HENNEPIN COUNTY

FREIGHT STUDY

2016

Task 3: Truck System Performance

Contents

Introduction

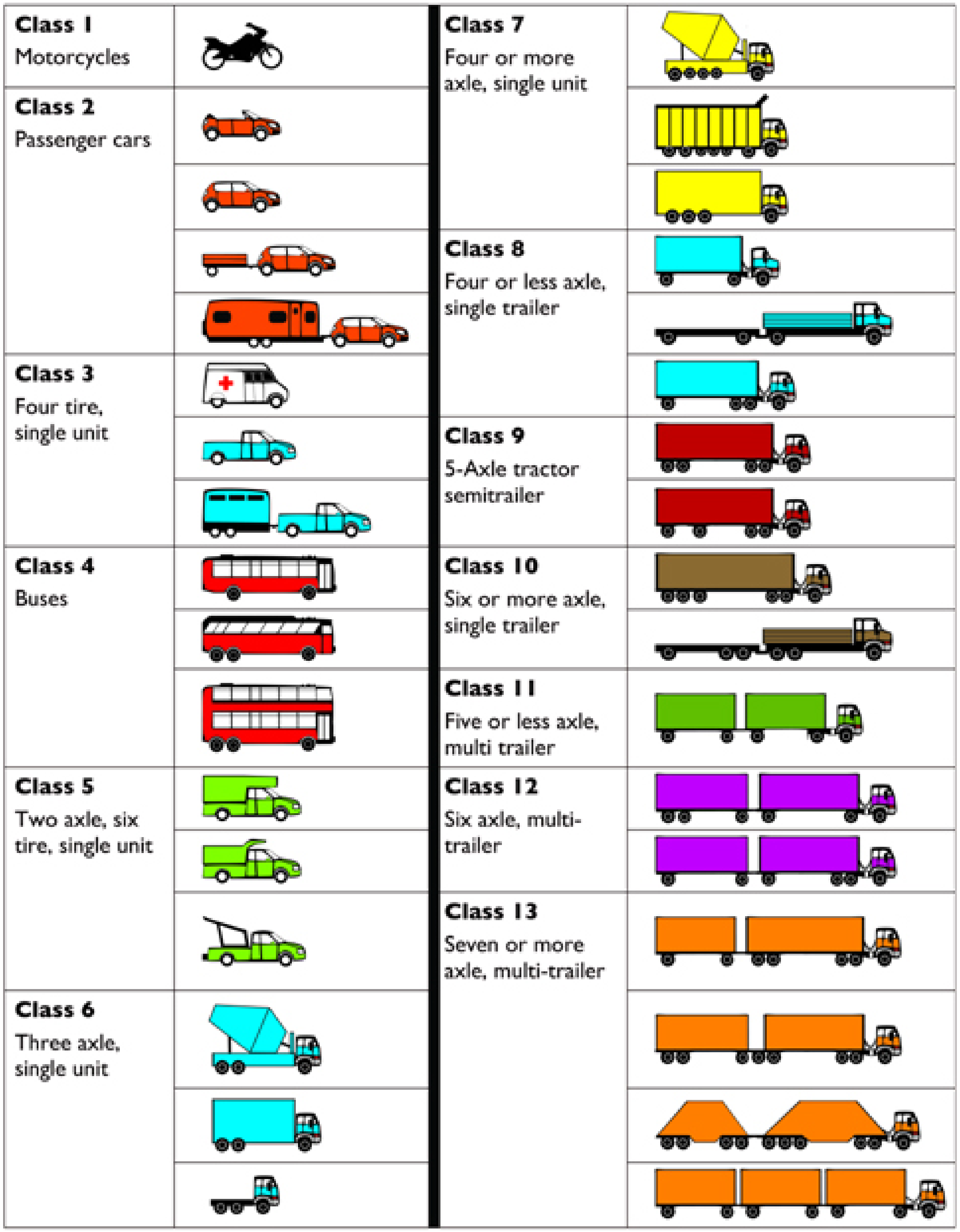
Hennepin County is undertaking a Freight Study to understand how the County's transportation networks are being used for the handling of freight. The study will examine how current freight uses are evolving, and how projected trends may affect the County's priorities, projects, and policies regarding the freight system. This technical memorandum documents Task 3, measuring truck performance on the Hennepin County roadway network.

Understanding network performance is important for identifying locations where operational and/or infrastructure investments are needed to improve roadway user experience and safety. In this analysis, truck crash data from the Hennepin County Public Works Department and truck global positioning system (GPS) data from the American Transportation Research Institute (ATRI) are utilized. Truck GPS data from ATRI is important for gauging congestion and reliability performance measures for the County highway network as these roadways are typically not covered in the Federal Highway Administration's National Performance Research Management Data Set. The primary source of ATRI truck GPS data is onboard communications equipment installed on large commercial vehicles (typically Class 8 and higher as shown in Figure 1).

For the analysis conducted as part of this study, ATRI truck GPS data was acquired for four two-week periods in the year 2015 for the months of March, May, August, and October. By examining data over various months throughout a calendar year, the analysis is able to reflect changes in performance or County roadway network use due to seasonality. The data covers Hennepin County including a 1-mile radius around the County's boundaries, and includes the entire roadway system, including County-owned roads. There were 112,346 trucks included in the data. As most previous analysis has focused on the performance of the National Highway System, this study focuses on the County roadway network.

The remainder of this report is divided into the following sections: analysis of truck speeds; truck travel time reliability; truck volumes; safety; and general conclusions. Following the main body of the report are two appendices containing additional methodological details of the analysis and maps.

Figure 1: FHWA Vehicle Category Classification



Source: Federal Highway Administration.

Overview of Truck Performance Analysis

The performance analysis utilizes the truck GPS data to derive measures of truck speed and truck travel time reliability for the Hennepin County roadway network. Similar types of analysis have been conducted and are underway by the Minnesota Department of Transportation and the Metropolitan Council; however, these focus on the NHS system only and do not include information on county roadways. It is important for Hennepin County to understand the performance of its entire system for trucks, both on County owned and other roadways. This analysis identifies corridors and locations of limited mobility for trucks in the County. Additionally, from the GPS data the analysis identifies those routes on the County network that have high volumes of truck traffic. Finally truck crash data from the Hennepin County Public Works Department was also analyzed to identify locations on the County network where truck crashes are prevalent.

PREVIOUS MNDOT ANALYSIS OF THE STATE SYSTEM

The Minnesota Department of Transportation (MnDOT) released a study in 2014 on utilizing truck GPS data for performance analysis in the Twin Cities Metropolitan Area. In addition to ATRI truck GPS data, that study also utilized Weigh-in-Motion (WIM) data, loop detector data, and truck travel time data from the National Performance Management Research Data Set (NPMRDS) among others. For the analysis of the ATRI truck GPS data, the study primarily focused on interstate highways, U.S. routes, and State routes. However, County State Aid Highways (CSAH) 32, 42, and 101 were included in the analysis. The MnDOT study calculated a number of performance measures for roadways in the Twin Cities area including average speeds and delay. From that analysis, MnDOT was able to identify bottlenecks based on delay, unreliability, and the total time spent traveling below a threshold speed along the region’s primary freight corridors.

The MnDOT study concluded that most truck bottlenecks in the Twin Cities metropolitan area are located at interchanges. In Hennepin County, the top morning peak truck bottlenecks identified included I-494 at I-94 near Maple Grove, US 169 at I-94, TH 100 at I-94, I-394 at I-94, and I-694 at I-94. The top evening peak truck bottlenecks identified included I-494 at I-394, US 169 at I-394, I-494 between US 169 and I-35 W, TH 62 at US 169, and I-35 W at I-94. As the MnDOT analysis concentrated on the region’s primary highways, none of the identified freight bottlenecks were located on the County’s network.

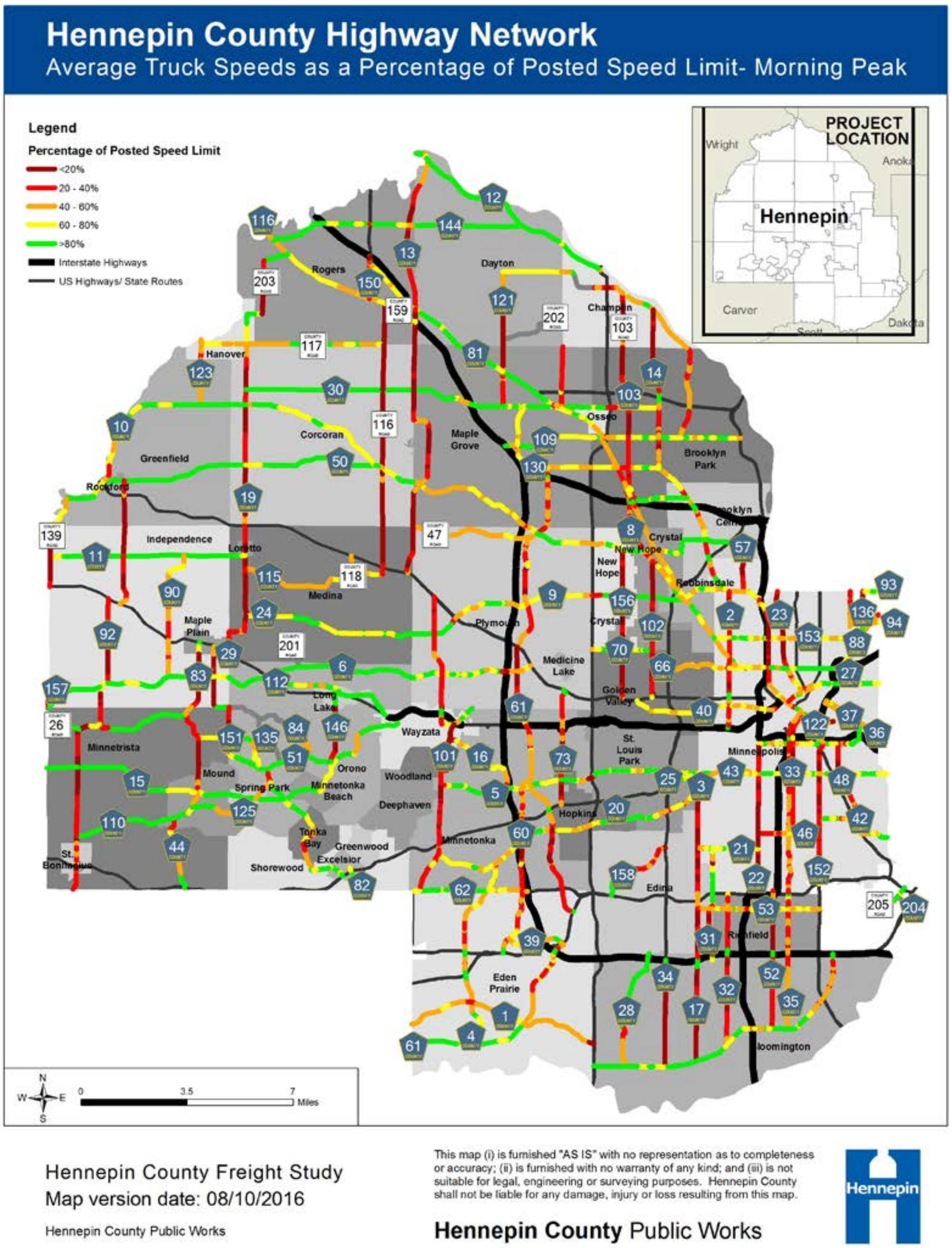
Truck Speed Analysis

Figures 2 and 3 show truck speeds as a percentage of posted speed limit on the Hennepin County roadway network for both the morning and evening peak periods. The results shown in these figures average truck speeds across all months for which the data was available – March, May, August, and October 2015. In this manner, the results indicate general performance levels as opposed to speeds affected by seasonality. For the analysis, truck travel at 80 percent of the posted speed limit was utilized as the reference point for congestion. Therefore, speeds at percentages below that reference indicate relatively poor performance.

As shown in Figure 2, the results of the truck speed analysis indicate that during the morning peak period motor carriers are generally able to operate at higher rates of speed outside of the perimeter formed by I-494 and I-94 than within it. This is intuitive as the County's more densely populated municipalities, namely the City of Minneapolis, are located within the perimeter. While the average truck speeds closer to the urban core likely reflect congestion to some degree, they also likely reflect motor carriers purposefully operating at lower speeds even beyond to the posted speed limit. This can be due to the need to operate at lower speeds to ensure the safety of the driver and other roadway users.

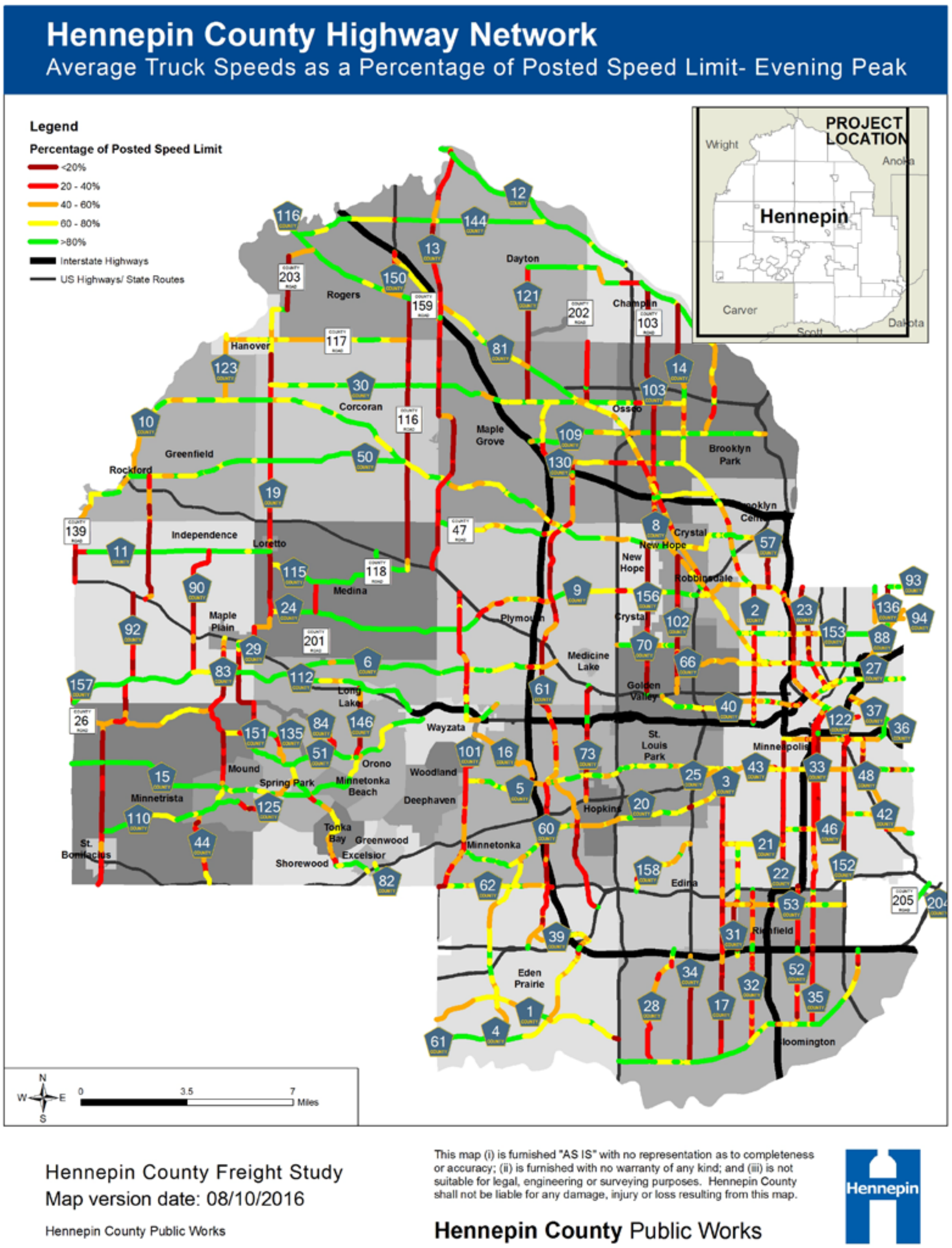
Figure 3 suggests similar performance during the evening peak period. Generally, lower average truck speeds are observed on the same portions of the network (i.e. the County's urban core and some north-south routes west of I-494). While there are differences in performance throughout the network, the results indicate that the overall magnitude of truck speeds as a percentage of posted speed limit are largely consistent through the course of a day. Figures 4 and 5 contain the same information as Figures 2 and 3, respectively, but zoom in on the perimeter formed by I-494 and I-94/I-694. These maps show the concentration of low truck speeds in the urban core of the County.

