



Evaluation and Testing of Regional Models – Phase I

Task 4b – Sensitivity Analysis

February 22, 2010
Revised May 10, 2010

Prof. Maria Boile
Co-Director, Freight and Maritime Program, and
Associate Professor, Civil and Environmental
Engineering

Prof. Sotirios Theofanis
Director of Strategic Planning, CAIT, and
Co-Director, Freight and Maritime Program

Prof. Mihalios Golias
Affiliated Faculty,
Freight and Maritime Program

Patrick Dougherty
Graduate Assistant,
Freight and Maritime Program

Center for Advanced Infrastructure
and Transportation
Freight and Maritime Program
Rutgers, The State University of
New Jersey
100 Brett Road
Piscataway, NJ 08854

prepared for

**New York Metropolitan
Transportation Council**

Table of Contents

1. INTRODUCTION	8
1.1 Task 4b Overview	9
2. DESCRIPTION OF SCENARIOS	12
2.1 B1: Impact of truck demand changes.....	12
2.2 B2: Impacts of changes in tolls.....	14
2.3 B3: Impact of disruption of infrastructure	16
3. DATA ANALYSES	17
3.1 B1: Impact of truck demand changes.....	17
3.2 B2: Impacts of changes in tolls.....	29
3.3 B3: Impact of disruption of infrastructure	68
4. SUMMARY	115
5. APPENDIX.....	119

List of Figures

Figure 1: Selected Origins and Destinations (<i>B1</i>).....	13
Figure 2: Map of Area Corresponding to Selected O-D's	13
Figure 3: Location of Verrazano-Narrows Bridge.....	15
Figure 4: Five mile buffers around Verrazano-Narrows Bridge.....	16
Figure 5: Total Delay on Network in AM period (6AM -10AM) <i>B1</i>	18
Figure 6: Total Delay on Network in MD period (10AM -3PM) <i>B1</i>	19
Figure 7: Total Delay on Network in PM period (3PM -7PM) <i>B1</i>	19
Figure 8: Total Delay on Network in NT period (7PM-6AM) <i>B1</i>	20
Figure 9: Total VHT in AM period (6AM -10AM) <i>B1</i>	21
Figure 10: Total VHT in MD period (10AM -3PM) <i>B1</i>	21
Figure 11: Total VHT in PM period (3PM -7PM) <i>B1</i>	22
Figure 12: Total VHT in NT period (7PM -6AM) <i>B1</i>	22
Figure 13: Total VMT in AM period (6-10) <i>B1</i>	23
Figure 14: Total VMT in MD period (10A-3P) <i>B1</i>	24
Figure 15: Total VMT in PM period (3-7) <i>B1</i>	24
Figure 16: Total VMT in NT period (7P-6A) <i>B1</i>	25
Figure 17: Flow on major links AM period (6AM-10AM) <i>B1</i>	26
Figure 18: Flow on major links MD period (10A-3P) <i>B1</i>	27
Figure 19: Flow on major links PM period (3-7) <i>B1</i>	27
Figure 20: Flow on major links NT period (7P-6A) <i>B1</i>	28
Figure 21: Legend for total VMT in AM period (6AM-10AM).....	30
Figure 22: Total VMT in AM period (6AM-10AM) within 5 mile buffer zone	30
Figure 23: Total VMT in AM period (6AM-10AM) within 10 mile buffer zone	31
Figure 24: Total VMT in AM period (6AM-10AM) within 15 mile buffer zone	31
Figure 25: Total VMT in AM period (6AM-10AM) within 20 mile buffer zone	32
Figure 26: Total VMT in AM period (6AM-10AM) within 25 mile buffer zone	32
Figure 27: Total VMT in AM period (6AM-10AM) within 30 mile buffer zone	33
Figure 28: Legend for total VMT in MD period (10AM-3PM)	33
Figure 29: Total VMT in MD period (10AM-3PM) within 5 mile buffer zone	34
Figure 30: Total VMT in MD period (10AM-3PM) within 10 mile buffer zone	34

Figure 31: Total VMT in MD period (10AM-3PM) within 15 mile buffer zone	35
Figure 32: Total VMT in MD period (10AM-3PM) within 20 mile buffer zone	35
Figure 33: Total VMT in MD period (10AM-3PM) within 25 mile buffer zone	36
Figure 34: Total VMT in MD period (10AM-3PM) within 30 mile buffer zone	36
Figure 35: Legend for total VMT in PM period (3PM-7PM).....	37
Figure 36: Total VMT in PM period (3PM-7PM) within 5 mile buffer zone	37
Figure 37: Total VMT in PM period (3PM-7PM) within 10 mile buffer zone	38
Figure 38: Total VMT in PM period (3PM-7PM) within 15 mile buffer zone	38
Figure 39: Total VMT in PM period (3PM-7PM) within 20 mile buffer zone	39
Figure 40: Total VMT in PM period (3PM-7PM) within 25 mile buffer zone	39
Figure 41: Total VMT in PM period (3PM-7PM) within 30 mile buffer zone	40
Figure 42: Legend for total VMT in NT period (7PM -6AM)	40
Figure 43: Total VMT in NT period (7PM -6AM) within 5 mile buffer zone	41
Figure 44: Total VMT in NT period (7PM -6AM) within 10 mile buffer zone	41
Figure 45: Total VMT in NT period (7PM -6AM) within 15 mile buffer zone	42
Figure 46: Total VMT in NT period (7PM -6AM) within 20 mile buffer zone	42
Figure 47: Total VMT in NT period (7PM -6AM) within 25 mile buffer zone	43
Figure 48: Total VMT in NT period (7PM -6AM) within 30 mile buffer zone	43
Figure 49: Legend for total VHT in AM period (6AM-10AM)	44
Figure 50: Total VHT in AM period (6AM-10AM) within 5 mile buffer zone	45
Figure 51: Total VHT in AM period (6AM-10AM) within 10 mile buffer zone	45
Figure 52: Total VHT in AM period (6AM-10AM) within 15 mile buffer zone	46
Figure 53: Total VHT in AM period (6AM-10AM) within 20 mile buffer zone	46
Figure 54: Total VHT in AM period (6AM-10AM) within 25 mile buffer zone	47
Figure 55: Total VHT in AM period (6AM-10AM) within 30 mile buffer zone	47
Figure 56: Legend for total VHT in MD period (10AM-3PM).....	48
Figure 57: Total VHT in MD period (10AM-3PM) within 5 mile buffer zone.....	48
Figure 58: Total VHT in MD period (10AM-3PM) within 10 mile buffer zone.....	49
Figure 59: Total VHT in MD period (10AM-3PM) within 15 mile buffer zone.....	49
Figure 60: Total VHT in MD period (10AM-3PM) within 20 mile buffer zone.....	50
Figure 61: Total VHT in MD period (10AM-3PM) within 25 mile buffer zone.....	50
Figure 62: Total VHT in MD period (10AM-3PM) within 30 mile buffer zone.....	51
Figure 63: Legend for total VHT in PM period (3PM-7PM)	52
Figure 64: Total VHT in PM period (3PM-7PM) within 5 mile buffer zone	52
Figure 65: Total VHT in PM period (3PM-7PM) within 10 mile buffer zone	52
Figure 66: Total VHT in PM period (3PM-7PM) within 15 mile buffer zone	53
Figure 67: Total VHT in PM period (3PM-7PM) within 20 mile buffer zone	53
Figure 68: Total VHT in PM period (3PM-7PM) within 25 mile buffer zone	54
Figure 69: Total VHT in PM period (3PM-7PM) within 30 mile buffer zone	54
Figure 70: Legend for total VHT in NT period (7PM -6AM)	55
Figure 71: Total VHT in NT period (7PM -6AM) within 5 mile buffer zone.....	55
Figure 72: Total VHT in NT period (7PM -6AM) within 10 mile buffer zone.....	56
Figure 73: Total VHT in NT period (7PM -6AM) within 15 mile buffer zone.....	56
Figure 74: Total VHT in NT period (7PM -6AM) within 20 mile buffer zone.....	57
Figure 75: Total VHT in NT period (7PM -6AM) within 25 mile buffer zone.....	57
Figure 76: Total VHT in NT period (7PM -6AM) within 25 mile buffer zone.....	58

