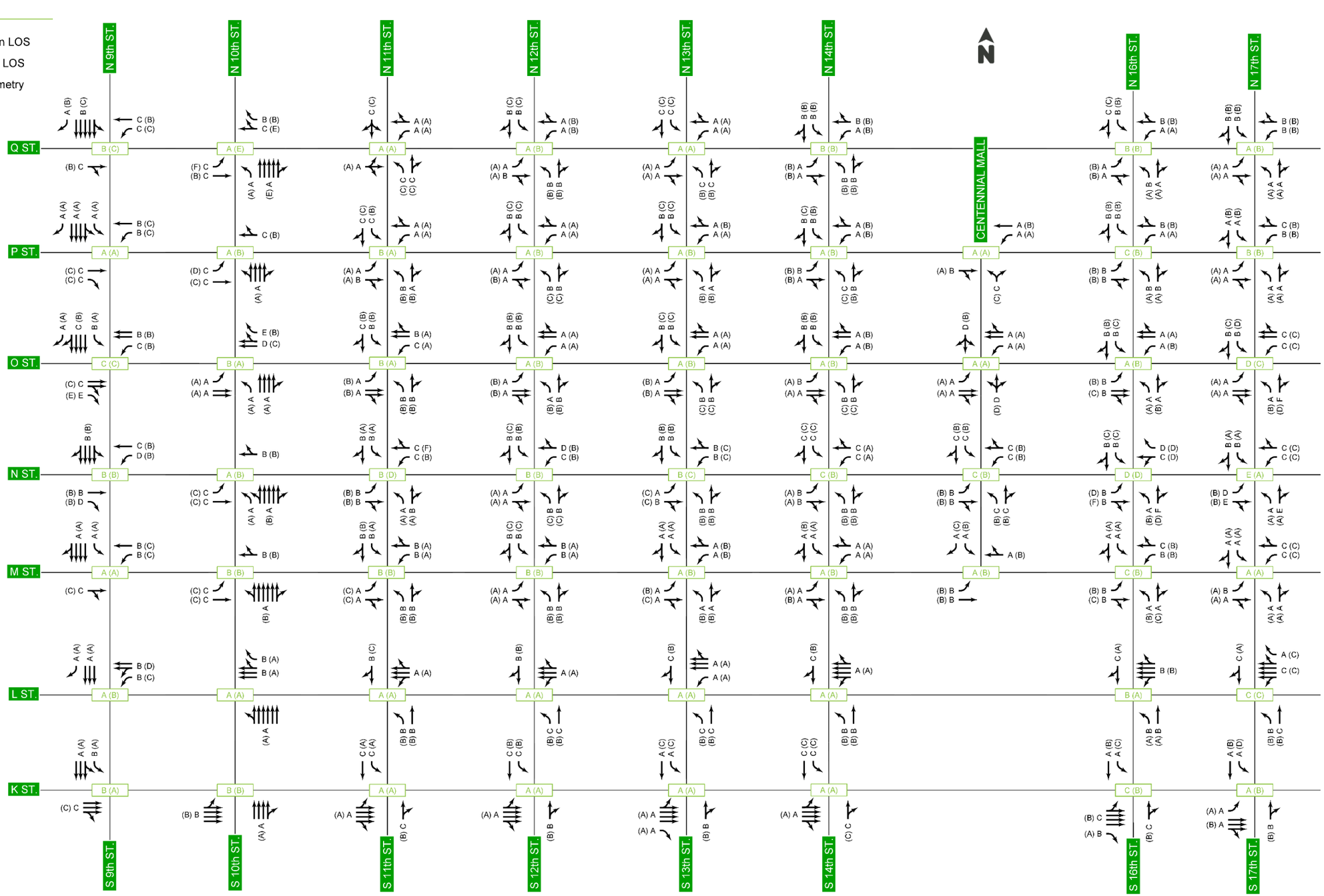

Figure 19. Scenario 3 Capacity Analysis (North)