Figure 2: Morning Peak Average Truck Speeds as a Percentage of Posted Speed Limit on the Hennepin County Roadway Network



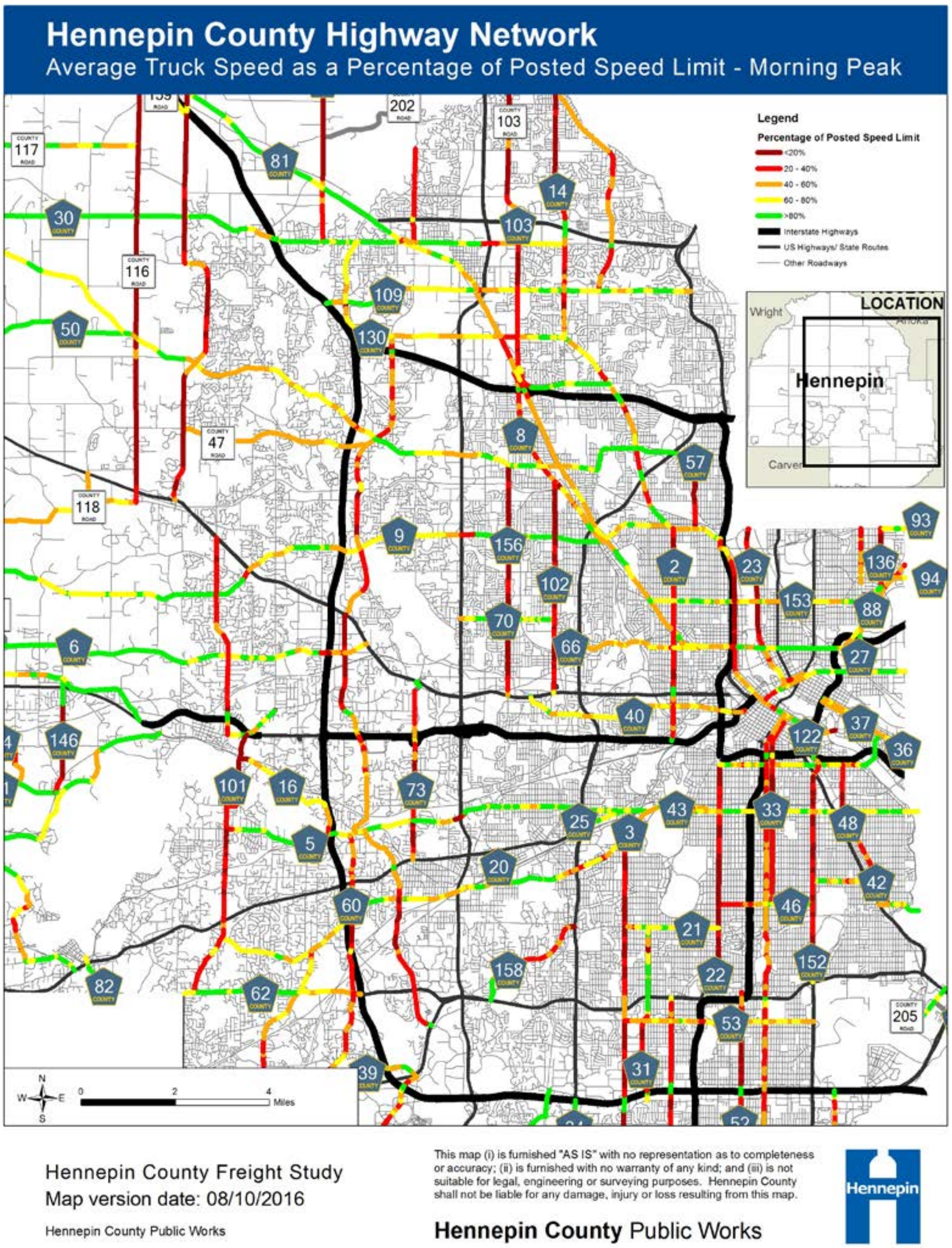
Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

Figure 3: Evening Peak Average Truck Speeds as a Percentage of Posted Speed Limit on the Hennepin County Roadway Network



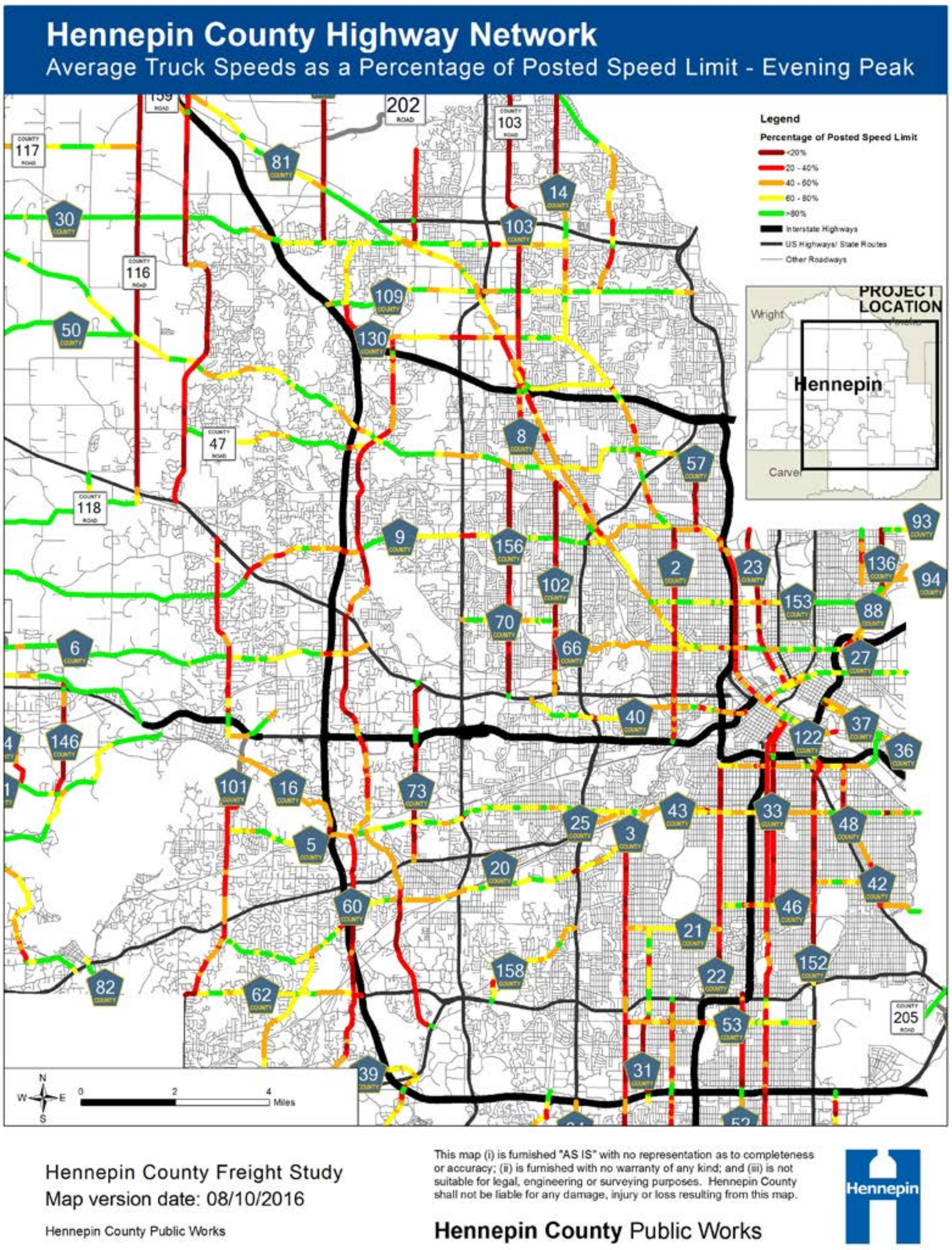
Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

Figure 4: Morning Peak Average Truck Speeds as a Percentage of Posted Speed Limit on the Hennepin County Roadway Network



Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

Figure 5: Evening Peak Average Truck Speeds as a Percentage of Posted Speed Limit on the Hennepin County Roadway Network



Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

To the west of I-494, the analysis suggests that north-south routes throughout the County tend to exhibit slower average truck speeds than east-west roadways. For instance, CSAH 19 (from CSAH 117 to U.S. 12), CSAH 83/CR 110 (from U.S. 12 to CSAH 44), CSAH 90 (from CSAH 11 to CSAH 6), CSAH 92 (from TH 55 to TH 7), and CR 116 (from CSAH 116/CSAH 159 to TH 55) all exhibit average speeds that generally range from 12 to 24 miles per hour as shown in Table 1. The worst performing roadway was CR 116 which had average truck speeds of 6 and 7 mph during the morning and evening peak periods, respectively. It should be noted, however, in 2015 there was construction on I-494 in the Maple Grove and Plymouth areas in which through truck movements were diverted to alternate routes. This likely contributed to the observed congestion at this location and also along CSAH 61.

Given that many of these roadways do not traverse densely populated areas of the county, their low speeds are not likely due to congestion. Several of these roadways consist of only one lane in each direction and in some cases have grade-level crossings (e.g. CSAH 19 and CSAH 90) which could contribute to their performance. Many of these roadways' travel lanes appear to measure 12 feet wide which could also be a contributing factor as trucks generally require wider lanes to achieve higher speeds. In addition, some of these roadways appear to serve agricultural areas which could indicate that the observed trucks are farm-related. All together, these factors likely create operating environments which encourage slower truck travel.

The primary implication of the truck speed analysis is that much of the Hennepin County highway network provides for adequate rates of speed given the location and functional classification of roadways. Roadways outside of the County's urban core, generally west of I-494, exhibit average truck speeds that approach their posted speed limits. In addition, roadways with higher functional classifications (namely arterials) provide for higher average truck speeds. However, several of the County's north-south roadways tend to exhibit slower speeds.

Table 1: Corridors with the Lowest Average Speeds

Corridor	Average Morning Peak Truck Speed (Miles per hour)	Average Evening Peak Truck Speed (Miles per hour)
CSAH 19	12	12
CSAH 83/CSAH 110	13	13
CSAH 90/Lake Sarah Rd.	24	13
CSAH 92/Main St.	13	13
CR 116	6	7

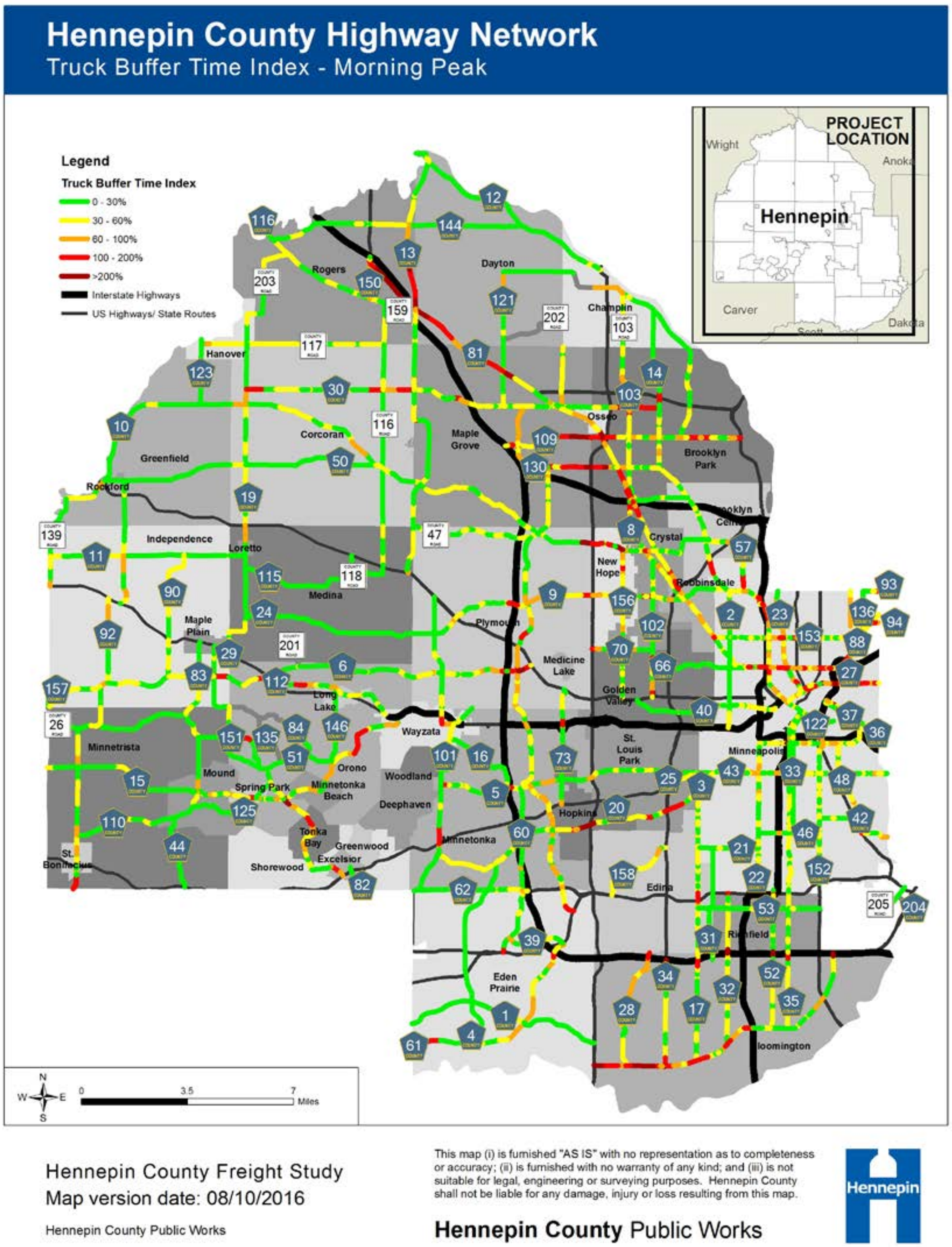
Truck Travel Time Reliability Analysis

Travel time reliability is a measure of the variability of the travel time on a segment of roadway. In this analysis, it is measured through the calculation of a buffer time index. The buffer time index indicates the amount of extra time (i.e., buffer) that must be scheduled into a trip that ensures on-time arrival for 95 percent of trips. For a given roadway segment, the buffer time index is calculated as the difference between the 95th percentile and average travel times divided by the average travel time: (95th Percentile Truck Travel Time – Average Truck Travel Time) / Average Truck Travel Time. A higher buffer time index indicates poorer travel time reliability while lower values indicate relatively good travel time reliability. As an example, suppose that the average trip time between two locations is 10 minutes and the buffer time index for travel between the two locations is 50. Then, to achieve an on-time performance of 95 percent, it is necessary for a truck to plan for a 15-minute trip (i.e., 10 minutes + 10 x 50 percent = 15 minutes).

Figures 6 and 7 show the truck travel time reliability during the morning and evening peak periods. Figures 8 and 9 contain the same information, but zoom in on the perimeter formed by I-494 and I-94/I-694. Like the truck speed analysis, the buffer time indices were averaged across all months of available data to present a single overall measure by time period. A buffer time index of 30 percent was chosen as the reference point for the maps. Buffer time measures exceeding 30 percent suggest poor reliability on the network.

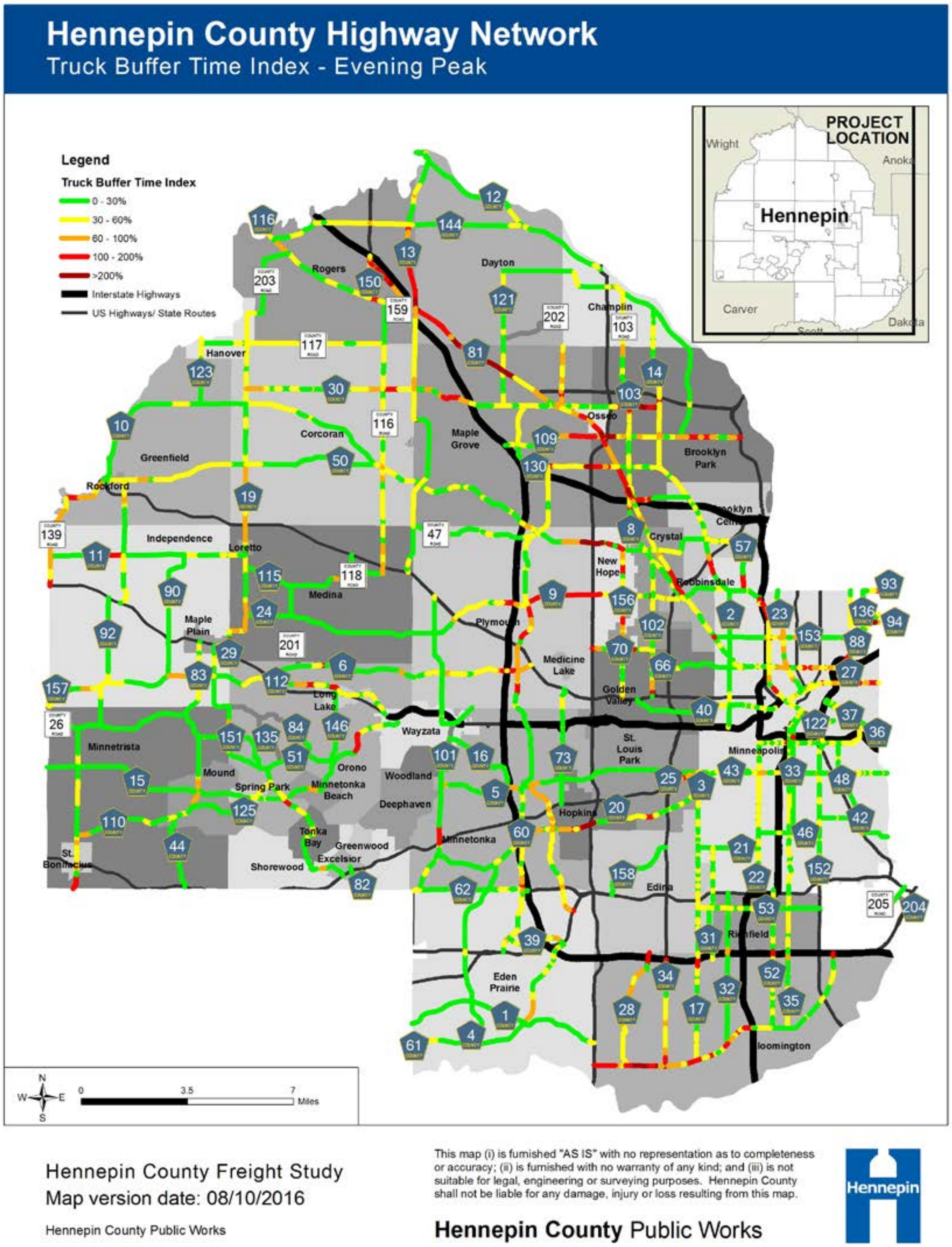
Overall, the results suggest that much of the County's network provides for reliable truck travel times. Buffer times on the network are largely below 60 percent indicating that motor carriers do not have factor significant amounts of extra times into their schedules. This is important as extra scheduled time directly affects motor carrier operating costs. Given the results observed in the truck speed analysis the reliability results also indicate that though average speeds on several portions of the network are relatively slow, they are consistent.