Figure 77: Total delay in AM period (6AM -10AM)	59
Figure 78: Total delay in MD period (10AM -3PM).....	60
Figure 79: Total delay in PM period (3PM -7PM)	61
Figure 80: Total delay in NT period (7PM-6AM).....	62
Figure 81: Flow on Verrazano in AM period (6-10)	63
Figure 82: Flow on Verrazano in MD period (10A-3P)	64
Figure 83: Flow on Verrazano in PM period (3PM-7PM)	65
Figure 84: Flow on Verrazano in NT period (7PM-6AM)	66
Figure 85: Legend for total VMT in AM period (6AM-10AM).....	68
Figure 86: Total VMT in AM period (6AM-10AM) within 5 mile buffer zone	69
Figure 87: Total VMT in AM period (6AM-10AM) within 10 mile buffer zone	69
Figure 88: Total VMT in AM period (6AM-10AM) within 15 mile buffer zone	70
Figure 89: Total VMT in AM period (6AM-10AM) within 20 mile buffer zone	70
Figure 90: Total VMT in AM period (6AM-10AM) within 25 mile buffer zone	71
Figure 91: Total VMT in AM period (6AM-10AM) within 30 mile buffer zone	71
Figure 92: Legend for total VMT in MD period (10AM-3PM)	72
Figure 93: Total VMT in MD period (10AM-3PM) within 5 mile buffer zone	72
Figure 94: Total VMT in MD period (10AM-3PM) within 10 mile buffer zone	73
Figure 95: Total VMT in MD period (10AM-3PM) within 15 mile buffer zone	73
Figure 96: Total VMT in MD period (10AM-3PM) within 20 mile buffer zone	74
Figure 97: Total VMT in MD period (10AM-3PM) within 25 mile buffer zone	74
Figure 98: Total VMT in MD period (10AM-3PM) within 30 mile buffer zone	75
Figure 99: Legend for total VMT in PM period (6PM-10PM).....	76
Figure 100: Total VMT in PM period (6PM-10PM) within 5 mile buffer zone	76
Figure 101: Total VMT in PM period (6PM-10PM) within 10 mile buffer zone	77
Figure 102: Total VMT in PM period (6PM-10PM) within 15 mile buffer zone	77
Figure 103: Total VMT in PM period (6PM-10PM) within 20 mile buffer zone	78
Figure 104: Total VMT in PM period (6PM-10PM) within 25 mile buffer zone	78
Figure 105: Total VMT in PM period (6PM-10PM) within 30 mile buffer zone	79
Figure 106: Legend for total VMT in NT period (10AM-3PM)	80
Figure 107: Total VMT in NT period (10AM-3PM) within 5 mile buffer zone	80
Figure 108: Total VMT in NT period (10AM-3PM) within 10 mile buffer zone	81
Figure 109: Total VMT in NT period (10AM-3PM) within 15 mile buffer zone	81
Figure 110: Total VMT in NT period (10AM-3PM) within 20 mile buffer zone	82
Figure 111: Total VMT in NT period (10AM-3PM) within 25 mile buffer zone	82
Figure 112: Total VMT in NT period (10AM-3PM) within 30 mile buffer zone	83
Figure 113: Legend for total VHT in AM period (6AM -10AM)	84
Figure 114: Total VHT in AM period (6AM -10AM) within 5 mile buffer zone	85
Figure 115: Total VHT in AM period (6AM -10AM) within 10 mile buffer zone	85
Figure 116: Total VHT in AM period (6AM -10AM) within 15 mile buffer zone	86
Figure 117: Total VHT in AM period (6AM -10AM) within 20 mile buffer zone	86
Figure 118: Total VHT in AM period (6AM -10AM) within 25 mile buffer zone	87
Figure 119: Total VHT in AM period (6AM -10AM) within 30 mile buffer zone	87
Figure 120: Legend for total VHT in MD period (10AM -3PM).....	88
Figure 121: Total VHT in MD period (10AM -3PM) within 5 mile buffer zone.....	89
Figure 122: Total VHT in MD period (10AM -3PM) within 10 mile buffer zone.....	89

Figure 123: Total VHT in MD period (10AM -3PM) within 15 mile buffer zone.....	90
Figure 124: Total VHT in MD period (10AM -3PM) within 20 mile buffer zone.....	90
Figure 125: Total VHT in MD period (10AM -3PM) within 25 mile buffer zone.....	91
Figure 126: Total VHT in MD period (10AM -3PM) within 30 mile buffer zone.....	91
Figure 127: Legend for total VHT in PM period (3PM-7PM)	92
Figure 128: Total VHT in PM period (3PM-7PM) within 5 mile buffer zone	93
Figure 129: Total VHT in PM period (3PM-7PM) within 10 mile buffer zone	93
Figure 130: Total VHT in PM period (3PM-7PM) within 15 mile buffer zone	94
Figure 131: Total VHT in PM period (3PM-7PM) within 20 mile buffer zone	94
Figure 132: Total VHT in PM period (3PM-7PM) within 25 mile buffer zone	95
Figure 133: Total VHT in PM period (3PM-7PM) within 30 mile buffer zone	95
Figure 134: Legend for total VHT in NT period (7PM -6AM)	96
Figure 135: Total VHT in NT period (7PM -6AM) within 5 mile buffer zone.....	96
Figure 136: Total VHT in NT period (7PM -6AM) within 10 mile buffer zone.....	97
Figure 137: Total VHT in NT period (7PM -6AM) within 15 mile buffer zone.....	97
Figure 138: Total VHT in NT period (7PM -6AM) within 20 mile buffer zone.....	98
Figure 139: Total VHT in NT period (7PM -6AM) within 25 mile buffer zone.....	98
Figure 140: Total VHT in NT period (7PM -6AM) within 30 mile buffer zone.....	99
Figure 141: Total delay in AM period (6AM -10AM)	101
Figure 142: Total delay in MD period (10AM -3PM).....	102
Figure 143: Total delay in PM period (3PM -7PM)	103
Figure 144: Total delay in NT period (7PM -6AM)	104
Figure 145: Flow on Verrazano in AM period (6AM-10AM)	106
Figure 146: Flow on Verrazano in MD period (10AM-3PM)	107
Figure 147: Flow on Verrazano in PM period (3PM-7PM)	108
Figure 148: Flow on Verrazano in NT period (7PM-6AM)	109
Figure 149: Travel Time on Verrazano in AM period (6AM-10AM).....	110
Figure 150: Travel Time on Verrazano in MD period (10AM-3PM)	111
Figure 151: Travel Time on Verrazano in PM period (3PM-7PM).....	112
Figure 152: Travel Time on Verrazano in AM period (7PM-6AM)	112
Figure 153: B1_BC_AM_Delay	119
Figure 154: B1_2007_AM_Delay	120
Figure 155: B1_2012_AM_Delay	121
Figure 156: B1_2017_AM_Delay	122
Figure 157: B1_2022_AM_Delay	123
Figure 158: B1_BC_PM_Delay.....	124
Figure 159: B1_2007_PM_Delay	125
Figure 160: B1_2012_PM_Delay	126
Figure 161: B1_2017_PM_Delay	127
Figure 162: B1_2022_PM_Delay	128
Figure 163: B2_BC_AM_Delay	129
Figure 164: B2_S1_AM_Delay	130
Figure 165: B2_S2_AM_Delay	131
Figure 166: B2_S3_AM_Delay	132
Figure 167: B2_BC_PM_Delay.....	133
Figure 168: B2_S1_PM_Delay.....	134

Figure 169: B2_S2_PM_Delay.....	135
Figure 170: B2_S3_PM_Delay.....	136
Figure 171: B3_BC_AM_Delay.....	137
Figure 172: B3_S1_AM_Delay.....	138
Figure 173: B3_S2_AM_Delay.....	139
Figure 174: B3_S3_AM_Delay.....	140
Figure 175: B3_S4_AM_Delay.....	141
Figure 176: B3_S5_AM_Delay.....	142
Figure 177: B3_S6_AM_Delay.....	143
Figure 178: B3_BC_PM_Delay.....	144
Figure 179: B3_S1_PM_Delay.....	145
Figure 180: B3_S2_PM_Delay.....	146
Figure 181: B3_S3_PM_Delay.....	147
Figure 182: B3_S4_PM_Delay.....	148
Figure 183: B3_S5_PM_Delay.....	149
Figure 184: B3_S6_PM_Delay.....	150

List of Tables

Table 1: County Codes.....	8
Table 2: Percent Increases for <i>B1</i> OD.....	14
Table 3: Percent change in delay from BC (2002) <i>B1</i>	20
Table 4: Percent change in VHT from BC (2002) <i>B1</i>	23
Table 5: Percent change in VMT from BC (2002) <i>B1</i>	25
Table 6: Percent Change in VMT from BC (AM).....	33
Table 7: Percent Change in VMT from BC (MD).....	37
Table 8: Percent Change in VMT from BC (PM).....	40
Table 9: Percent Change in VMT from BC (NT).....	44
Table 10: Percent Change in VHT from BC (AM).....	48
Table 11: Percent Change in VHT from BC (MD).....	51
Table 12: Percent Change in VHT from BC (PM).....	55
Table 13: Percent Change in VHT from BC (NT).....	58
Table 14: Percent change in total delay from BC (AM).....	59
Table 15: Percent change in total delay from BC (MD).....	60
Table 16: Percent change in total delay from BC (PM).....	61
Table 17: Percent change in total delay from BC (NT).....	62
Table 18: Percent change in flow from BC (AM).....	63
Table 19: Percent change in flow from BC (MD).....	64
Table 20: Percent change in flow from BC (PM).....	65
Table 21: Percent change in flow from BC (NT).....	66
Table 22: Percent Change in VMT from BC (AM).....	72
Table 23: Percent Change in VMT from BC (MD).....	75
Table 24: Percent Change in VMT from BC (PM).....	79
Table 25: Percent Change in VMT from BC (NT).....	83
Table 26: Percent change in total VHT from BC (AM).....	88
Table 27: Percent change in total VHT from BC (MD).....	92
Table 28: Percent change in total VHT from BC (PM).....	96

Table 29: Percent change in total VHT from BC (NT)	99
Table 30: Percent change in total delay from BC (AM).....	101
Table 31: Percent change in total delay from BC (MD).....	102
Table 32: Percent change in total delay from BC (PM).....	103
Table 33: Percent change in total delay from BC (NT).....	104
Table 34: Percent change in flow from BC (AM)	106
Table 35: Percent change in flow from BC (MD)	107
Table 36: Percent change in flow from BC (PM)	108
Table 37: Percent change in flow from BC (NT)	109

1. INTRODUCTION

New York Metropolitan Transportation Council (NYMTC), an association of governments, transportation providers, and environmental organizations, handles the metropolitan transportation planning throughout New York City, Long Island and the Lower Hudson Valley. In the early 1990s, NYMTC developed a transportation model, the New York Best Practices Model (NYBPM), in response to federal regulations on surface planning, specifically the Intermodal Surface Transportation Efficiency Act (ISTEA) and the Clean Air Act (CAA). The NYBPM was created to analyze adjusting traffic patterns due to changes within demographic agendas and other changes in transportation systems in the area, and has become a very valuable tool to planners. The NYBPM network consists of 3,586 zones in 28 counties, shown in Table 1, and includes 118 external stations spanning New York, New Jersey and Connecticut.