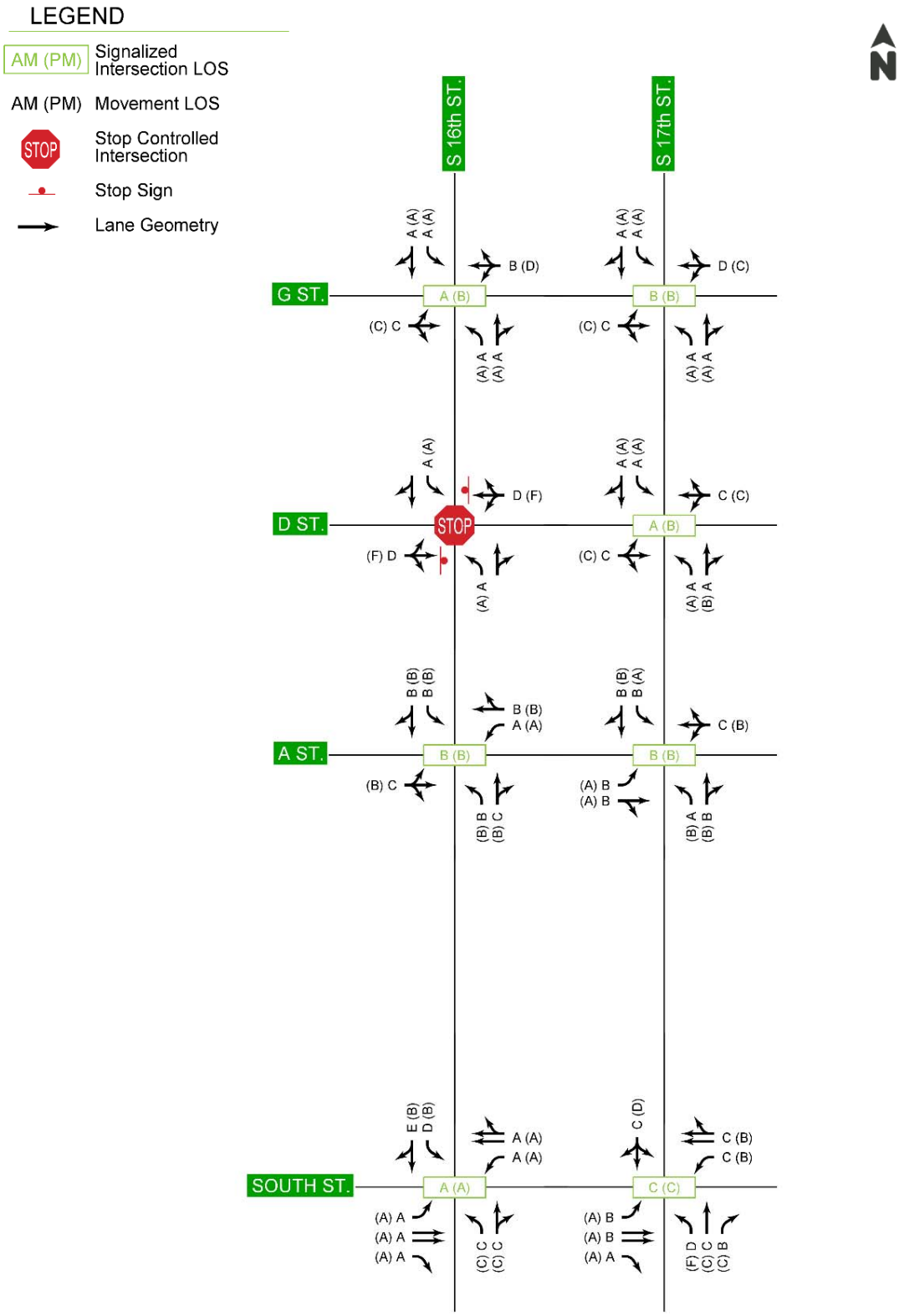

Figure 20. Scenario 3 Capacity Analysis (South)

At the intersection of 27th and Q streets, geometric modifications would be necessary to provide a full movement T-intersection. Under unsignalized control, further evaluation would be necessary to determine if allowing an eastbound left-turn is a safe and best practice. Future access management practices may convert this intersection to RIRO operations.