Figure 6: Morning Peak Average Truck Travel Time Reliability on the Hennepin County Roadway Network



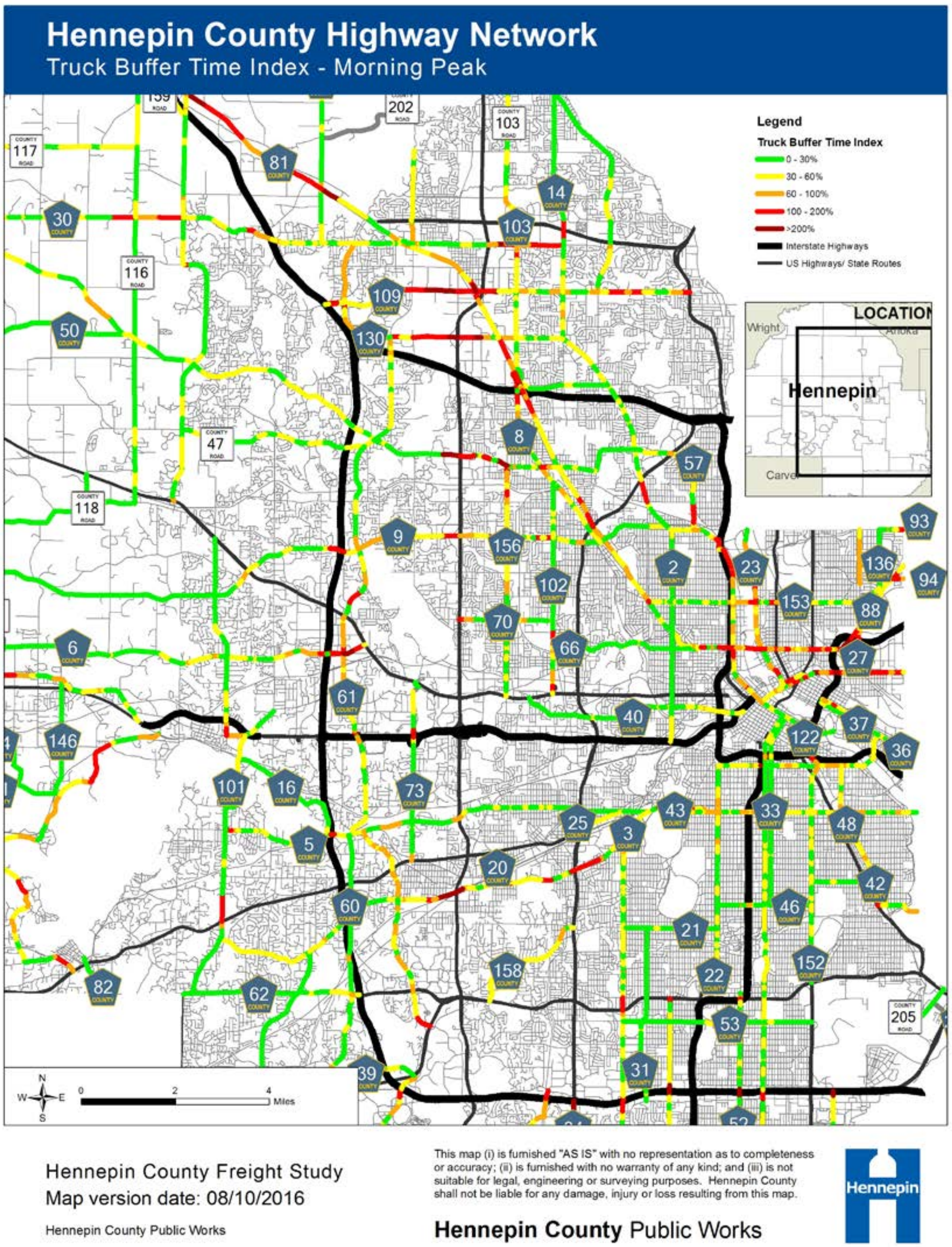
Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

Figure 7: Evening Peak Average Truck Travel Time Reliability on the Hennepin County Roadway Network



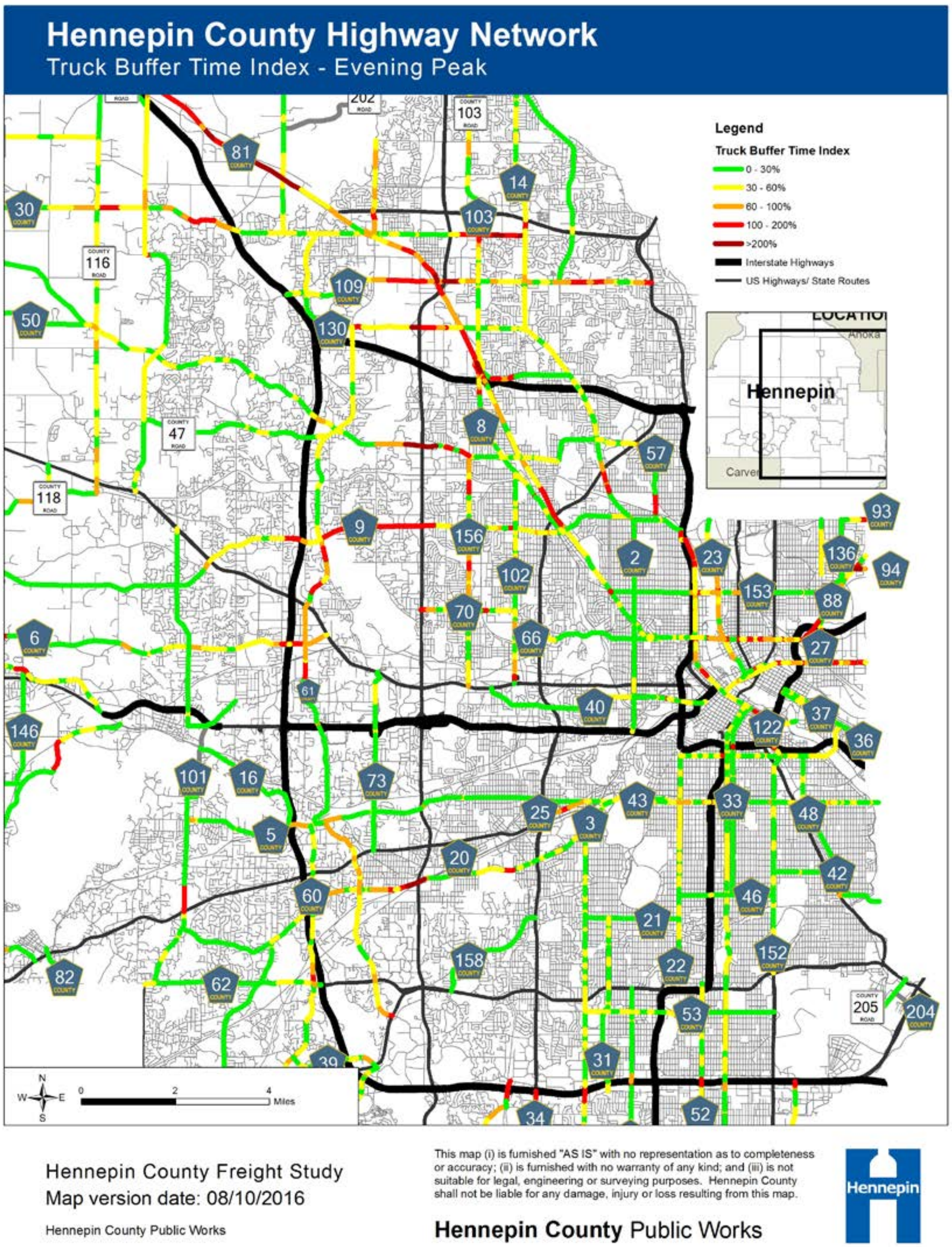
Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

Figure 8: Morning Peak Average Truck Travel Time Reliability on the Hennepin County Roadway Network



Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

Figure 9: Evening Peak Average Truck Travel Time Reliability on the Hennepin County Roadway Network



Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

Table 2: Corridors with the Highest Average Unreliability

Corridor	Average Morning Peak Truck Travel Time Reliability	Average Evening Peak Truck Travel Time Reliability
CSAH 1/West 98th St.	102%	92%
CSAH 9/Rockford Road	78%	101%
CSAH 61/Northwest Blvd.	61%	57%
CSAH 81/Bottineau Blvd.	162%	169%
CSAH 109/Weaver Lake Road	120%	73%

Relatively poor reliability is observed on a handful of routes throughout the County. These include CSAH 81 (between TH 101 and CSAH 121), CSAH 109 (between I-94 and U.S. 169), CSAH 9 (between U.S. 169 and I-494), CSAH 61 (between CSAH 9 and I-394), and CSAH 1 (between U.S. 169 and I-35W), among others. These routes are primarily located in the Cities of Brooklyn Park, Plymouth, and Bloomington. Several of these routes closely align with regional freight/industrial and commercial centers (such as CSAH 1 in Bloomington and CSAH 61 in Plymouth).

The unreliable travel times observed in these areas are likely due to trucks navigating roadways with increased demand. According to MnDOT traffic count data, several of these corridors (namely CSAH 1, CSAH 61, CSAH 109, and CSAH 81) are among the most heavily utilized routes in Hennepin County. Several have observed average annual daily traffic (AADT) levels greater than 30,000 vehicles along some portions. Demand at this level can contribute to poor truck travel time reliability as roadways approach capacity-constrained conditions.

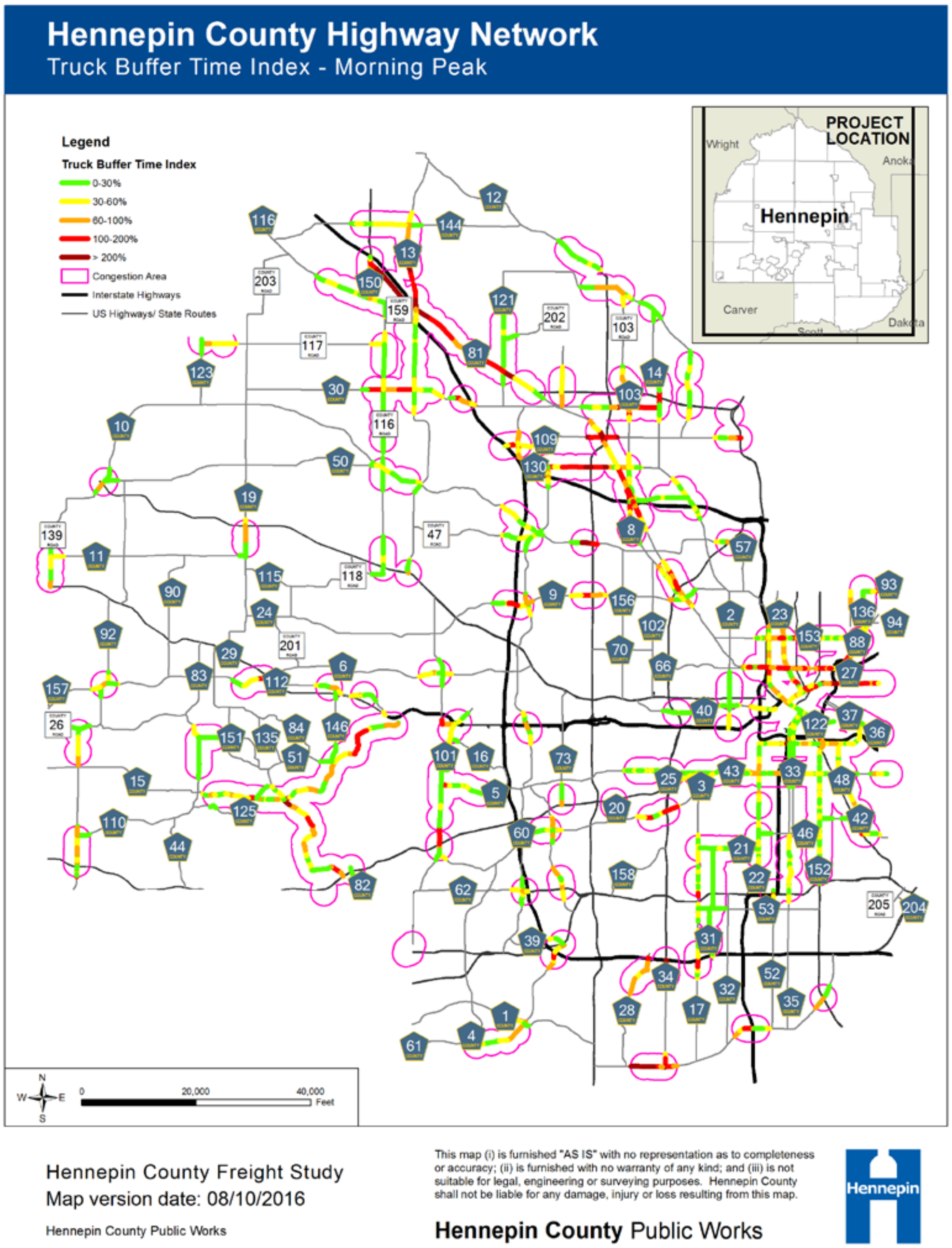
In addition, the portions of the routes with the most unreliable travel times also tend to contain major intersections. For instance, the portion of CSAH 9 identified intersects with CSAH and has on/off-ramps with U.S. 169 and I-494; the portion of CSAH 61 identified intersects with CSAH 9 and TH 55; CSAH 81 intersects with I-94, TH 610, and U.S. 169. The presence of several large intersections within a relatively short distance can contribute to poor reliability due to the significant amount control delay imposed at each signalized intersection.

FUTURE YEAR CONGESTION

The 2030 Comprehensive Plan identified portions of the Hennepin County highway system that are predicted to experience significant congestion by the year 2030. Roadways that were predicted to have volume/capacity ratios of 1.0 – 1.20 were classified as areas of possible congestion while roadways with volume/capacity ratios exceeding 1.20 were classified as areas of probable congestion. In this analysis, those future year congestion areas are shown in conjunction with the truck travel time reliability results. As seen in Figures 10 and 11, there is significant overlap between areas identified in the 2030 Comprehensive Plan and areas identified as experiencing poor reliability as part of this study's analysis. For instance, portions of CSAH 81, CSAH 15, CSAH 130, and CSAH 19 were all identified as exhibiting performance challenges in both analyses. This suggests that truck performance along these corridors will likely worsen over time.