Table 1: County Codes

Code	Description	Code	Description
1	New York (Manhattan)	15	Passaic
2	Queens	16	Hudson
3	Bronx	17	Essex
4	Kings (Brooklyn)	18	Union
5	Richmond (Staten Island)	19	Morris
6	Nassau	20	Somerset
7	Suffolk	21	Middlesex
8	Westchester	22	Monmouth
9	Rockland	23	Ocean
10	Putnam	24	Hunterdon
11	Orange	25	Warren
12	Dutchess	26	Sussex
13	Fairfield	27	New Haven
14	Bergen	28	Mercer

All types of road facilities, from minor arterials and above are represented in the model's highway network, and all forms of public transportation are represented at the individual route level in the transit network database. The model has the ability to study relationships between the current transportation systems and how people in the region live, work and move. This information can be used to understand travel decisions, predict future travel patterns, and evaluate the effectiveness of proposed transportation improvements. NYBPM can mold itself to focus on any size project within the region, thus enabling the model to be used in various situations and projects. The NYBPM allows for a study of varying demographic agendas, such as public transportation possibilities and variable destinations, while also incorporating physical aspects such as construction changes, capacity changes, toll variations, and freight movement increase.

The NYBPM incorporates TransCAD GIS but its data can be applied in Arc View, Dbase, and Excel.

The body of the data used to develop the NYBPM was gathered from a regional travel survey, conducted by NYMTC in conjunction with the North Jersey Transportation Planning Authority (NJTPA) over an 18-month period from 1996 to 1997. The survey was in the form of a 24-hour travel diary, where each member of the household had to describe every journey taken on that day. The households were selected at random for each of the 28 counties in the area. 11,264 households completed and returned surveys. Out of these surveys 10,971 were for weekday “travel days” and 275 were for weekend “travel days”. The diaries provide information on the percentage of trips made by car, bus, commuter rail, subway, foot and other modes revealing travel patterns by age, gender, purpose, time of day and other factors.

The highway network database consists of standard link attributes as well as a Physical Link Type field that is used to determine the free flow speed, capacity per hour per lane, and the type of vehicle density function in the NetPrep model. For each base highway network, there are 4 derived period networks: AM peak (6AM – 10AM), midday (10AM – 3PM), PM peak (3PM – 7PM), and night (7PM – 6AM). In order to enhance assignment accuracy, the Base Network is used to create four separate networks by time period (the “Period Networks”), and those networks are used as the basis for traffic assignment.

An innovative feature of the model is the concept of “journeys” rather than “trips”. The journey is defined as travel between principal locations including stops on the way and back in a loop following the same sequence. The traditional trip simply identifies a point of origin and destination and does not include daily stops such as the gym, food store, etc. The use of the journey provides more realistic analysis on the decisions made by travelers. One other innovative feature of the model is that it uses a microsimulation method to simulate the travel pattern of each person in the region increasing accuracy and usefulness of the model. The Household, Auto-Ownership and Journey-Frequency (HAJ) Model in NYBPM replaces the traditional trip generation model. It estimates the total number of households by income size, number of children, number of workers and number of autos, and then determines the number of journeys that will be produced for each subgroup over a 24-hour period. The Mode Destination Stop Choice (MDSC) Model replaces the traditional trip distribution. Based on the person and household characteristics, along with land-use densities around the journey origin, this model predicts which modes of travel each person chooses, where the person goes and if the person stops along the way on the journey.

1.1 Task 4b Overview

The purpose of the work presented in this report is to test and demonstrate the capabilities of NYMTC’s Best Practices Model for policy analysis in the New York Metropolitan Region, through sensitivity analysis.

This evaluation of the NYBPM is important for both helping establish the model's credibility as a tool for policy analysis, and in persuading NYMTC's partners to support continued investment in the model's improvements. For this reason it was important to select scenarios for analysis that help clarify the model's abilities and limitations, without choosing unrealistically difficult tests that examine questions known to be outside the model's current design capabilities. Scenario's to be tested in this task were chosen based on the following five selection criteria:

1. Appropriateness. The scenario must test an interaction that is theoretically within the scope of the model's capabilities.
2. Data. In order to assess whether the model's sensitivity to changes in input data is reasonable, it is important to be able to compare the model's results with real data or estimated elasticities in the published literature.
3. Multimodality. Collectively, the case studies should examine impacts on a variety of modes.
4. Relevance. Case studies should be relevant to the issues facing NYMTC member agencies and the New York Metropolitan Region more generally.
5. Simplicity. Case studies should be simple enough to assess the model's sensitivity to the proposed change.

From these selection criteria, two sets of proposed scenarios were developed. The first set of sensitivity tests are at an aggregate level, focusing on the stability and sensitivity of model outputs to alternative growth forecasts. The second set of sensitivity tests is looking at a detailed level, at how the model responds to network or policy changes.

The following scenarios were proposed and agreed upon for sensitivity analysis:

A. Aggregate-Level Analyses

A1: Sensitivity to transit fare changes. This case will test the sensitivity of NYBPM to changes in the transit fares (including bus, train, ferry, etc) in the NYMTC region. It will examine scenarios for transit fare changes for the entire NYMTC region, ranging from -100% to +100% of the current fare.

A2: Changes in socioeconomic and demographic (SED) characteristics. This case will test how the model responds to socioeconomic and demographic changes associated with adding 10,000 new residents to a single transportation analysis zone. A baseline scenario will examine the impacts of adding 10,000 residents while maintaining all other characteristics of the zone. Other scenarios will examine the impacts of varying the ratio of population to households, the average zonal household income, and the ratio of labor force to households.

A3: Change in the spatial distribution of population and employment. This case will test the sensitivity of the model to spatial location of population and employment changes.

Scenarios will test the model's sensitivity to differences in land use, transit accessibility, and transportation network congestibility.

B. Network-Level Analyses

B1: Impact of truck demand changes. In NYBPM, truck origin-destination (O-D) demand matrices are represented by fixed tables. This is different than the passenger side of the model, which uses an activity-based microsimulation model to generate trips. For the sensitivity analysis, fixed O-D demand matrices will allow for more control over the changes that will be made. This sensitivity test will focus on the change in freight demand and its impact on overall traffic.

In this sensitivity analysis, freight demand will be changed for a number of origin and destination pairs that are expected to have an impact on the traffic originating from New Jersey and destined to Manhattan. Demand for these specific O-D pairs will be increased by a certain percentage each year to observe changes in the model output. The zonal and link-level effects on passenger travel will be observed as the level of traffic on the major corridors into Manhattan rises.

B2: Impacts of changes in tolls. The tolls at the Verrazano-Narrows Bridge will be varied to observe the effects on traffic at other crossings. The Verrazano was chosen because of the salience of tolling policy at this facility. Scenarios that will be tested include shifting toll collection from the westbound to the eastbound direction, switching to a bi-directional tolling regime, and maintaining the current westbound-only tolls but doubling the rate.

B3: Impact of disruption of infrastructure. This scenario tests how travel choices change at the facility level if the capacity of a bridge is reduced due to construction, maintenance, or unplanned events. Because of NYBPM's known difficulties forecasting traffic levels on Manhattan's East River Crossings, this scenario will focus on a facility that does not enter Manhattan. The Verrazano-Narrows Bridge, which is undergoing repairs that require lane closures, has been selected.

This report focuses on the three network-level scenarios just mentioned. In the following section the three scenarios (*B1*, *B2*, and *B3*) will be described in detail and a data analysis of the results produced by the NYBPM will be provided for each of the three scenarios.

For scenarios *B1*, *B2* and *B3* the NYBPM was run using the following outlined methodology. The procedures to run the model, including number of iterations and selected variables, follow the suggested procedures provided by Parsons Brinckerhoff in the NYBPM User Documentation. The modifications for the scenarios were primarily in Project TIP coding and Trip Table Modification, as mentioned below.