4.5 Safety

One of the most important evaluations of whether a conversion is appropriate is the safe movement of all transportation modes within the system. This report generally provides safety comparisons of one-way and two-way operations. In the citywide study, some of the intersections with higher rates or severity rate of crashes based on characteristics of the intersection occur within the study area. These intersections include:

9th Street	10th Street	13th Street	16th Street	17th Street
• M Street	• K Street	• O Street	• K Street	• K Street
• O Street	• N Street		• P Street	• O Street
• Q Street	• O Street		• Q Street	
	• P Street			

Some downtowns across the United States have studied implementing two-way conversion of one-way streets, but the overall number of projects completed is relatively low. Comprehensive analysis of the safety benefits for multiple projects in a variety of locations is not readily available to discern good practices from similar projects, but some conversions in specific communities have been analyzed for safety and network characteristic changes. In a study of one-way to two-way conversions in downtown Louisville, Kentucky, the rate of crashes decreased on converted streets by 40-70% even as average daily traffic increased when comparing the data immediately before and after construction (*Two-Way Street Conversion: Evidence of Increased Livability in Louisville*, 2015). This is consistent with research that has shown that one-way to one-way left-turns are considered the most dangerous for pedestrians due to the unique positioning of vehicles near the crosswalk at the beginning of the turn. This spacing creates a visual check for drivers that is not consistent with any other left-turn movements made by vehicles and the negotiation of shared space occurs in a condensed time frame. Two-way traffic increases the friction with competing priorities of parking, turning vehicles, and the generally slower operating speeds likely play into the increased safety. Two-way operations would also eliminate wrong way on one-way crashes.

With a 3-lane section as analyzed in Scenario 2A, intersections would have dedicated left-turn lanes at intersections. Removing left-turn vehicles from a shared thru lane better identifies the conflicts between pedestrians and left-turning vehicles. This eliminates the potential of the first vehicle in a single lane queue holding up all vehicles when waiting to turn left against oncoming traffic. Any scenario where drivers are under less pressure to make quick judgements to avoid long delays can reduce aggressive behavior. Left-turn lanes would be expected to reduce rear-end, side-swipe, and right-angle crashes.

With a 2-lane section as analyzed in Scenario 2B, some intersections are identified as potential unsignalized intersections with all-way stop-control (ASWC). AWSC intersections eliminate permissive behavior of signalized intersections, where users are specifically controlled by restricting access to enter the intersection until permission to enter is given at particular intervals and rely on all users negotiating conflicting movements. Pedestrians often experience a positive benefit from these types of intersections knowing all vehicles are to stop and may negotiate intersection crossings with less delay. Vehicles can be disadvantaged by the loss of pedestrian controlled access intervals. If compliance decreases due to long delays and decreased opportunities for vehicles to find sufficient gaps in other users, safety can be diminished.

4.6 One-Way vs. Two-Way Comparison

A summary of pros and cons for both networks are listed below:

<u>One-Way Operations</u>

Pros:

- Increased mobility
- Easier to bypass parking maneuvers
- Prevailing condition

Cons:

- Circuitous
- Unfamiliar/partial one-way network
- Increase safety risks
- Confusing
- Potential wrong-way on one-ways

<u>Two-Way Operations</u>

Pros:

- More accessibility
- Easily understood
- Safer operations for more users
- More uniform layout of intersections (expectations)

Cons:

- Less capacity for vehicular traffic
- Decreased mobility
- On-street parking supply