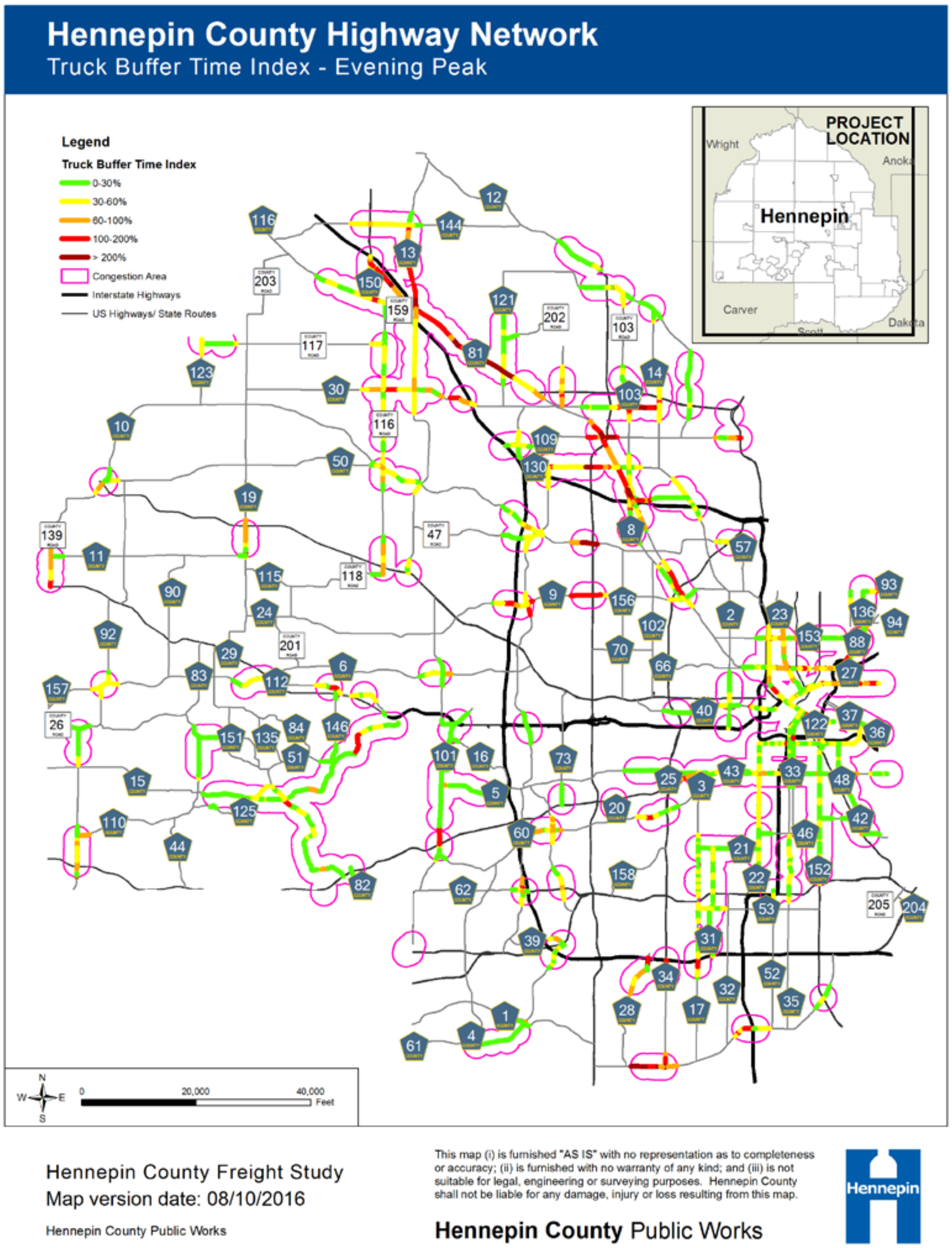
There are also locations that exhibit poor reliability in the analysis of truck GPS data that the travel demand model does not predict as having capacity constraints by the year 2030. These are shown in Figures 12 and 13. For instance, CSAH 61/Xenium Lane between TH 55 and I-394 and CSAH 6 between TH 55 and I-494 exhibit reliability challenges during both the morning and evening peaks. This area in Plymouth has a significant cluster of freight-intensive industries located along these routes. Similarly, portions of CSAH 1/ Old Shakopee Road have poor truck travel time reliability that fall outside of areas predicted to have capacity constraints in the year 2030. However, the locations predicted to have reliability challenges are adjacent to the area predicted to have capacity constraints – CSAH 1/ Old Shakopee Road between CSAH 28/Bush Lake Road and CSAH 34/Normandale Blvd. Interestingly, the predicted location of capacity constrained conditions on CSAH 1/Old Shakopee Roads directly centers on a freight cluster located along the south side of the roadway.

Figure 10: Overlay of 2030 Congestion Areas with Morning Peak Average Truck Travel Time Reliability on the Hennepin County Roadway Network



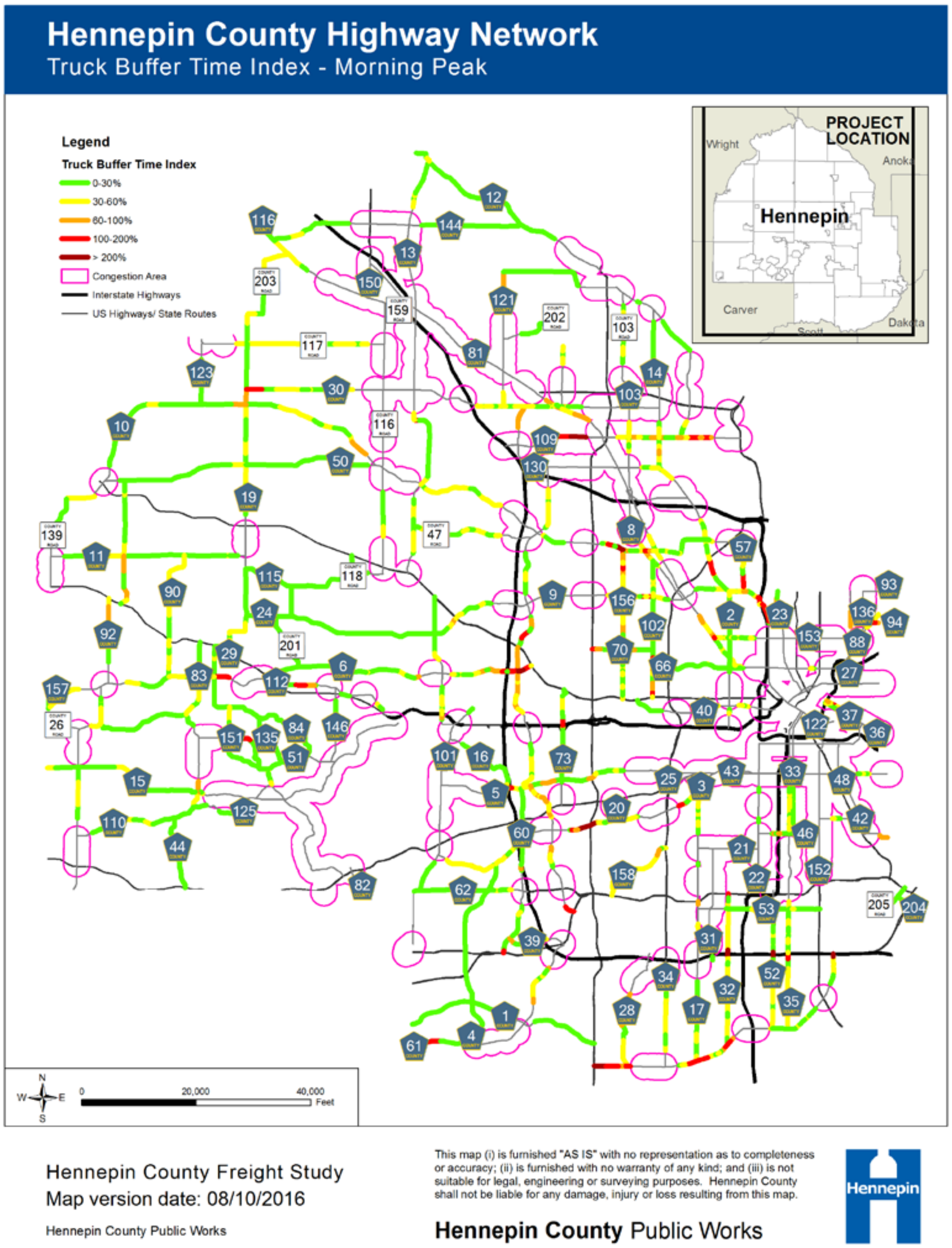
Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015); Hennepin County 2030 Comprehensive Plan.

Figure 11: Overlay of 2030 Congestion Areas with Evening Peak Average Truck Travel Time Reliability on the Hennepin County Roadway Network



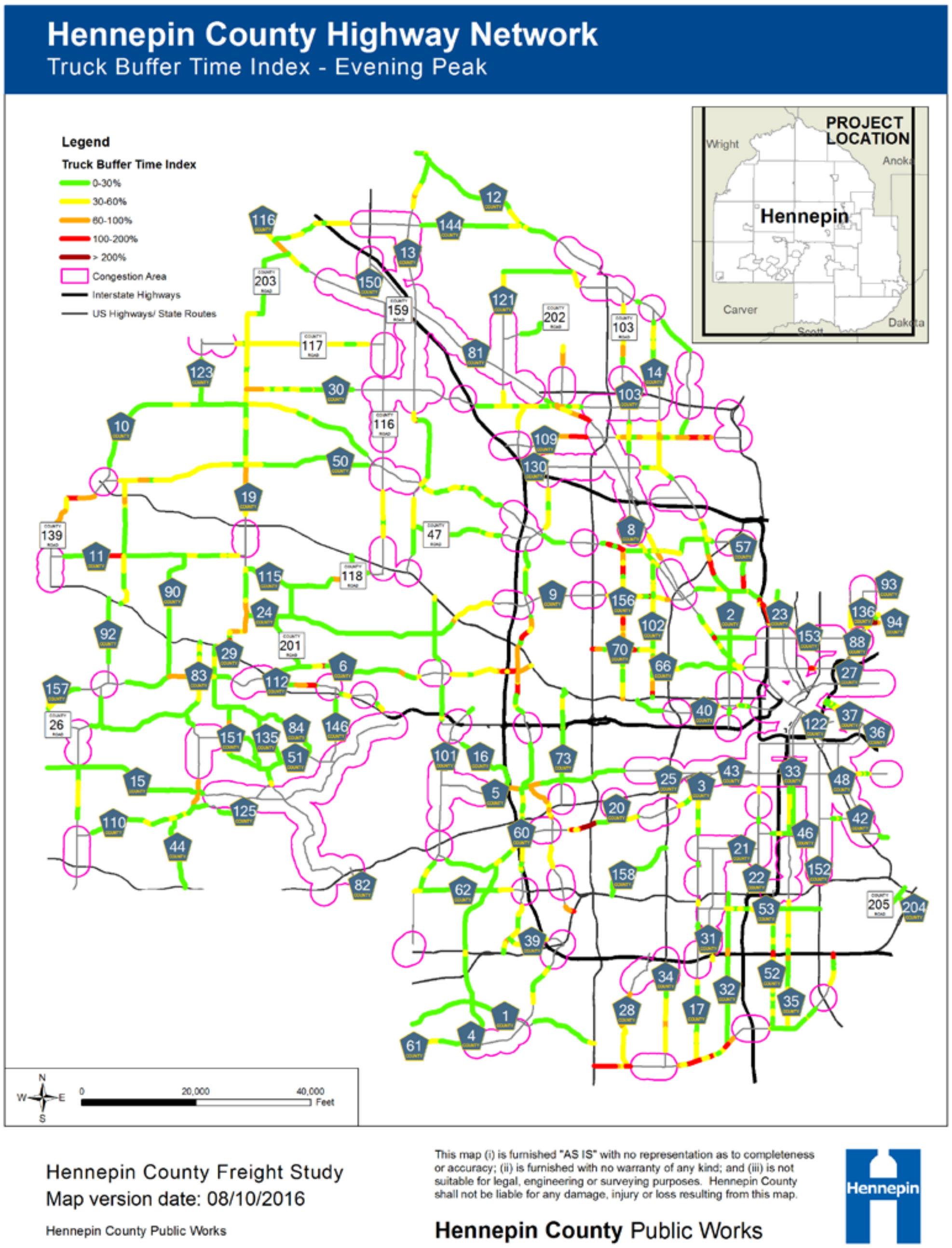
Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015); Hennepin County 2030 Comprehensive Plan.

Figure 12: Overlay of 2030 Congestion Areas with Morning Peak Average Truck Travel Time Reliability on the Hennepin County Roadway Network



Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015); Hennepin County 2030 Comprehensive Plan.

Figure 13: Overlay of 2030 Congestion Areas with Evening Peak Average Truck Travel Time Reliability on the Hennepin County Roadway Network



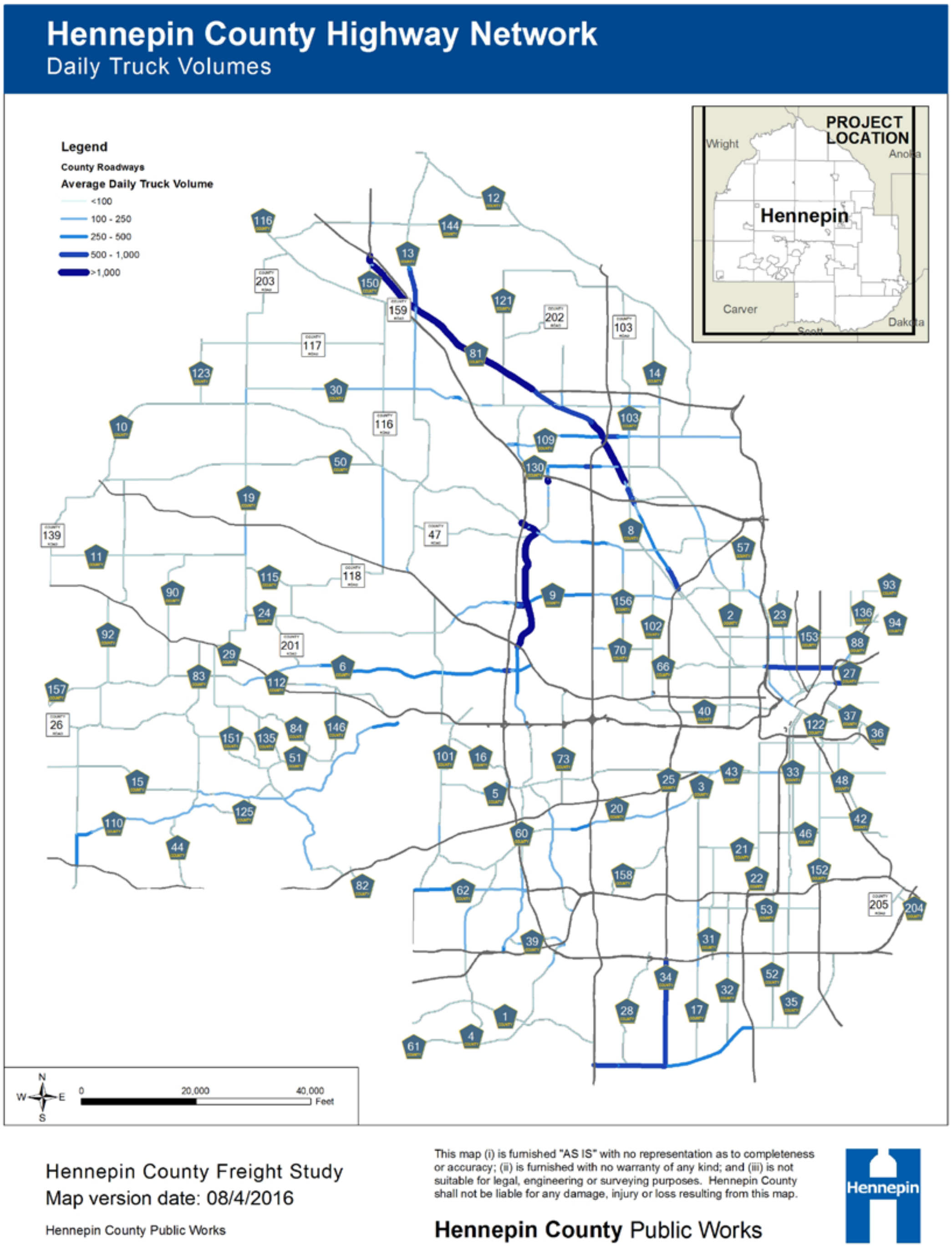
Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015); Hennepin County 2030 Comprehensive Plan.

Analysis of Truck Volumes

The ATRI truck GPS data is also used to estimate truck volumes on the Hennepin County network by identifying the routes with high truck volumes, as indicated by the GPS data. This analysis was done because MnDOT typically does not conduct vehicle classification counts on roadways that are not a part of the State’s system. It is important to note that the GPS data comprises only a sample of truck trips and not the full universe of trucking activity within the County or on any particular roadway. Thus, it can only provide an estimate of daily truck volumes. Tools such as pneumatic road tubes and induction loops have the ability to provide larger samples of data that more closely approach the population of trucking activity for any given roadway.