Model Run Procedures:

1. Create New Scenario Directory
2. Copy or Extract Required Input Data to Scenario Folder
 - a. SED data
 - b. Input SOV/HOV Skims
 - c. Base Year Transit Network
 - d. Base Year Highway Network
3. Modify Trip Tables
 - a. This step was omitted during scenario *B2* and *B3* since all sub-scenarios were run using the base year; only network modifications were made
 - b. There is a more specific explanation of trip table modification for scenario *B1* in *Section 2: Description of Scenarios*
4. Build The Scenario Year Highway Network from Coded Projects
 - a. Project TIP Coding was used to implement the toll changes in scenario *B2* and the lane closures in scenario *B3*
 - b. This step was omitted during scenario *B1* which only involved changes to the trip tables
5. Prepare Transit Network Database (for Bus Preloads)
6. NetPrep with Bus Preloads
7. Create Highway Pre-Skims
8. Build Transit Inputs
9. Create Transit and Highway Accessibilities
10. Run the Entire Highway Model in One Step

2. DESCRIPTION OF SCENARIOS

2.1 *B1: Impact of truck demand changes*

This scenario will show the zonal and link-level effects on passenger travel on the major corridors into Manhattan as the level of traffic rises on the network. Freight demands for a number of origin and destination pairs going from New Jersey into Manhattan will be gradually increased to observe the changes in the model output. The origins and destinations selected are shown in the following figure. The area shaded blue represents all the selected origins and the area shaded purple (Manhattan) represents all the selected destinations. A satellite image of the area is also shown to provide a descriptive image of the selected origins and destinations.

The origin TAZs that were selected are all New Jersey TAZs. The selected TAZs include all of Newark, Elizabeth, Jersey City, Hoboken, Bayonne and more. These specific TAZs were selected as origins of specific O-D pairs where truck traffic originates. The chosen area represents the Port of New York/New Jersey and the surrounding cities which produce a significant amount of truck traffic.

The destination TAZs that were chosen simply make up Manhattan as shown in the images. Manhattan TAZs were chosen as destinations to observe the impacts of increased truck traffic from the origins just mentioned on major corridors into Manhattan.

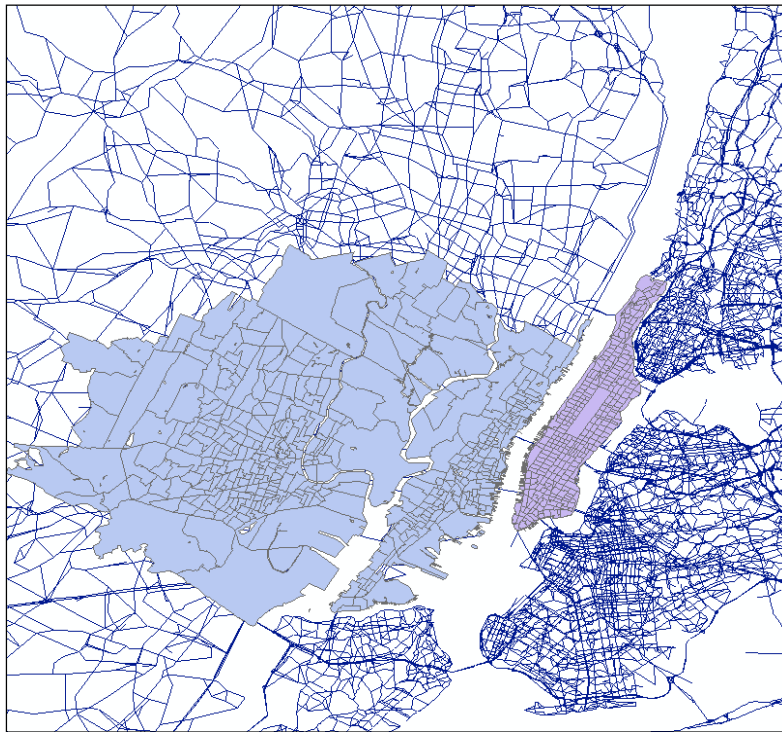


Figure 1: Selected Origins and Destinations (B1)

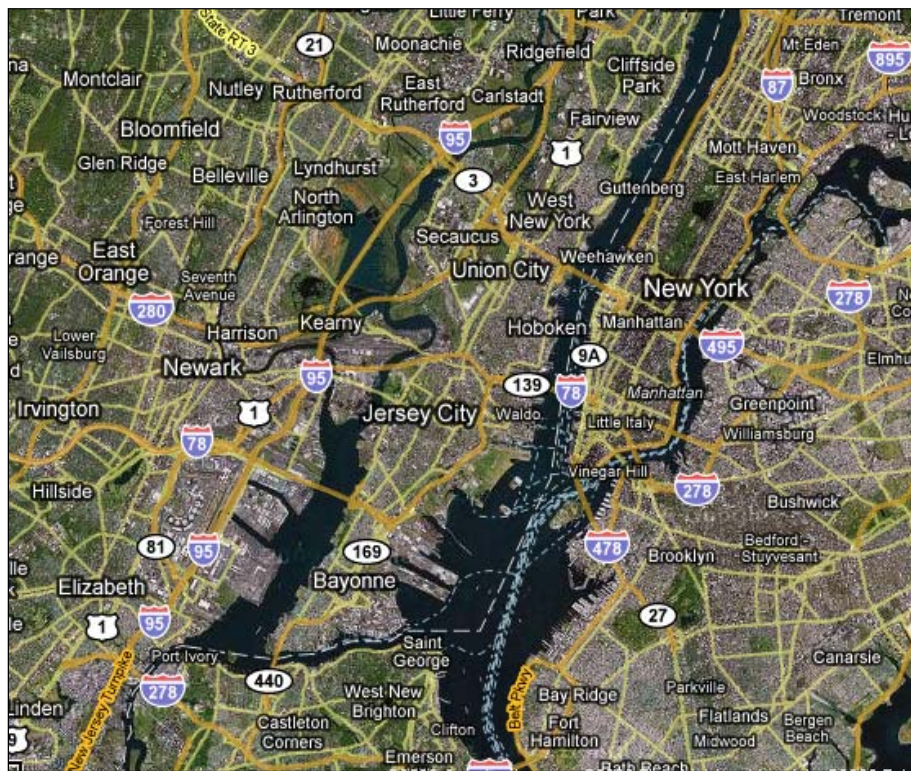


Figure 2: Map of Area Corresponding to Selected O-D's

The sensitivity analysis will consist of five different scenarios, one being the base case scenario from the given NYBPM input data (2002). The other four scenarios will be future year scenarios where truck traffic on the selected origin-destination pairs is increased. For each of the five scenarios the highway trip tables will be increased manually by defined percentages and tests will be limited to the highway assignment procedure. The scenarios include:

- Base Case (2002) – no change
- Scenario One (2007) – five year projection
- Scenario Two (2012) – ten year projection
- Scenario Three (2017) – fifteen year projection
- Scenario Four (2022) – twenty year projection

The base case scenario (2002) was run using the given input data from NYMTC. For the future year scenarios the base O-D's for each time period (AM, MD, PM, NT) were increased 2 percent per year with the exception of the selected truck O-D's previously mentioned. These specific O-D's were increased 5 percent per year in order to show an increase in the truck traffic from New Jersey into Manhattan, which reflects the projected above average increase in port related truck traffic. In order to obtain unique demand increases, the "Trip Table Inflation" procedure normally used to increase the O-D tables for future year scenarios was not used. Only specific O-D pairs within the "Trucks" matrix needed to be increased at a rate of 5 percent per year. The rest of the O-D pairs in the remaining matrices only needed to be increased at a rate of 2 percent per year. All matrices were increased within TransCAD, using the Geographic Information System Developer's Kit. In order to extract the selected truck O-D's and increase only these O-D's at a rate of 5 percent per year a code was written into TransCAD. Table 2 shows the total percentages that passenger vehicles and the selected truck O-D's were increased from the base case for each scenario.

Table 2: Percent Increases for *B1 OD*

% Increase	Passenger Vehicles	Selected Truck O-D's
BC (2002)	0	0
2007	10%	25%
2012	20%	50%
2017	30%	75%
2022	40%	100%

2.2 *B2: Impacts of changes in tolls*

This scenario will show the effects on traffic at other crossings when the tolls at the Verrazano-Narrows Bridge are varied. Scenarios that will be tested include shifting toll collection from the westbound to the eastbound direction, switching to a bi-directional tolling regime, and maintaining the current westbound-only tolls but doubling the rate.

The facility chosen for this scenario was the Verrazano-Narrows Bridge. Figure 3 shows the location of the facility within the region. The red star represents the bridge. The bridge is a key link in the region connecting Brooklyn on Long Island and Staten Island and providing the shortest route between the mid-Atlantic States and Long Island. In Brooklyn, the bridge connects to the Belt Parkway and the Brooklyn-Queens Expressway and to the large residential community of Bay-Ridge. On Staten Island the bridge joins the Staten Island Expressway. The bridge is double-decked with three lanes per direction (eastbound and westbound) on each deck.



Figure 3: Location of Verrazano-Narrows Bridge

The sensitivity analysis will consist of four different scenarios. For this scenario all standard procedures for running the BPM were used. This included running the highway network builder, creating new highway pre-skims, creating highway and transit accessibilities and running the entire highway model in one step. The four scenarios include:

- Base Case (BC) – no change
- Scenario One (S1) – eastbound toll
- Scenario Two (S2) – bi-directional toll
- Scenario Three (S3) – double current tolls

The base case will include no changes in toll policy on the Verrazano-Narrows Bridge. In Scenario One, the toll collection on the bridge will be changed from the westbound direction to the eastbound direction. In Scenario Two, the toll collection will become bi-directional with half of the current toll being collected in the westbound direction and half of the toll being collected in the eastbound direction. In Scenario Three, the toll collection will remain in the westbound direction however the current toll price will be doubled.