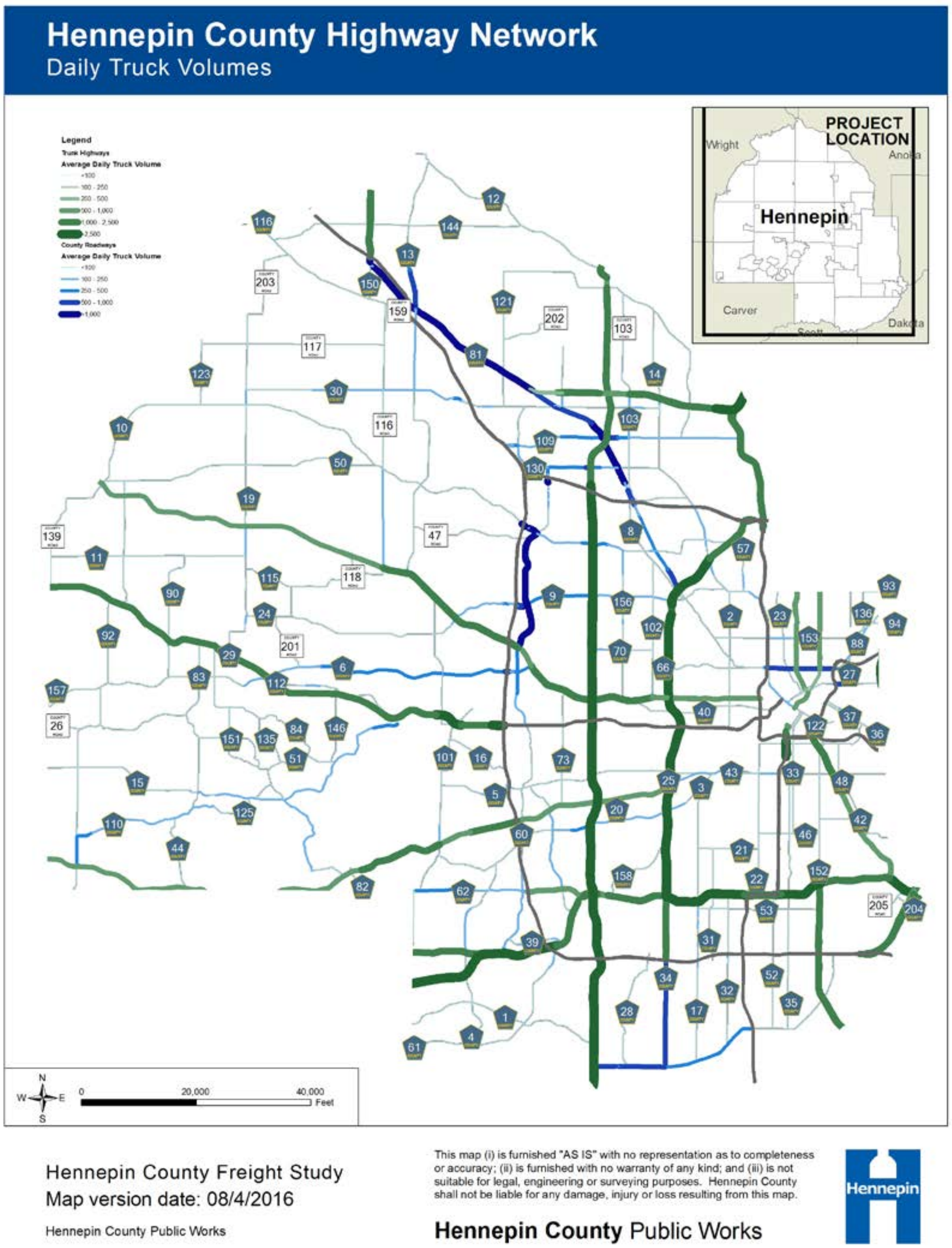
Figures 14 and 15 show the estimated daily truck volumes on the Hennepin County Roadway Network. Figure 14 shows only the volumes estimated as part of this study; while Figure 15 incorporates data on state system volumes provided by MnDOT. Truck volumes on interstate highways are purposefully omitted as those truck volumes are typically much higher than those observed on non-interstate highways (around 10,000 trucks per day, versus up to 2,000 trucks per day on State routes and less on County routes).

Figure 14: Estimated Daily Truck Volumes on the Hennepin County Roadway Network



Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

Figure 15: Estimated Daily Truck Volumes on the Hennepin County Roadway Network Compared to Trunk Highway Truck Volumes



Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

The results of the truck route analysis indicate that CSAH 6, CSAH 9, CSAH 61, CSAH 66, and CSAH 81 are among the most heavily utilized routes on the County's network. Portions of these roadways are estimated to carry upwards of 500 trucks per day. Some of these routes (namely CSAH 61 and CSAH 81) are estimated to carry over 1,000 trucks per day.

Another insight from the analysis of predominant truck routes is that several of the routes identified in the truck congestion analysis, do not appear to be heavily utilized by motor carriers. For instance, CSAH 19, CSAH 83, CSAH 90, CSAH 92, and CSAH 116 were all identified as having relatively low truck speeds given their locations. However, these routes are not estimated to have large volumes of trucks on a daily basis. Thus, though they have relatively low average speeds these routes do not affect many carriers utilizing the Hennepin County highway network.

Truck Safety Analysis

Safety data from Hennepin County was analyzed to understand the locations of truck-involved crashes in Hennepin County. Over the 2010 to 2014 time period, there were 893 truck-involved crashes on the Hennepin County highway network. As shown in Table 3, the majority of these (about 77 percent) were sideswipe and rear-end crashes which tend to have less severe outcomes. About 19 percent of truck-involved crashes occurring on the Hennepin County network were Angle and Head-On collisions.

As shown in Table 4, the vast majority of truck crashes (at least 82 percent) did not result in injuries. Based on information in the crash reports, 41 crashes (4.5 percent) over the 5-year time period resulted in injuries or fatalities. In total, there were 4 fatalities and 208 persons injured as a result of truck crashes from 2010 to 2014.

Figure 16 displays the location and severity of truck crashes in Hennepin County. While the majority of crashes are clustered near the City of Minneapolis, crashes with the most severe outcomes are widely distributed throughout the County. In addition, Figure 16 indicates that crashes tend to be clustered along certain routes. For instance, relatively large numbers of crashes occurred on CSAH 3, CSAH 81, and CSAH 152. However, crashes along these routes mostly resulted in property damage and no serious injuries or fatalities.

According to the Minnesota Department of Public Safety, Minneapolis and St. Paul combined accounted for 785 (about 19 percent) of total truck crashes.[1] Given the magnitude of truck crashes in the State's largest municipalities, the crash data does not suggest that safety is worse on the County network compared to other areas of the State. However, the locations at which fatalities occurred are obviously areas of concern. These include the intersections of CSAH 6 (6th Ave.) and CSAH 112 (Wayzata Blvd.), TH 7 and CSAH 101, and CSAH 46 (East 46th Street) and CSAH 33 (Park Avenue).

[1] Minnesota Department of Public Safety. https://dps.mn.gov/divisions/ots/reports-statistics/Documents/2015%20Crash%20Facts.pdf.

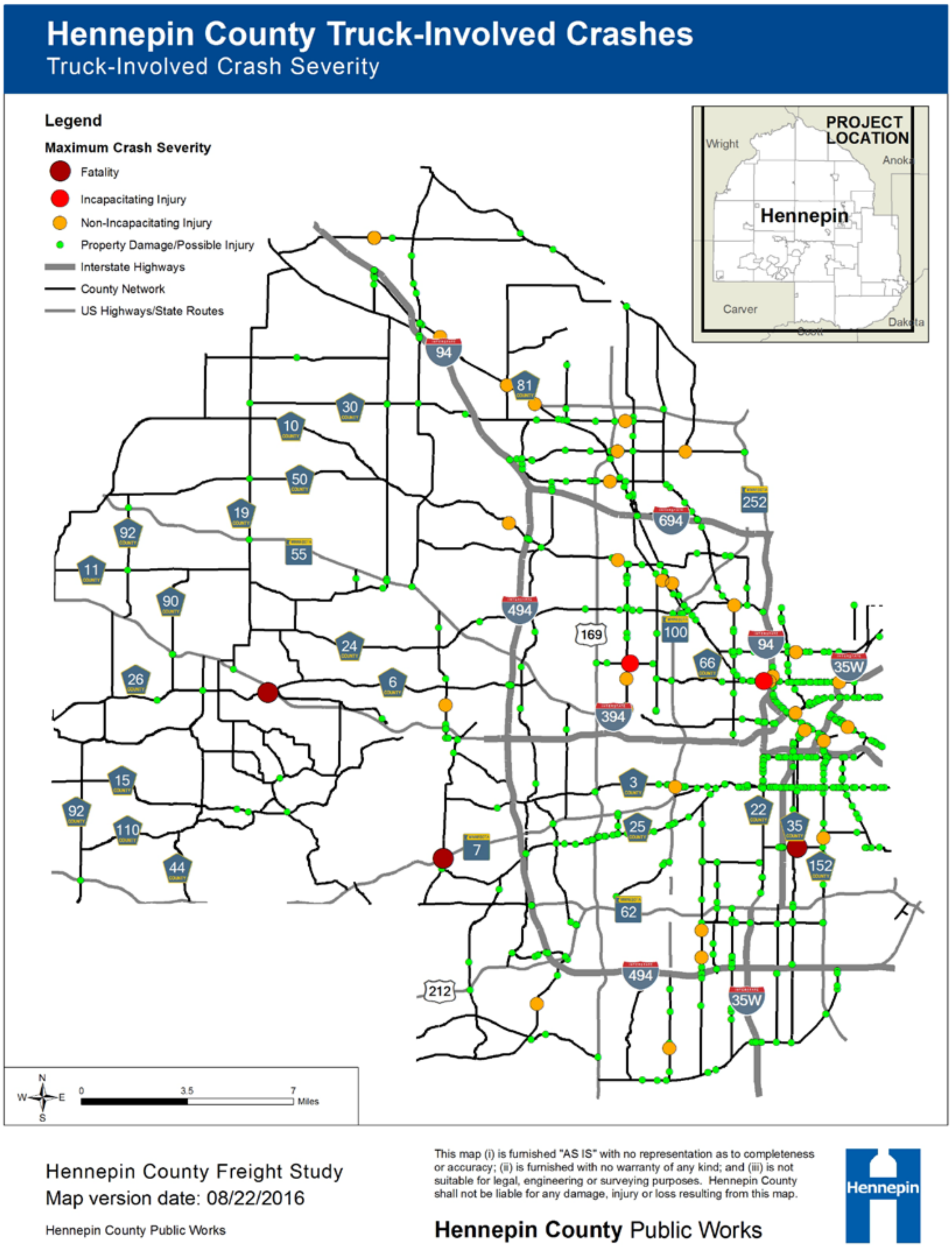
Table 3: Hennepin County Truck Crash Types, 2010 - 2014

Crash Type	No. of Crashes	Percent of Total
Head-On	3	0.3%
Angle	167	18.7%
Rear End	251	28.1%
Sideswipe	438	49.1%
All Others	34	3.8%
Total	893	100%

Table 4: Hennepin County Truck Crash Severity, 2010 - 2014

Crash Severity	No. of Crashes	Percent of Total
Fatality	3	0.3%
Incapacitating Injury	3	0.3%
Non-Incapacitating Injury	35	3.9%
Possible Injury	120	13.4%
Property Damage	732	82.0%
Total	893	100%

Figure 16: Truck-Involved Crashes on the Hennepin County Roadway Network



Source: Hennepin County Public Works.

Conclusions

Overall, the analysis of truck GPS data suggests that much of the Hennepin County roadway network provides for reliable truck travel at appropriate speeds. Truck performance west of I-494 is generally better than performance within the perimeter formed by I-494 and I-94/I-694. However, there are some roadways that exhibit relatively slow average truck speeds given their surrounding land uses and location within the County. These low speeds could be due to several of these roadways consisting of single travel lanes in each direction, limiting opportunities for passing and achieving higher rates of speed. It could also be reflective of trucks purposefully lowering their speeds as they near their destinations or home bases.

However, truck mobility is more challenged closer to the urban core of the County – within the perimeter formed by I-494 and I-94/I-694. In this area, average truck speeds significantly decline and reliability (as indicated by higher buffer time indices) worsens. Regarding average truck speeds, however, it is possible that the observed decreases are necessary for trucks to safely navigate more densely populated portions of Hennepin County with greater numbers of roadway users.

The technical memorandum also explored truck safety through the use of truck crash data on Hennepin County roadways. Over the 5-year timeframe from 2010 to 2014 there were very few truck-involved crashes that resulted in serious injuries or fatalities. Given the size of the Hennepin County roadway network and its traffic volumes, the crash data does not suggest that a significant safety problem exists though the locations at which fatalities occurred are obviously areas of concern.

Appendix. Methodology and Analysis of Truck GPS Data

OVERVIEW OF THE DATA

The American Transportation Research Institute (ATRI) continuously collects global positioning data (GPS) on key national corridors and local roads for large trucks. Typically, ATRI GPS data contains information on the location (i.e. latitude and longitude), speed, and heading of large trucks as well as a timestamp of the observation. The primary source of these data is onboard communications equipment installed on large commercial vehicles (typically Class 8 and higher). Though ATRI GPS data tends to better capture inter-regional as opposed to intra-urban commercial vehicle flows, it is a good sample of trucking activity. As such, truck GPS data can be used to identify performance issues on roadways, the predominant truck routes utilized throughout metropolitan regions and states, and sub-areas of regions that generate and attract truck trips.

ANALYSIS METHODOLOGY

The process for analyzing the truck GPS data includes sorting the data by truck identification and by timestamp in order to place the data in chronological order. The space mean speed is then calculated by dividing the distance traveled (calculated as the Great Circle distance using the reference and prior coordinate locations for each truck) by the lapsed time between observations. Because the data encompasses multiple truck trips over the course of each observation period, the derived space mean speeds must be filtered to remove observations that may include stops for deliveries, rest, refueling or other necessities.

Once the observations were filtered, they were then imported into GIS and joined to the Hennepin County highway network using the coordinates of each observation. Because the ATRI truck GPS data has a locational accuracy of around 3 to 5 meters, only observations within a 5 meter radius were matched to the network. After matching the observations to the network, the average speeds were calculated for each link based on its matched observations. For links to which no observations were matched, values were interpolated based on average speeds on links for that same roadway. This analysis was done for each month of data (March, May, August, and October) for the following time periods which were chosen to be consistent with the 2011 MnDOT analysis:

- Morning: 5:00 – 10:00 A.M.
- Midday: 10:00 A.M. – 2:00 P.M.
- Evening: 2:00 – 7:00 P.M.

TRUCK TRAVEL TIME RELIABILITY ANALYSIS METHODOLOGY

The space mean speeds derived from the truck GPS data were used to determine link-based travel times for each observed truck movement. From these travel times, travel time reliability was measured. For a given roadway segment, the buffer time index is measured as the difference between the 95th percentile and average travel times divided by the average travel time: (95th Percentile Truck Travel Time – Average Truck Travel Time) / Average Truck Travel Time.

TRUCK VOLUMES ANALYSIS METHODOLOGY

In determining the routes trucks took in Hennepin County, a methodology similar to what was performed in Florida Department of Transportation analyses of truck GPS data were employed.[2,3] The methodology is briefly explained here: First, the data is sorted by truck identification and timestamp in order to place the observations in chronological order. This also reveals where trucks began potential trips on the Hennepin County network. The space mean speed is then calculated based on the difference in time and space between a given truck GPS point and the point that preceded it. Based on the space mean speed, trucks are determined to either be stationary or moving. If stationary for more than 10 minutes, trucks are considered to have reached their trip end. The beginning points, interim points, and trip ends indicate the routes taken over the Hennepin County network.

The GPS points comprising the truck trip routes were then imported into ArcGIS. Using the ArcGIS Route tool and the Hennepin County roadway network GIS files, the truck trips were then routed over the network to determine the specific links used during operations. This produces a more complete picture of motor carrier use of roadways throughout the County. Given that ATRI truck GPS data represents only a sample of trucking activity, the number of trips assigned to each link is multiplied by an expansion factor to produce an estimate of total trucks.

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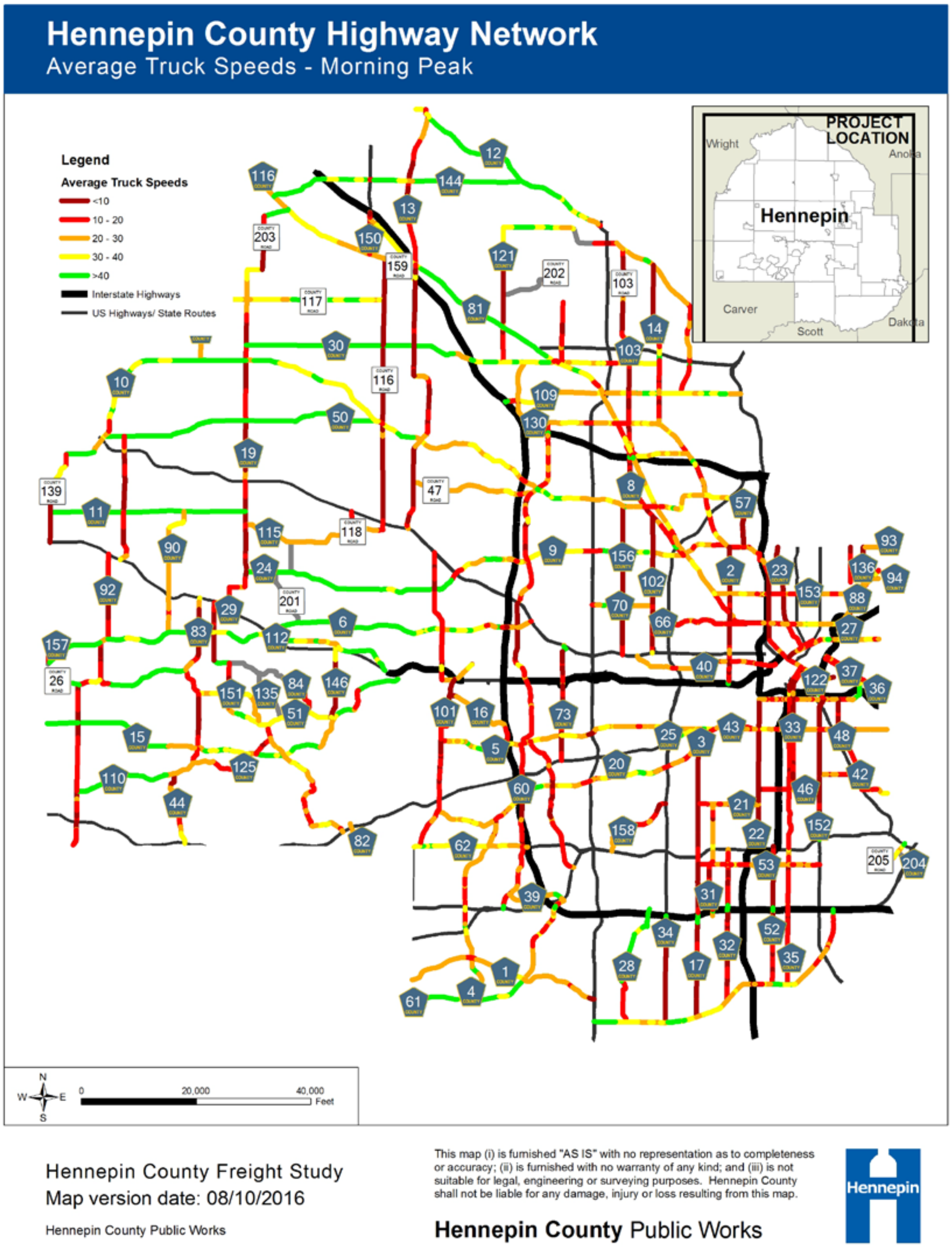
[2] Thakur et al. Development of Algorithms to Convert Large Streams of Truck GPS Data into Truck Trips. Transportation Research Record 2529, 2015, pp. 66-73.

[3] Bakhshi, A. et al. Estimation of Statewide Origin-Destination Truck Flows from Large Streams of GPS Data: Application for Florida Statewide Model. Transportation Research Record 2494, 2015, pp. 87-96.

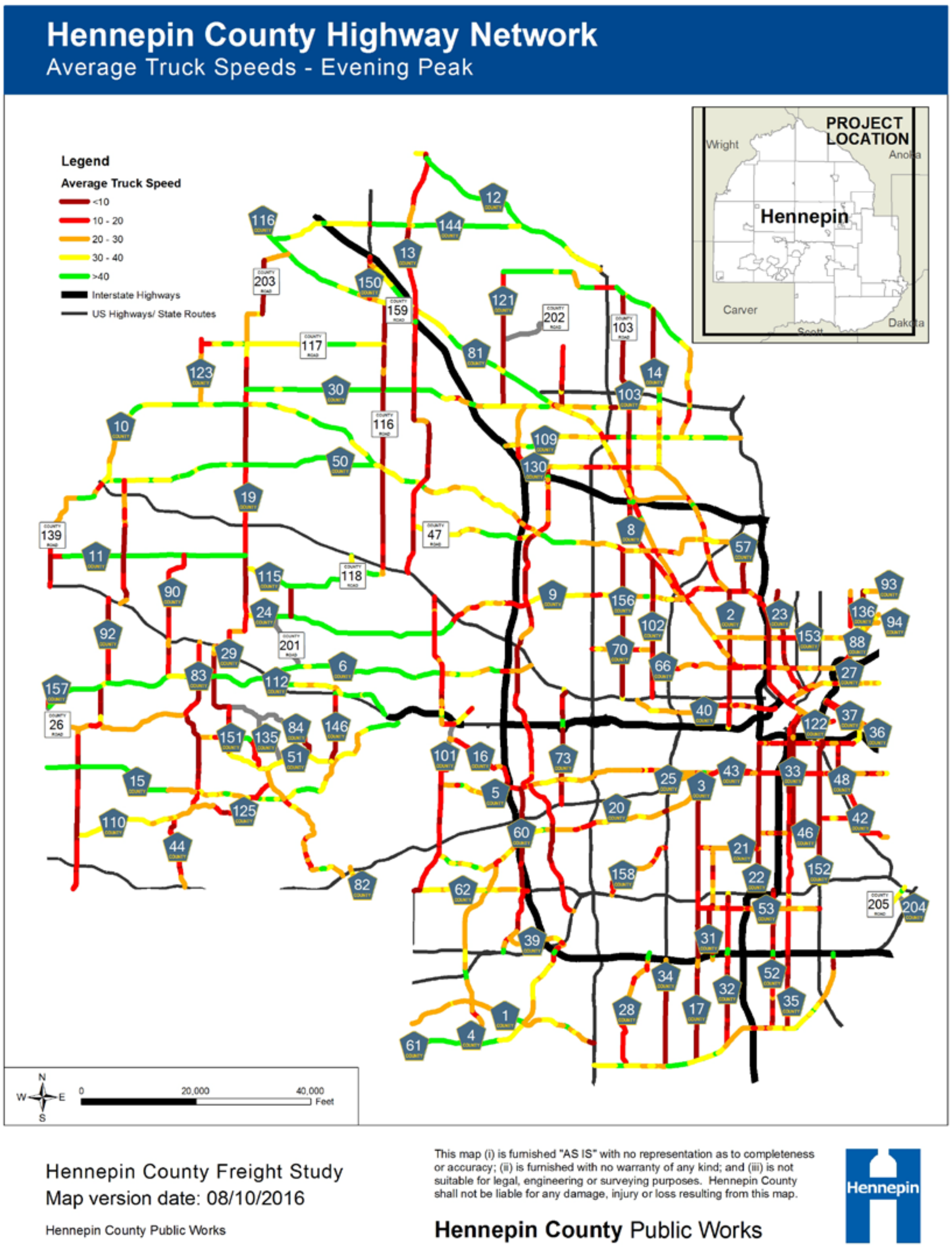
Appendix. Additional Maps

Figure 17: Morning Peak Average Truck Speeds on the Hennepin County Roadway Network



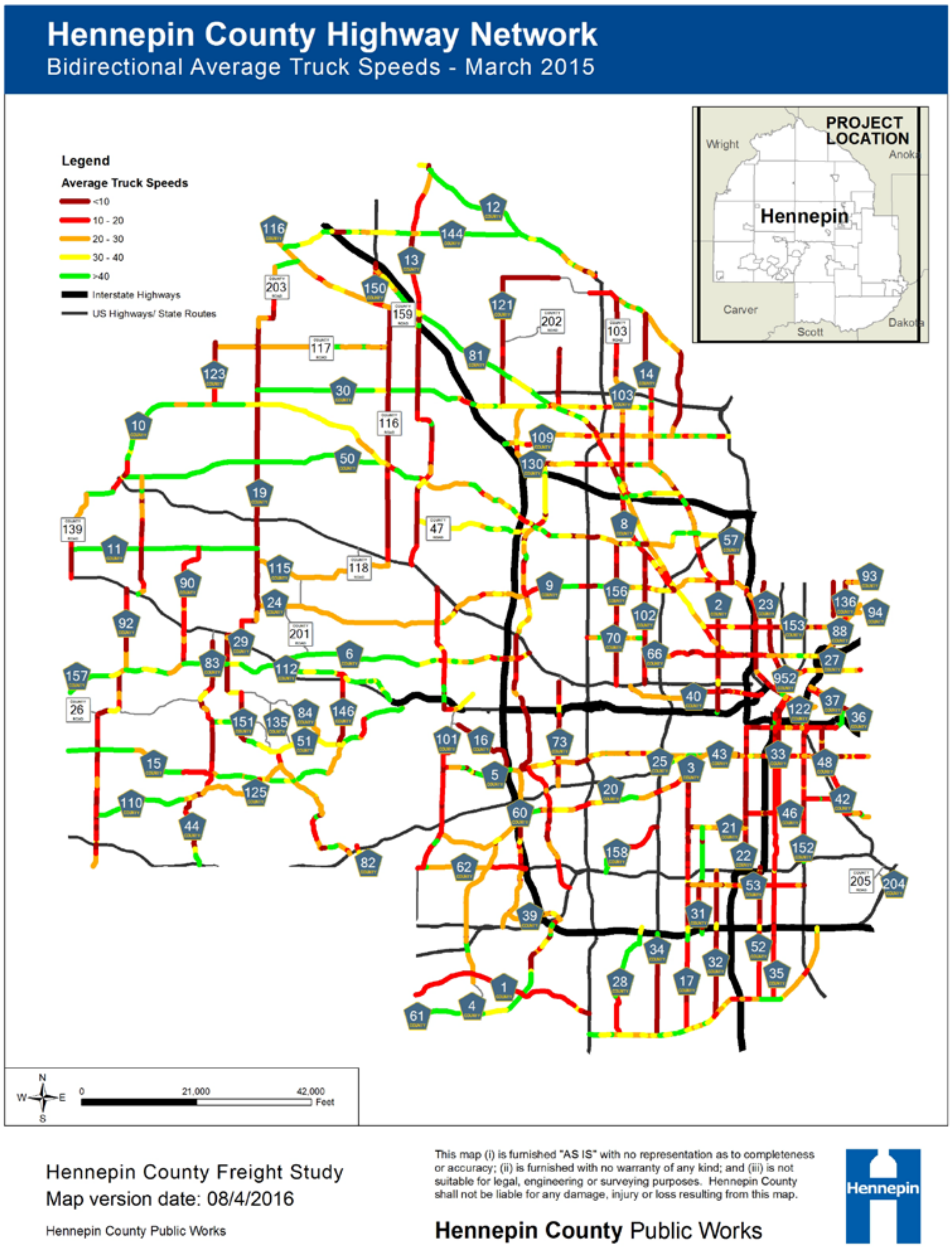
Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

Figure 18: Evening Peak Average Truck Speeds on the Hennepin County Roadway Network



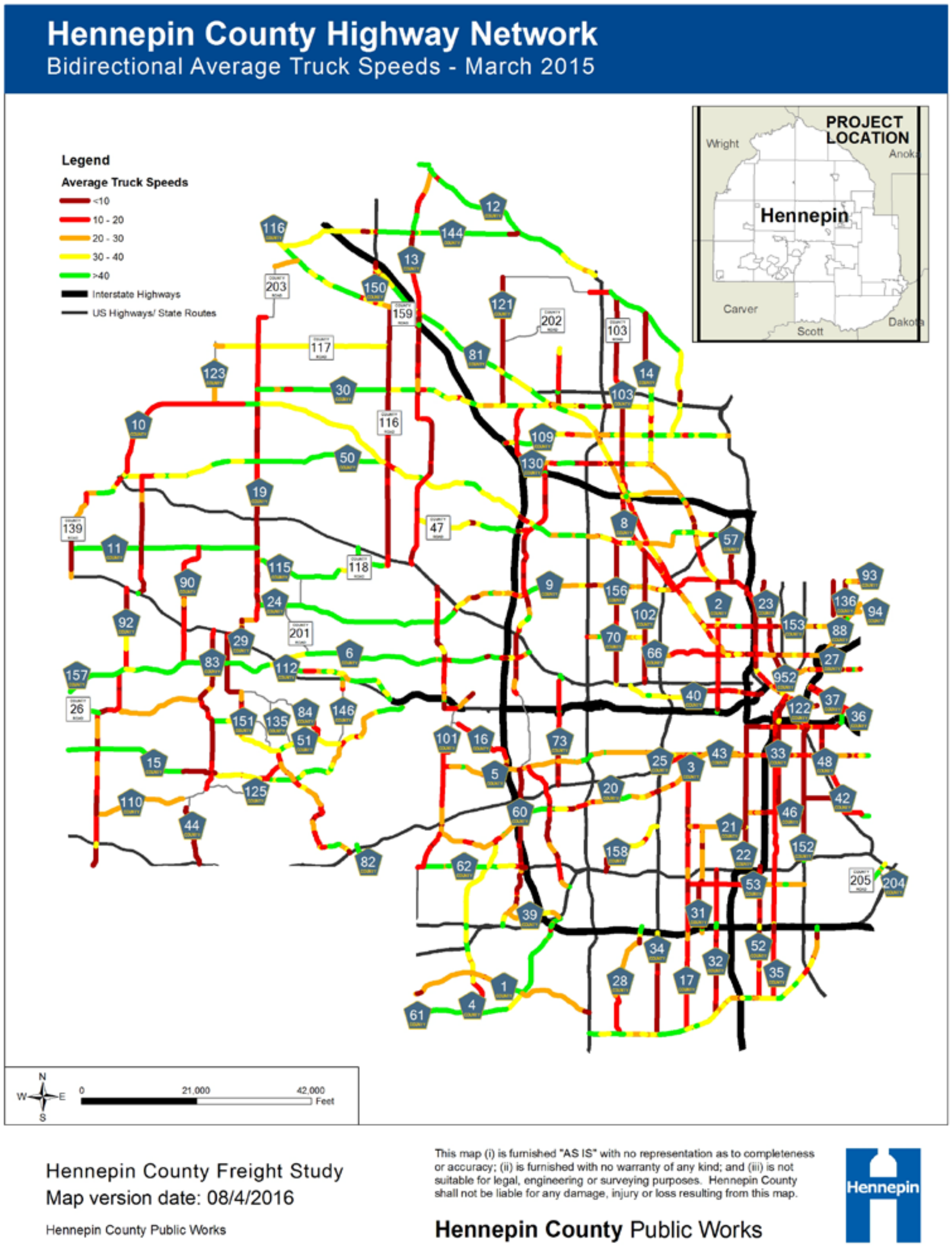
Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

Figure 19: Average Morning Truck Speeds on the Hennepin County Roadway Network



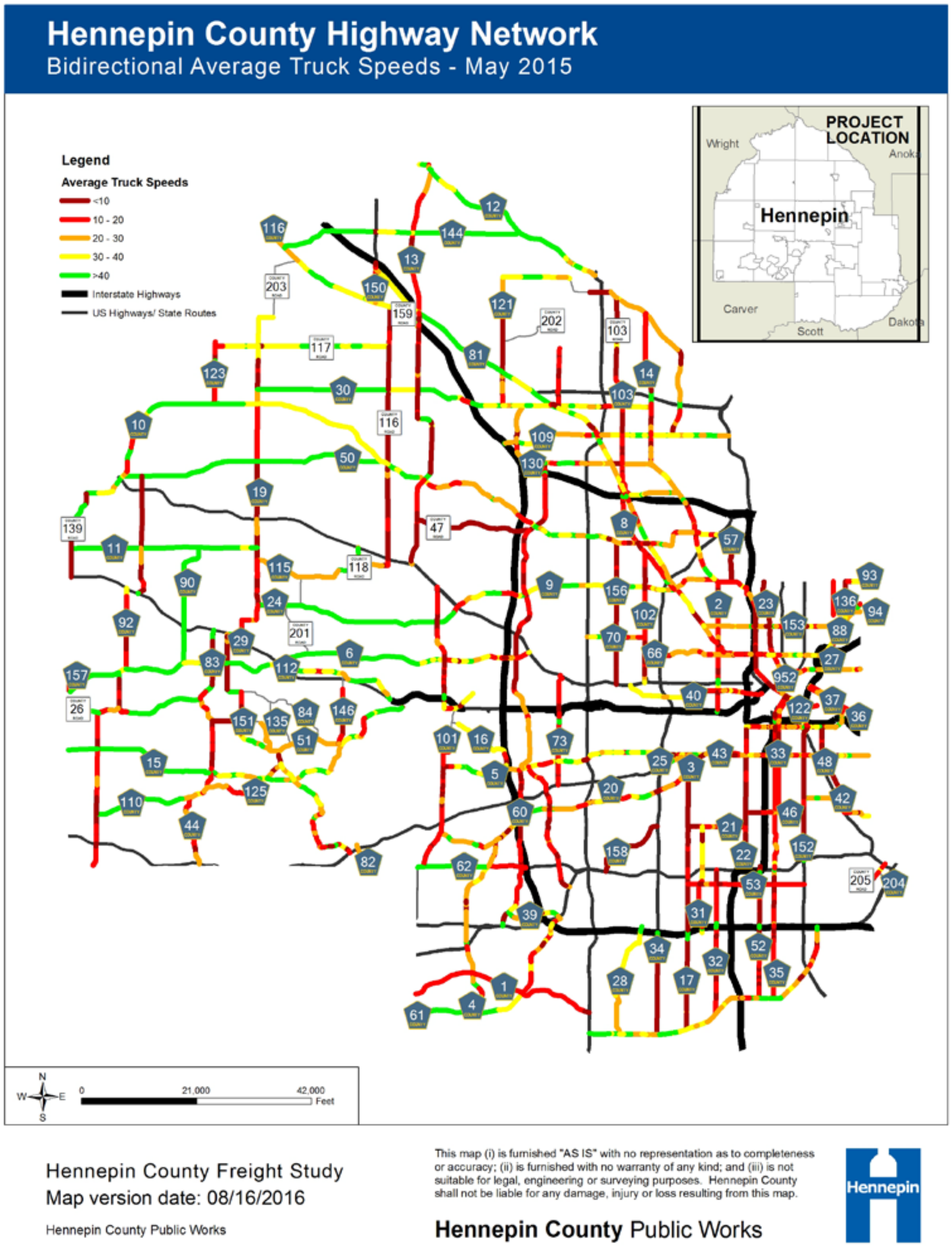
Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