Five mile buffer zones around the Verrazano-Narrows Bridge were created in order to observe aggregate results within a thirty mile radius around the bridge. The buffer distances included five miles, ten miles, fifteen miles, twenty miles, twenty five miles and thirty miles. The buffers are shown in Figure 4.

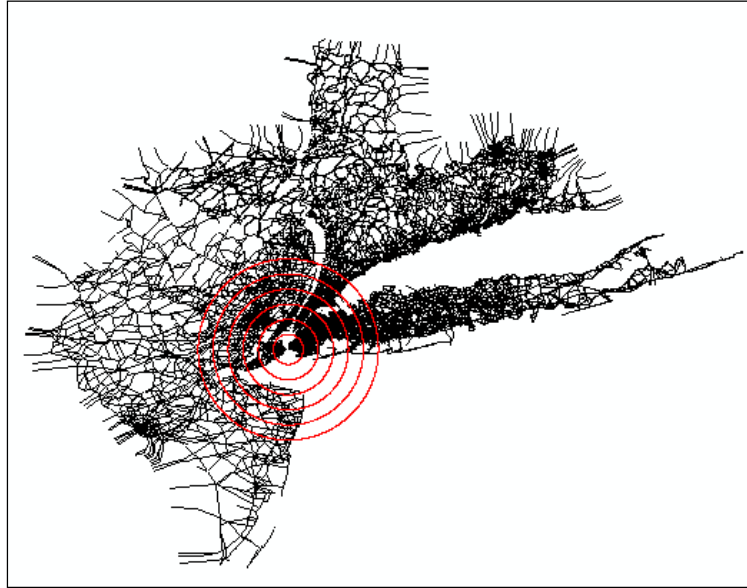


Figure 4: Five mile buffers around Verrazano-Narrows Bridge

2.3 B3: *Impact of disruption of infrastructure*

This scenario will show the impact of disruption of infrastructure within the region. The scenario will test how travel choices change at a facility level if the capacity of a bridge is reduced due to construction, maintenance, or unplanned events.

Similar to scenario B2 (impact of changes in tolls) the facility chosen for this scenario was the Verrazano-Narrows Bridge. As discussed in Section 2.2, the bridge is a key link in the region connecting Brooklyn on Long Island and Staten Island and providing the shortest route between the mid-Atlantic States and Long Island.

The sensitivity analysis will consist of seven different capacity reducing scenarios. For this scenario all standard procedures for running the BPM were used. This included running the highway network builder, creating new highway pre-skims, creating highway and transit accessibilities and running the entire highway model in one step. This will produce forecasts of short-term traffic impacts of closing zero, one, two, or three lanes of traffic. The seven scenarios include:

- Base Case (BC) – no change
- Scenario One (S1) – one lane eastbound reduction
- Scenario Two (S2) – one lane eastbound and westbound reduction

- Scenario Three (S3) – one lane westbound reduction
- Scenario Four (S4) – three lane westbound reduction
- Scenario Five (S5) – three lane eastbound reduction
- Scenario Six (S6) – three lane eastbound and westbound reduction

The base case will include no changes in capacity on the Verrazano-Narrows Bridge. The results from this case will be used as a basis to compare the results from the other scenarios. In Scenario One, one of the six lanes in the eastbound direction on the bridge will be closed. In Scenario Two, one lane in both the eastbound and westbound direction on the bridge will be closed. One of the six lanes in the westbound direction will be closed when running Scenario Three. Scenario Four will shut down three of the six westbound lanes on the Verrazano. Three of the six eastbound lanes will be shut down in Scenario Five and in Scenario Six three lanes will be shut down in both directions.

Similar to *B2* (Impact of Changes in Tolls) five mile buffer zones around the Verrazano-Narrows Bridge were created in order to observe aggregate results within a thirty mile radius around the bridge. The buffer distances included five miles, ten miles, fifteen miles, twenty miles, twenty five miles and thirty miles.

The tables and charts in the following sections summarize the results produced by the NYBPM. These results include analyses at a network level and a link level. On the network level total vehicle miles traveled within each buffer zone for each specified time period, total vehicle hours traveled within each buffer zone for each specified time period and total delay within each buffer zone for each specified time period are taken into account.

3. DATA ANALYSES

3.1 *B1: Impact of truck demand changes*

Total Delay on Network

This section shows the total delay on the entire NYBPM network for each of the five scenarios including the base case for all travel periods. The AM period is from 6AM-10AM, the MD period is from 10AM-3PM, the PM period is from 3PM-7PM and the NT period is from 7PM-6AM. The delay on each link was calculated by taking the difference of the average travel time output by the NYBPM for each link and the free flow travel time of that link. The total delay was then calculated by multiplying the average delay on each link by the total flow on that link. The total delay on the network dramatically increases for each five year scenario showing that the 2 percent increase in overall traffic per year along with the 5 percent increase in selected truck traffic per year is causing the network to reach capacity in many areas causing major delays throughout the network.

Figure 5 through Figure 8 show the delay for the base case (2002) and each future year scenario for the four travel periods. Table 3 shows the percent changes in delay from the base case, for each future year scenario and for all travel periods. From 2002 to 2022

the total delay on the network increases approximately 207 percent during the AM period, 198 percent during the MD, 204 percent during the PM period, and 183 percent during the NT period. This large increase in delay shows that by 2022 there will be heavy overall delays associated with travel in the region. As the volume of vehicles on the network continues to increase and major links begin to reach capacity, vehicle travel times will drastically increase leading to major delays.

Figures and Tables for Delay on Network

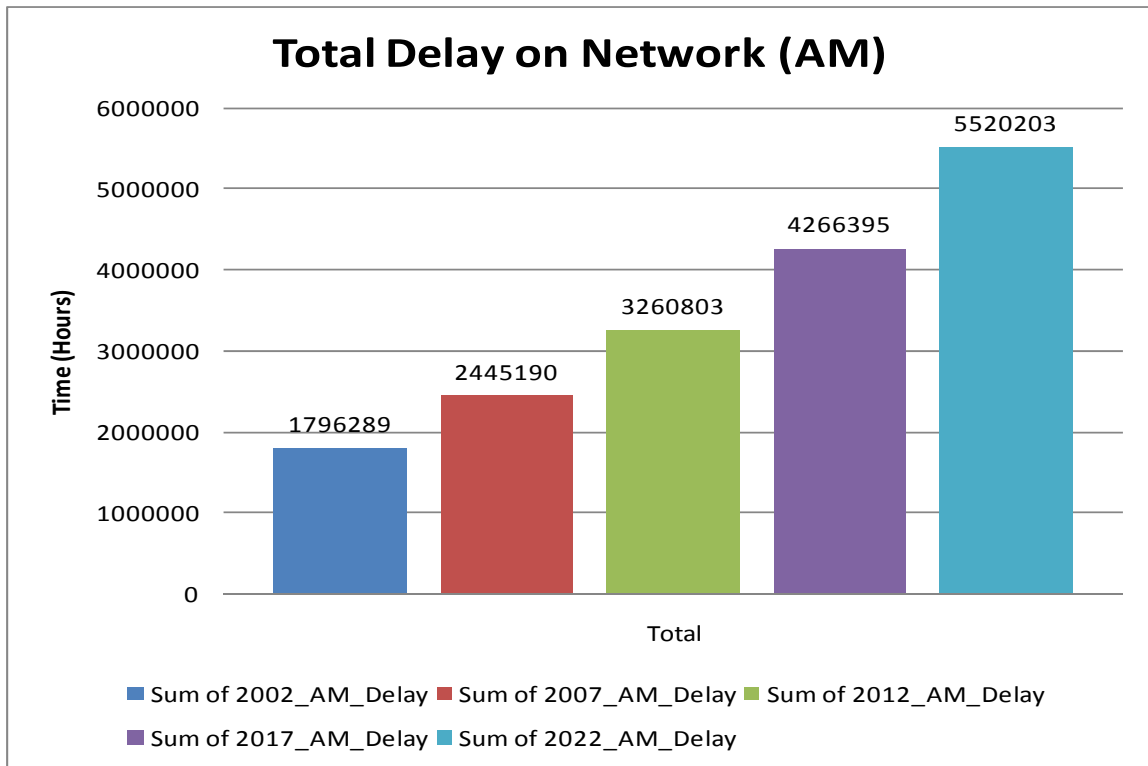


Figure 5: Total Delay on Network in AM period (6AM -10AM) B1

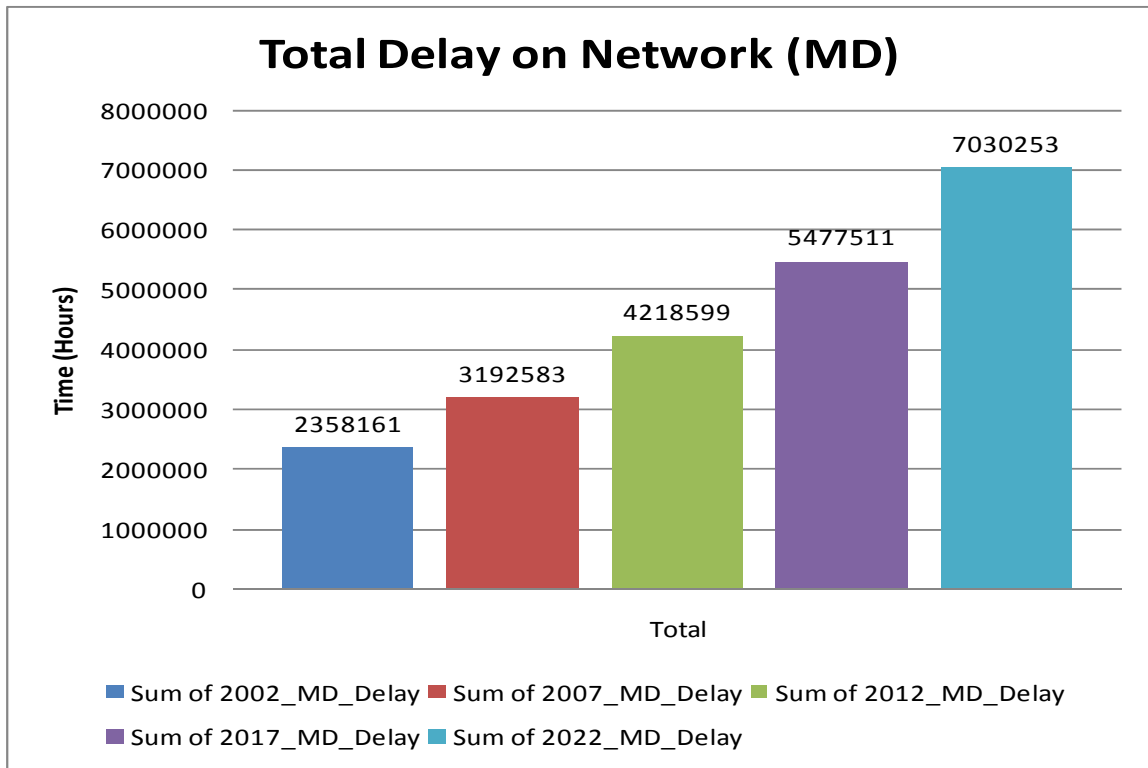


Figure 6: Total Delay on Network in MD period (10AM -3PM) B1

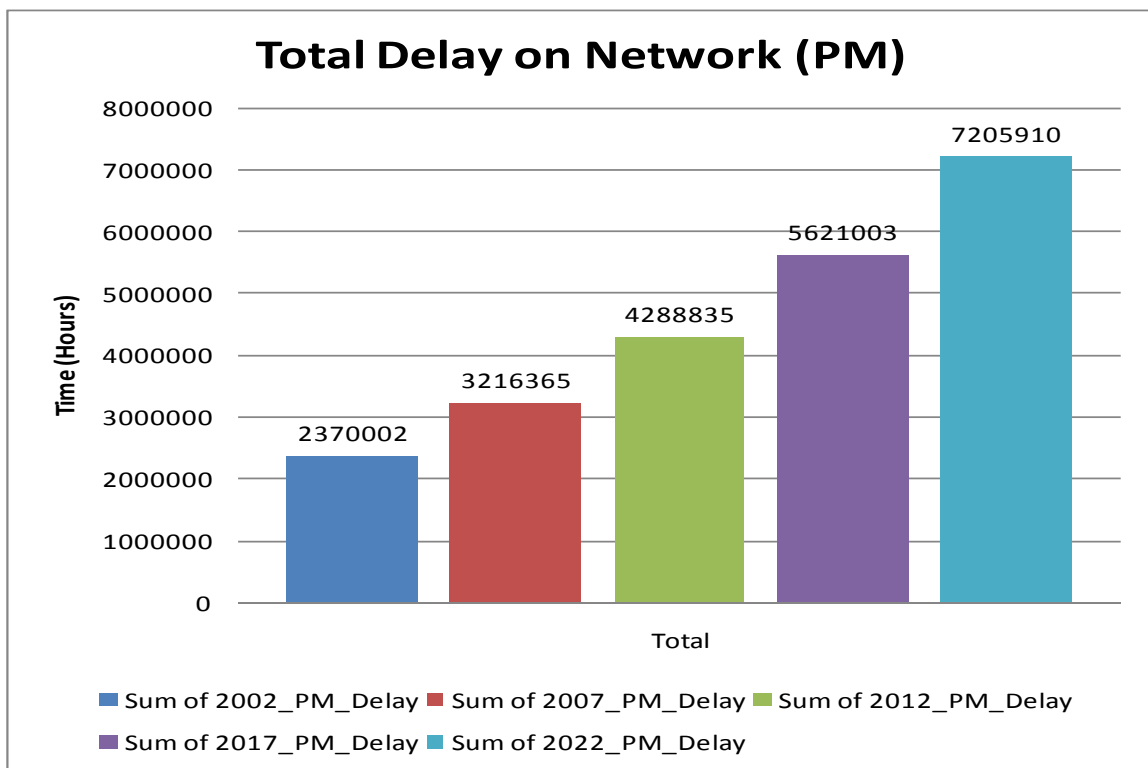


Figure 7: Total Delay on Network in PM period (3PM -7PM) B1

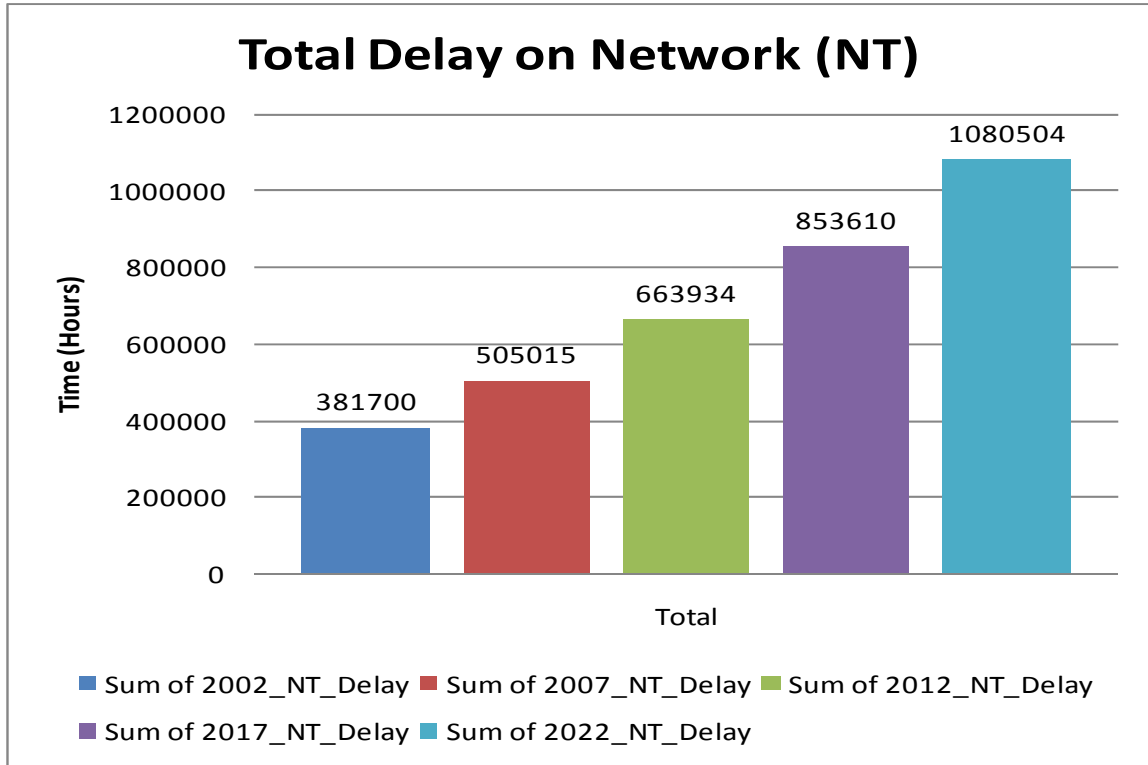


Figure 8: Total Delay on Network in NT period (7PM-6AM) B1

Table 3: Percent change in delay from BC (2002) B1

	2007	2012	2017	2022
AM	36.12	81.53	137.51	207.31
MD	35.38	78.89	132.28	198.12
PM	35.71	80.96	137.17	204.05
NT	32.31	73.94	123.63	183.08

Total Vehicle Hours Traveled

The total vehicle hours traveled on the network show how much time is spent on the highway network by travelers within the region. Figure 9 through Figure 12 show the change in total VHT for each future year scenario as the traffic increases at 2 percent per year with the exception of the selected truck O-D pairs which were increased at 5 percent per year.

As traffic increases travelers face major congestion on the highways and certain links on the network begin to reach capacity, significantly increasing the average link travel time. Table 4 shows the percent changes in VHT from the base case, for each future year scenario and for all travel periods. During the AM period the VHT increase from the 2002 base case nearly 12 percent in 2007, 22 percent in 2012, 37 percent in 2017, and 49 percent in 2022. For the other three travel periods the VHT percent changes from the 2002 base case to 2022 are: 47 percent during the MD period, 51 percent during the PM period and 32 percent during the NT period.