Figure 20: Average Evening Truck Speeds on the Hennepin County Roadway Network



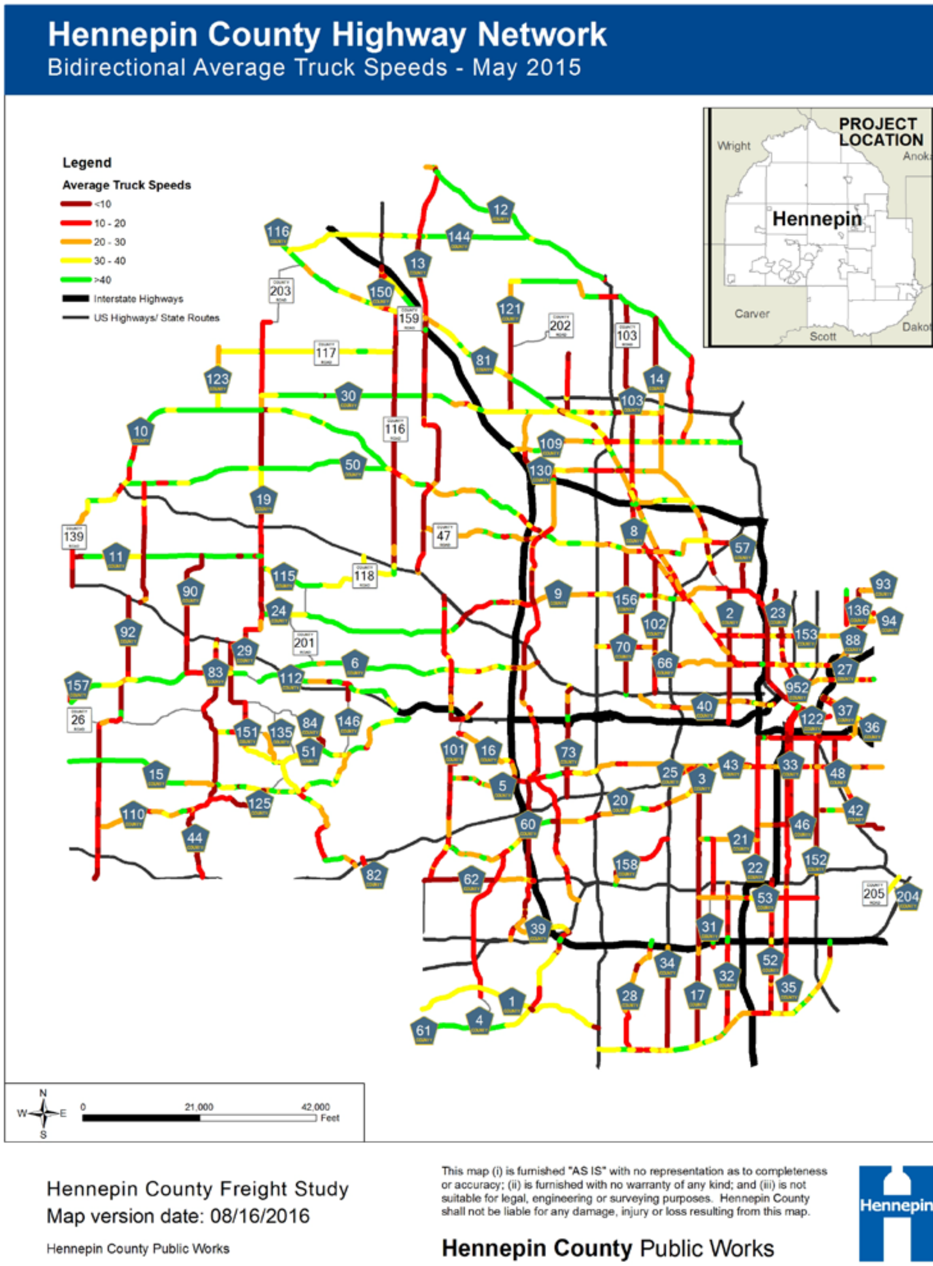
Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

Figure 21: Average Morning Truck Speeds on the Hennepin County Roadway Network



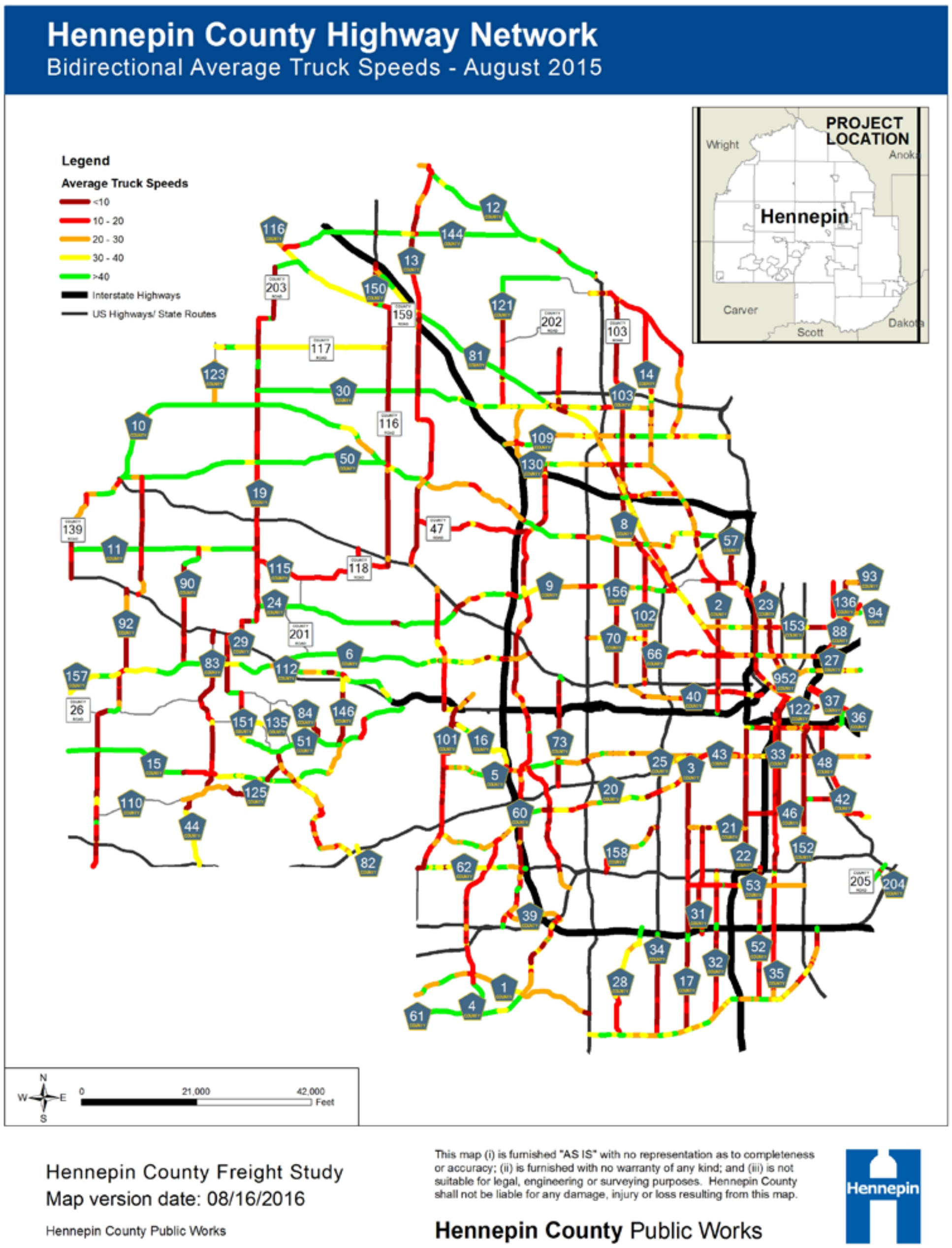
Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

Figure 22: Average Evening Truck Speeds on the Hennepin County Roadway Network



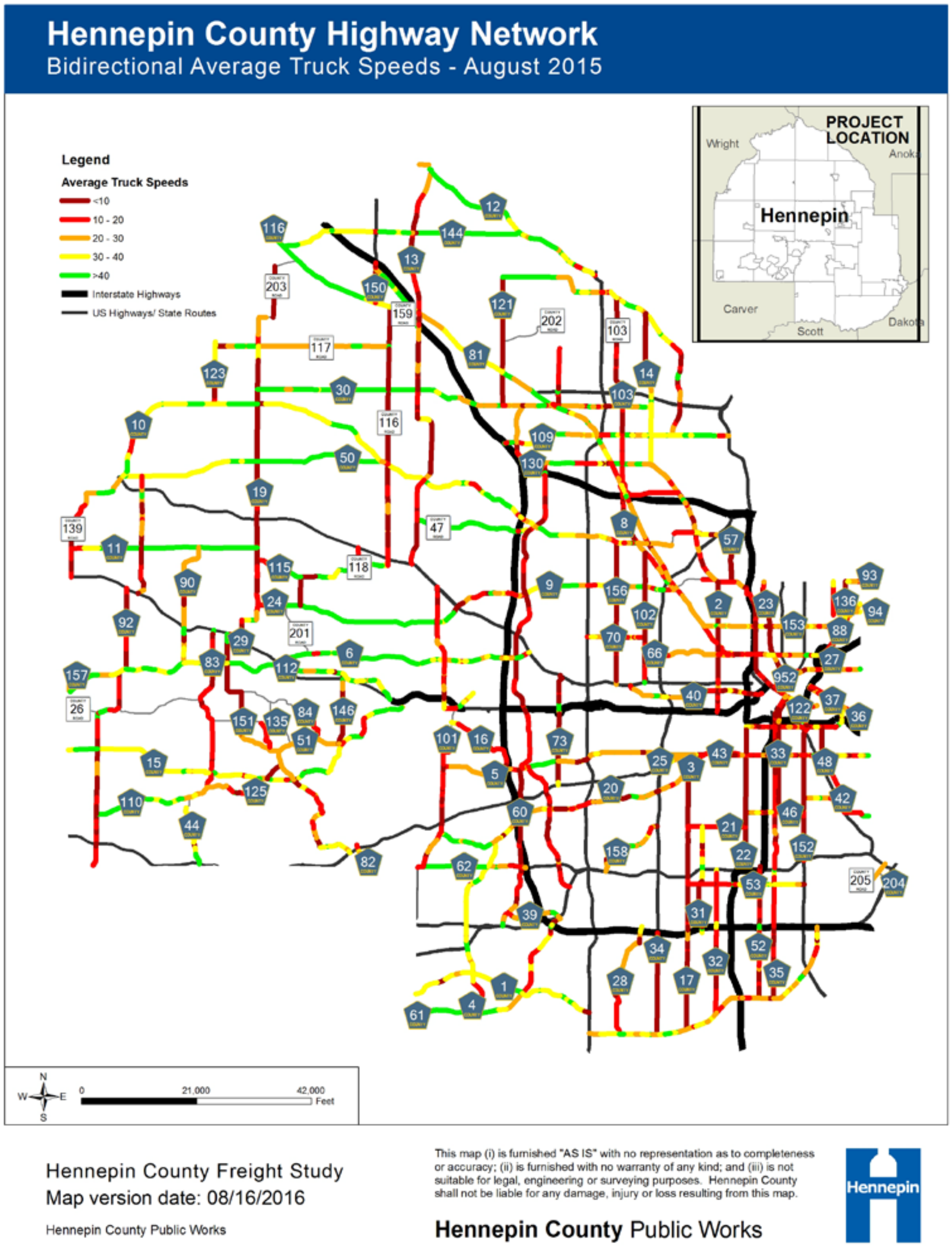
Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

Figure 23: Average Morning Truck Speeds on the Hennepin County Roadway Network



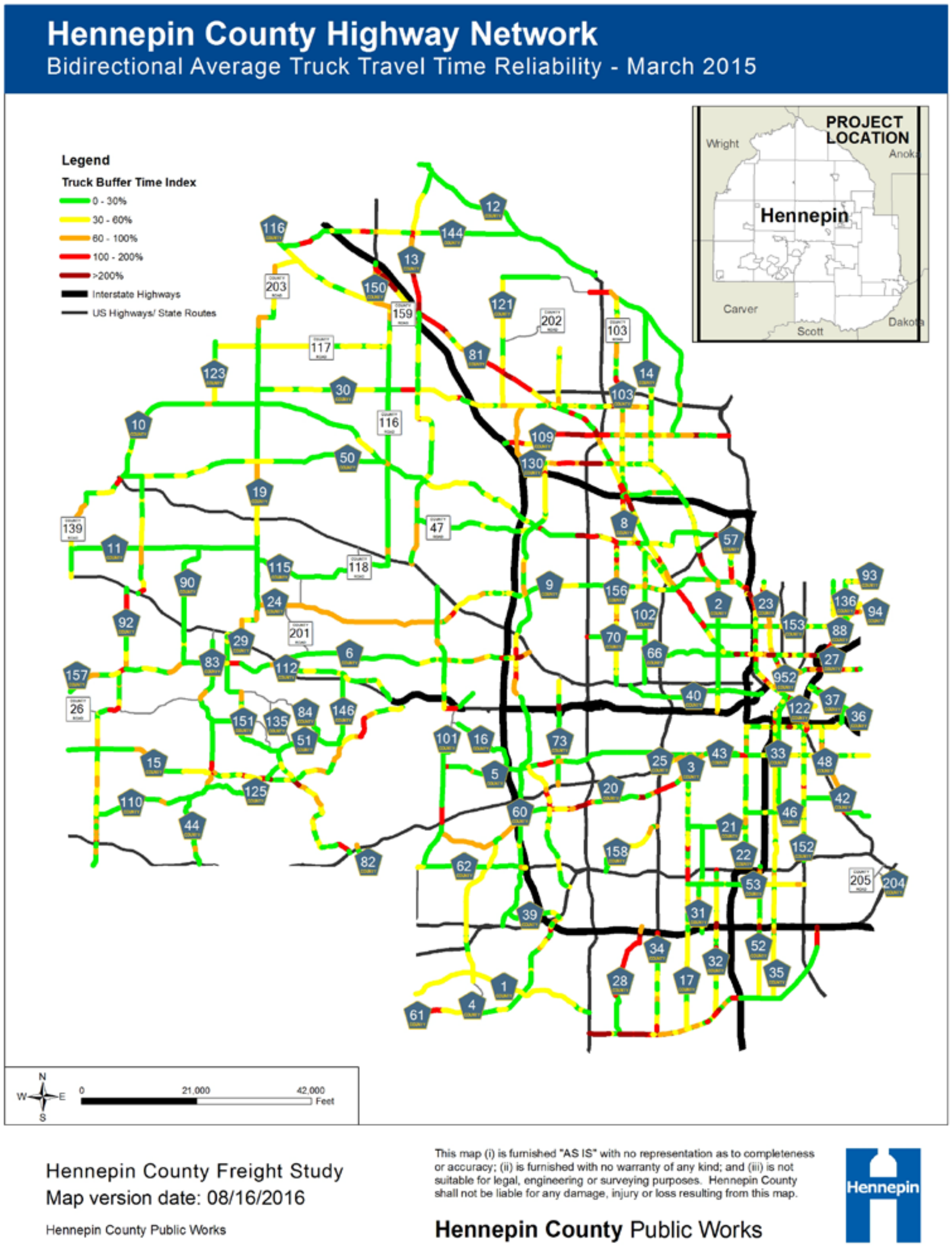
Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

Figure 24: Average Evening Truck Speeds on the Hennepin County Roadway Network



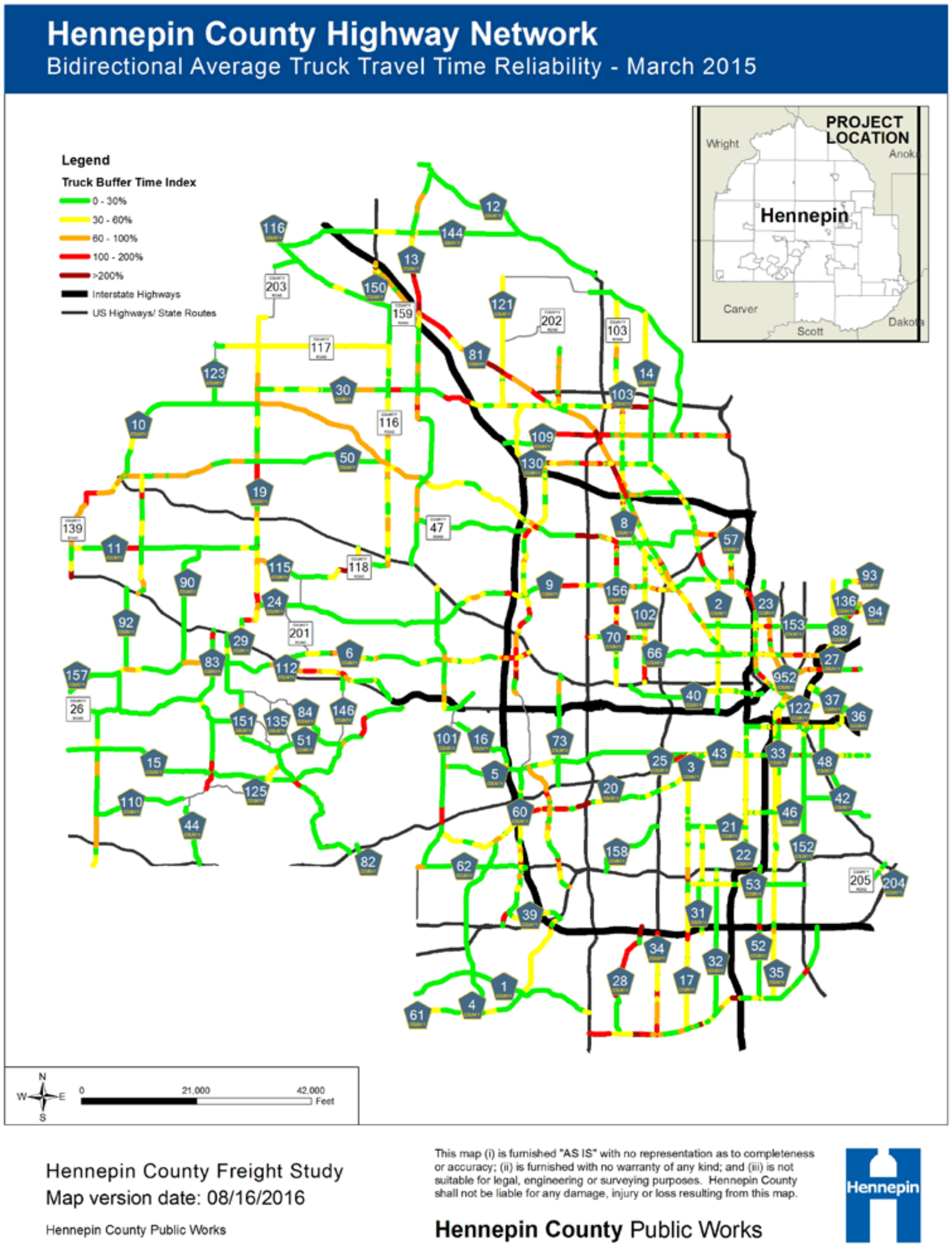
Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