Figures and Tables for Total Vehicle Hours Traveled

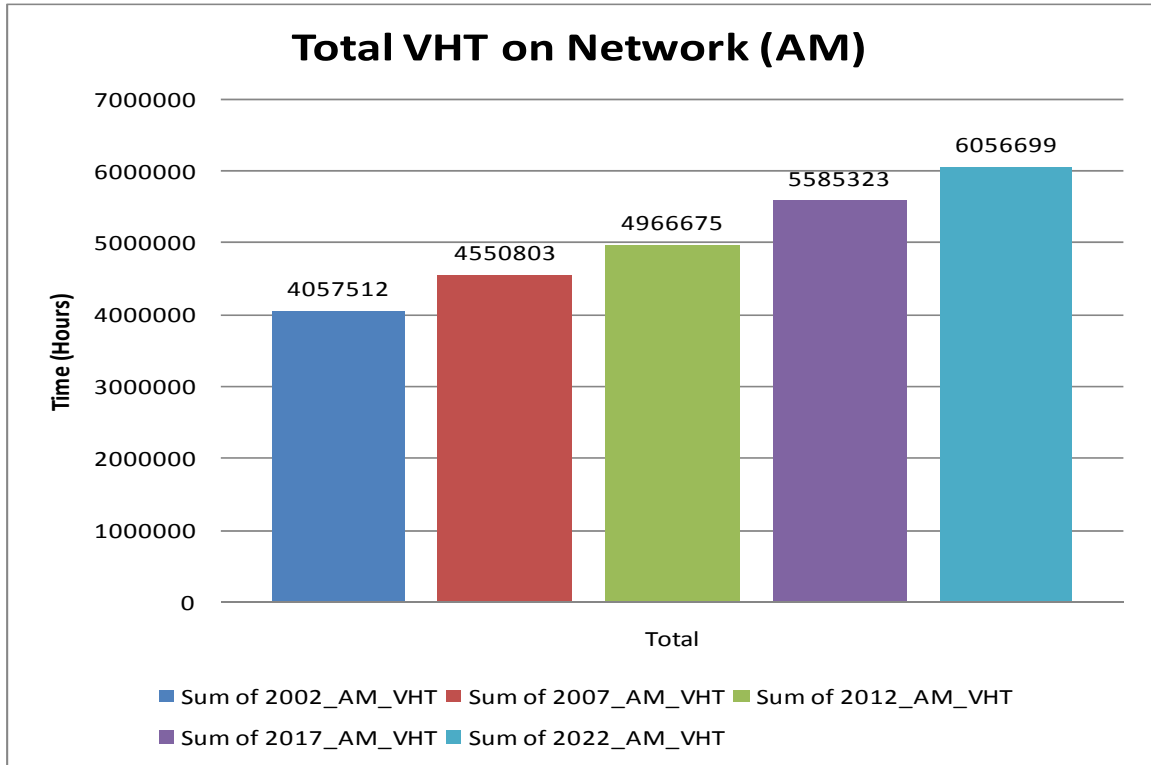


Figure 9: Total VHT in AM period (6AM -10AM) B1

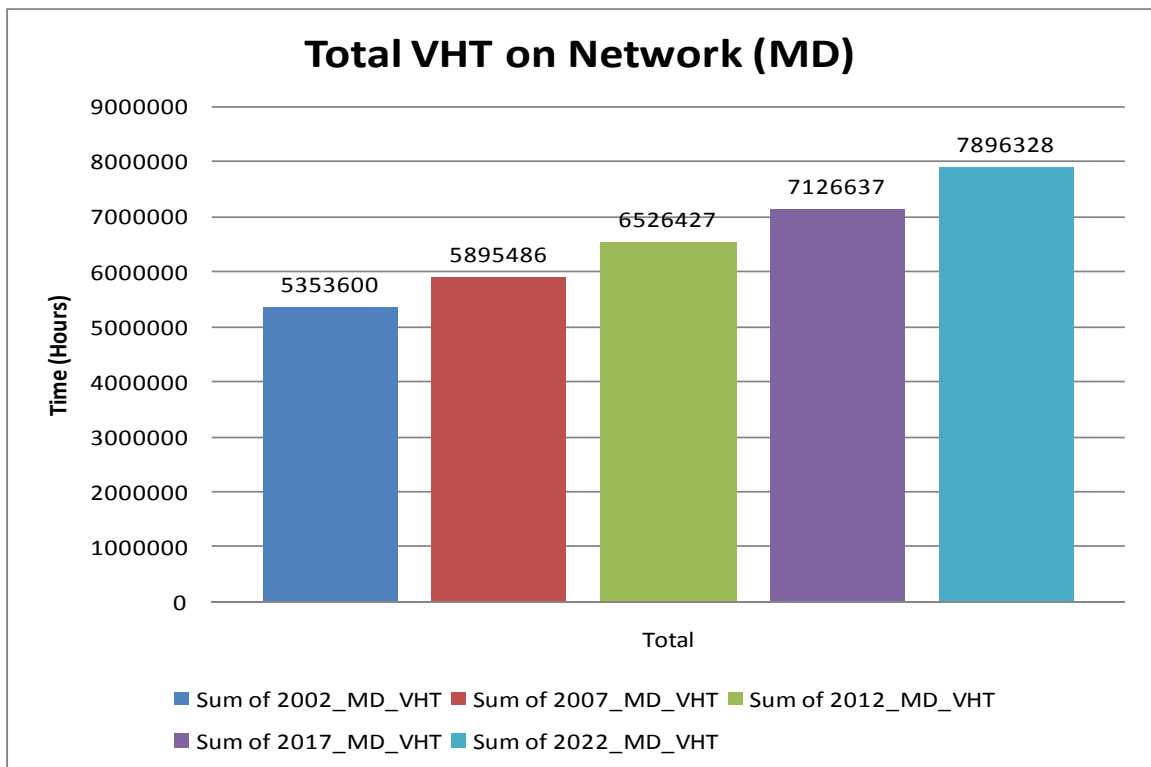


Figure 10: Total VHT in MD period (10AM -3PM) B1

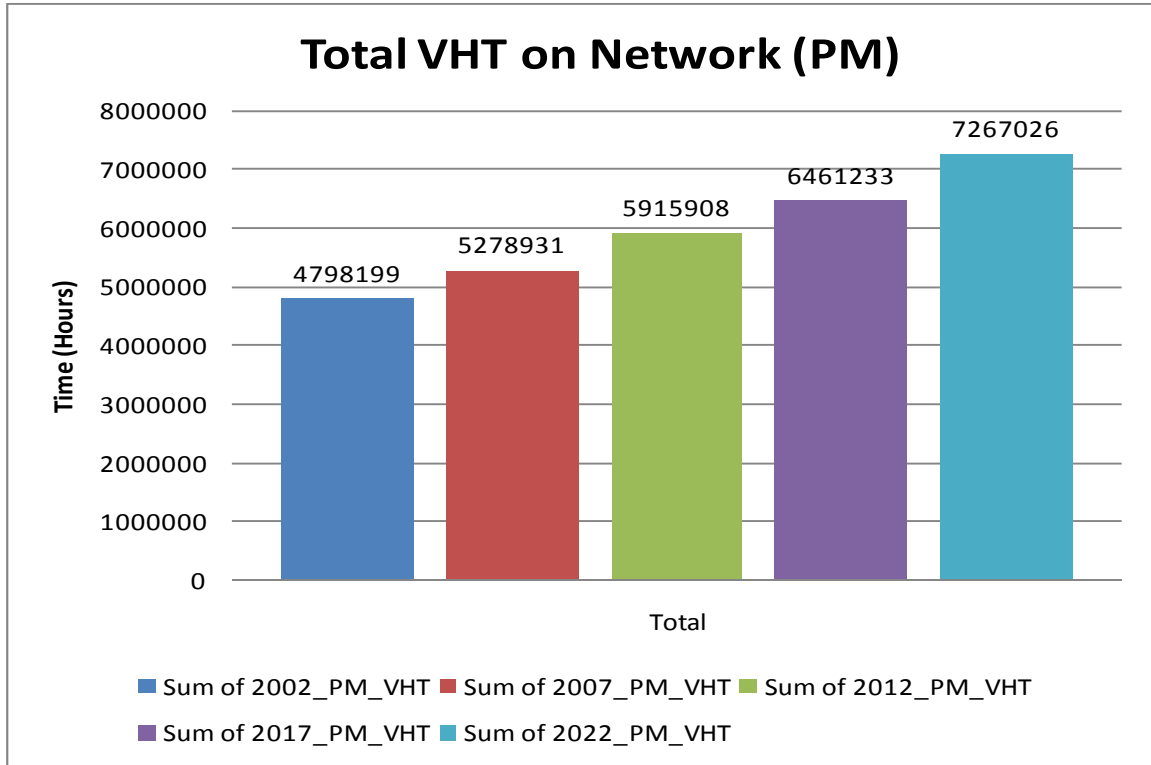


Figure 11: Total VHT in PM period (3PM -7PM) B1

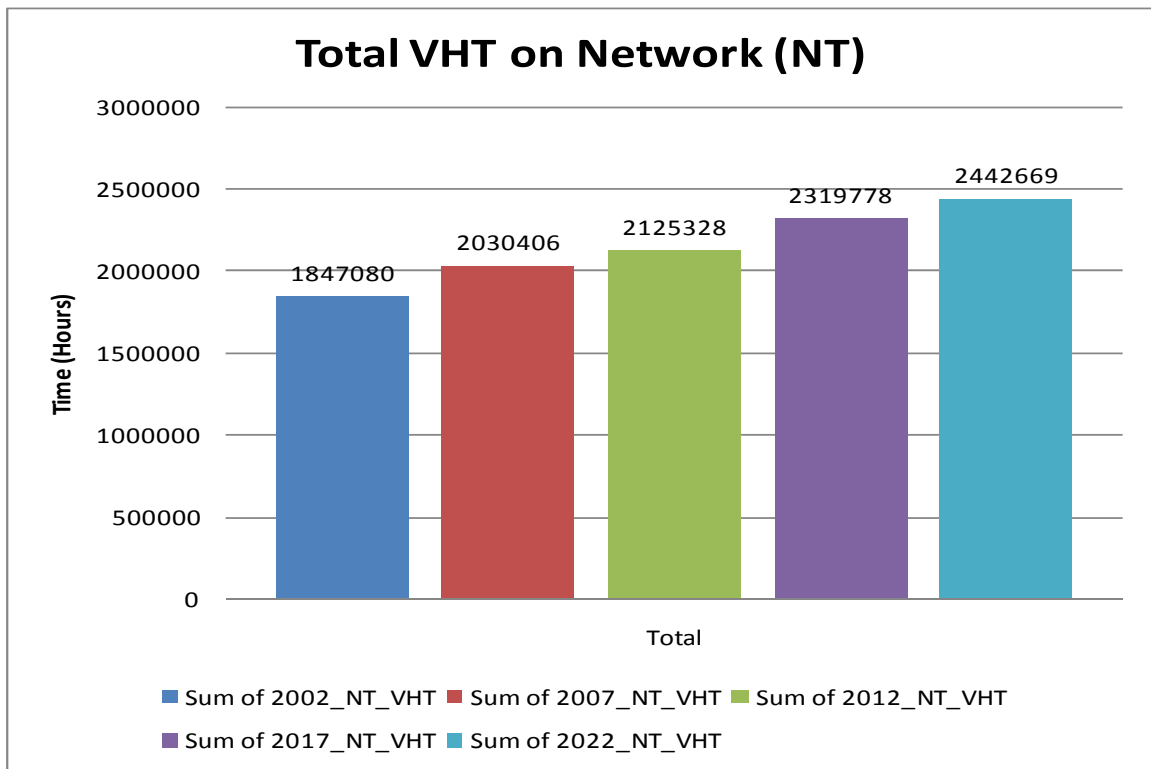


Figure 12: Total VHT in NT period (7PM -6AM) B1

Table 4: Percent change in VHT from BC (2002) *B1*

	2007	2012	2017	2022
AM	12.16	22.41	37.65	49.27
MD	10.12	21.91	33.12	47.50
PM	10.02	23.29	34.66	51.45
NT	9.93	15.06	25.59	32.24

Total Vehicle Miles Traveled

The next set of figures (figures 13-16) shows the total vehicle miles traveled on the NYBPM network for each scenario during each travel period (AM, MD, PM, NT). Table 5 shows the percent changes in