Figure 25: Average Morning Truck Travel Reliability on the Hennepin County Roadway Network



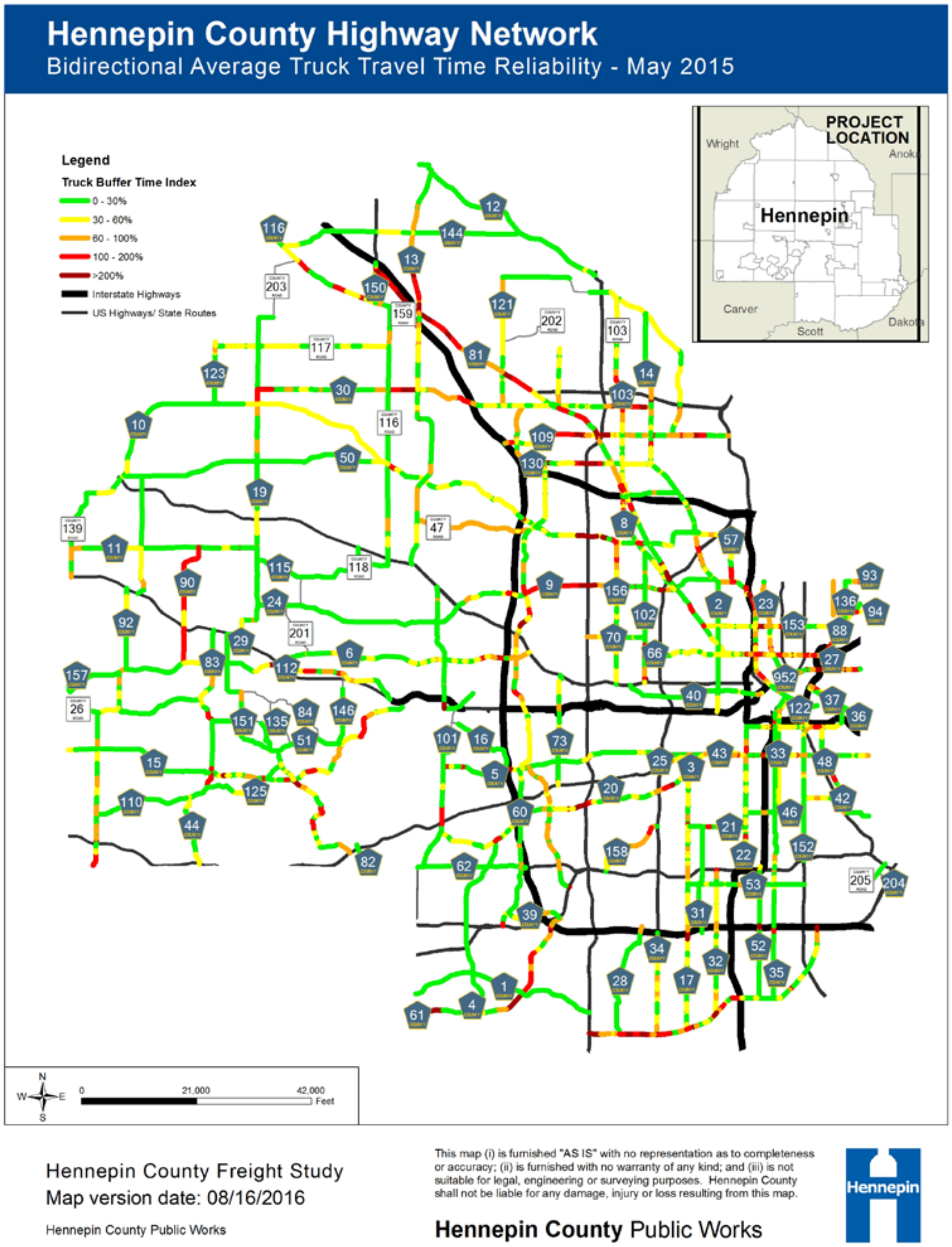
Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

Figure 26: Average Evening Truck Travel Time Reliability on the Hennepin County Roadway Network



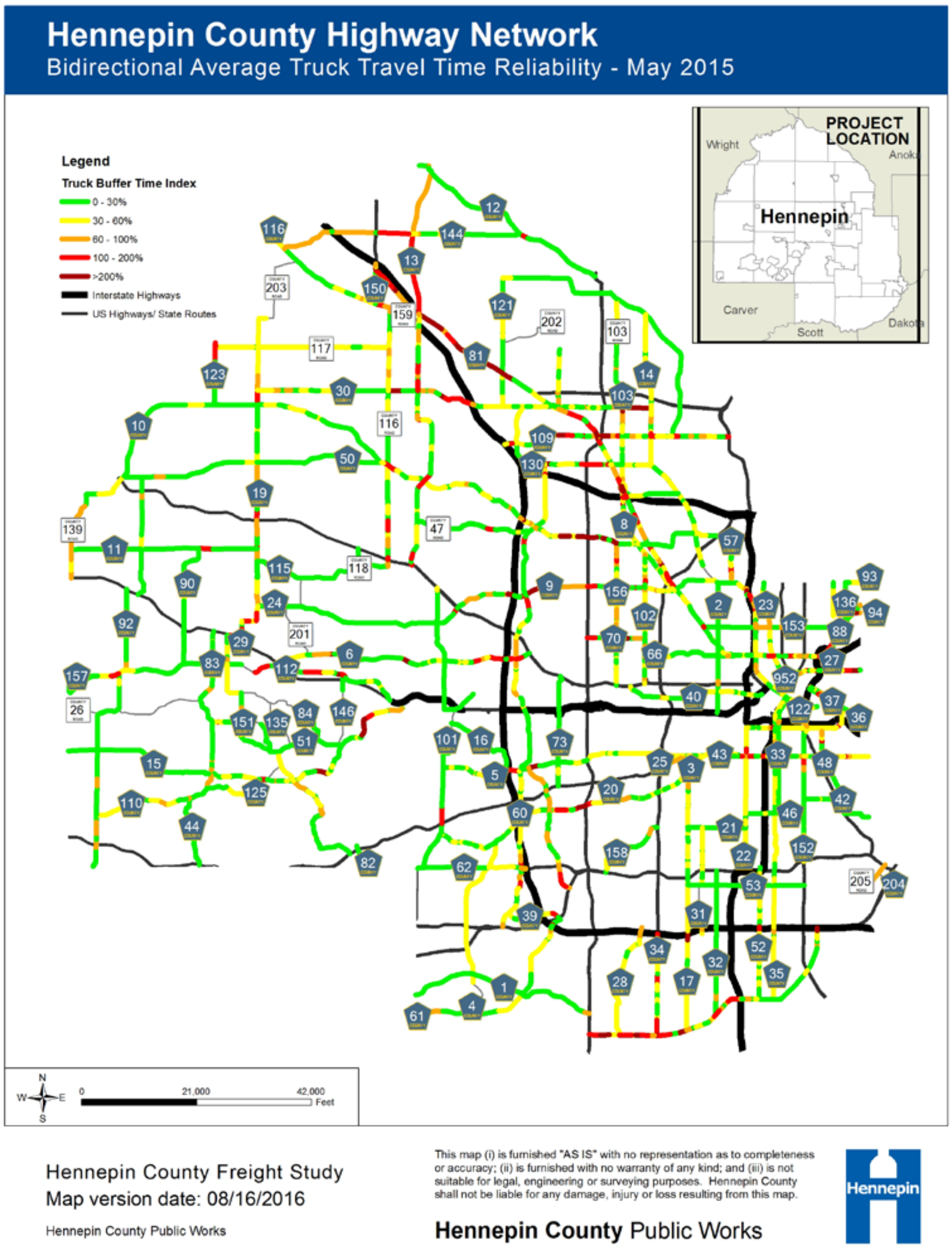
Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

Figure 27: Average Morning Truck Travel Time Reliability on the Hennepin County Roadway Network



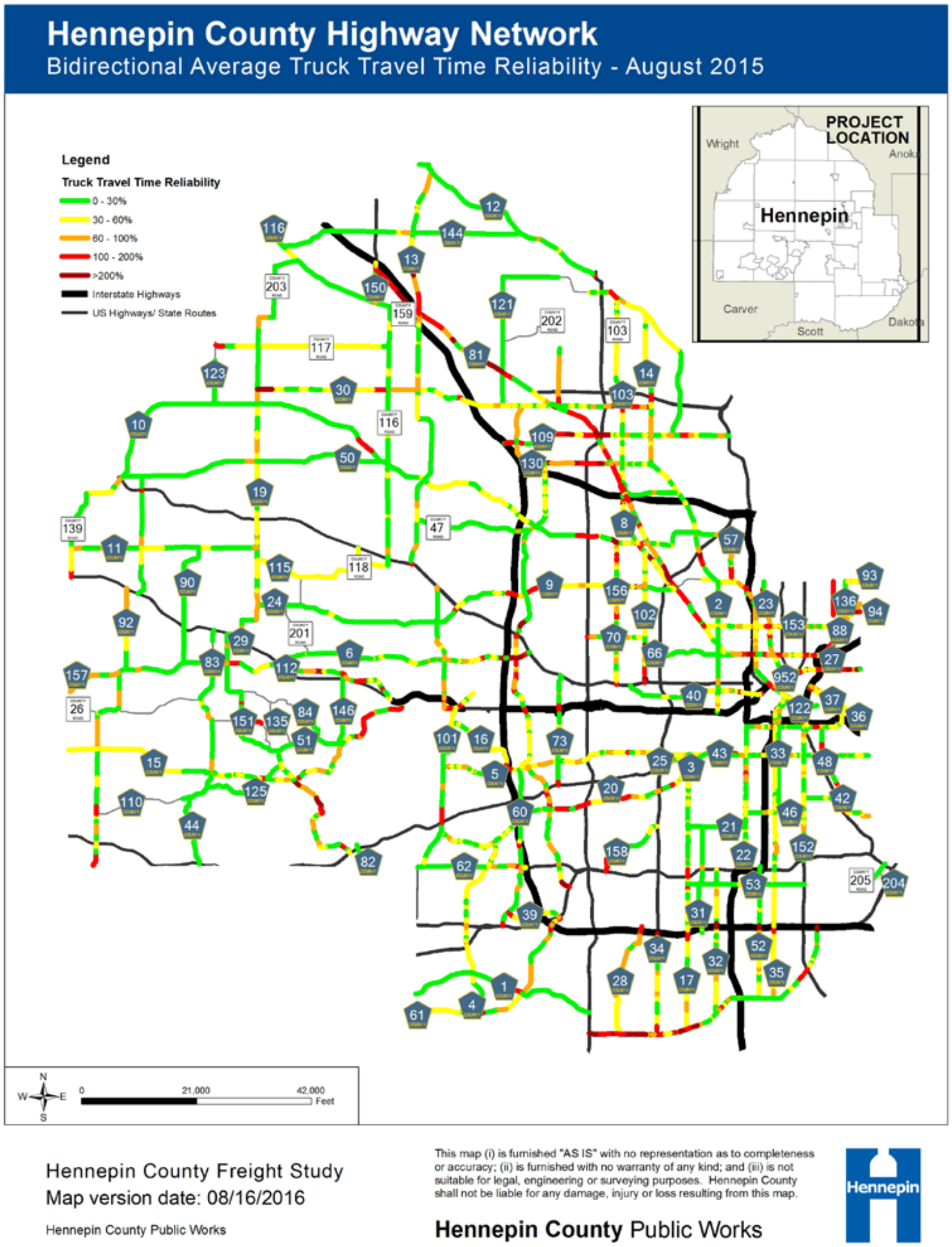
Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

Figure 28: Average Evening Truck Travel Time Reliability on the Hennepin County Roadway Network



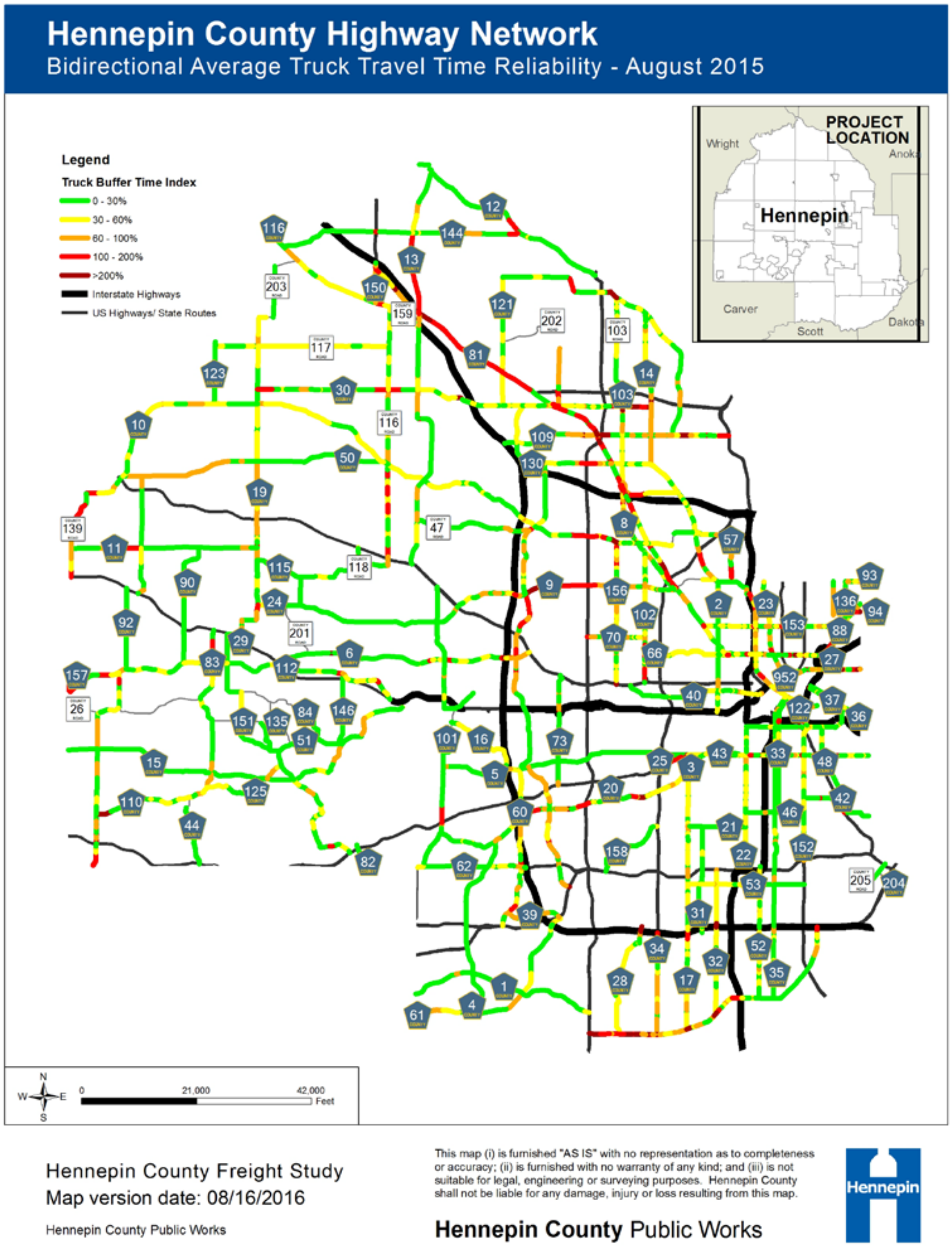
Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

Figure 29: Average Morning Truck Travel Time Reliability on the Hennepin County Roadway Network



Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

Figure 30: Average Evening Truck Travel Time Reliability on the Hennepin County Roadway Network



Source: Cambridge Systematics 2016 analysis of ATRI Truck GPS Data (2015).

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