VMT from the base case, for each future year scenario and for all travel periods. The increase in VMT for each scenario is very similar to the increase in VHT on the network. In the *B1* scenario O-D's were increased 2 percent per year, and 5 percent per year for the selected truck O-D's. This explains the fairly steady percentage increases in VMT. The figures show that for each time period there is a similar increase in VMT for each 5 year scenario. VMT percent changes from the 2002 base case to 2022 are: nearly 40 percent during the AM, MD and PM periods, and 39 percent during the NT period.

Figures and Tables for Total Vehicle Miles Traveled

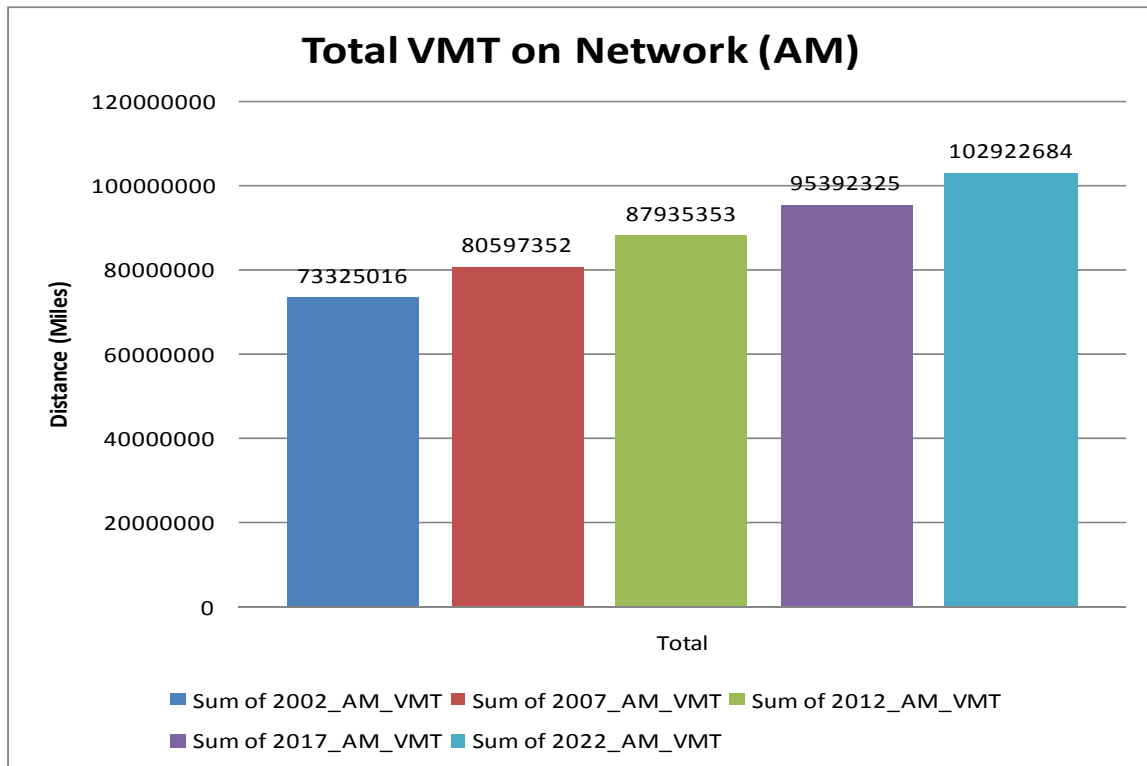


Figure 13: Total VMT in AM period (6-10) *B1*

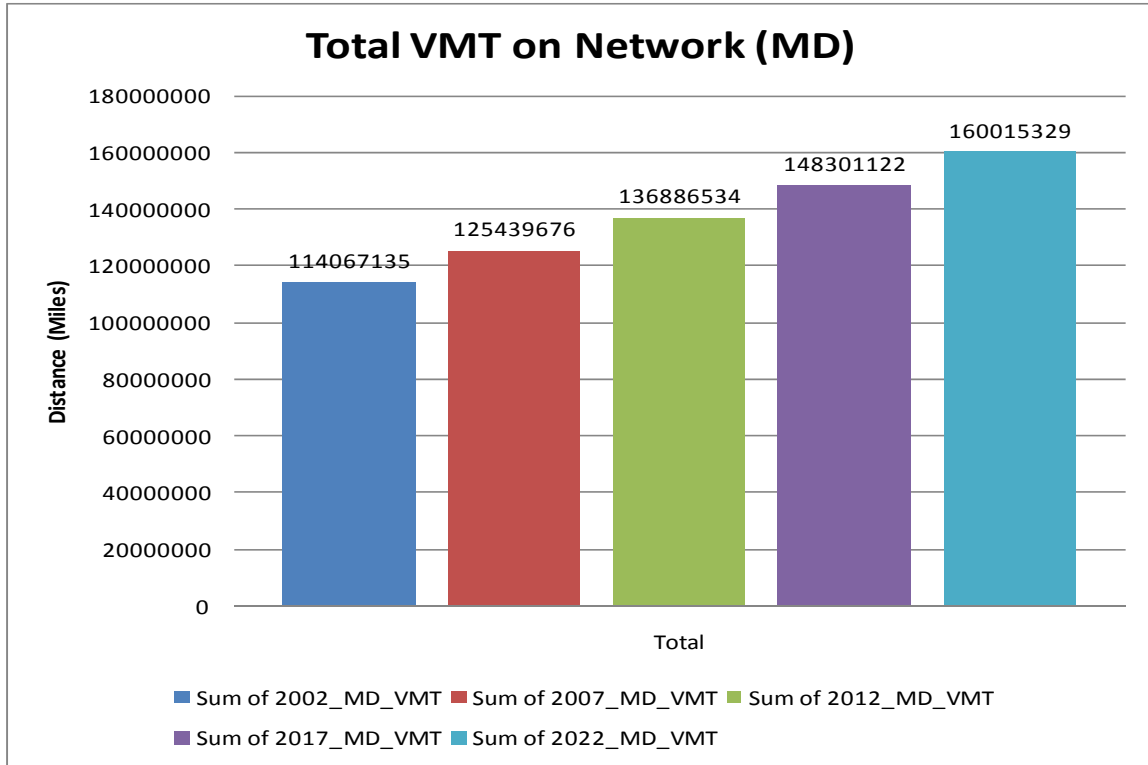


Figure 14: Total VMT in MD period (10A-3P) B1

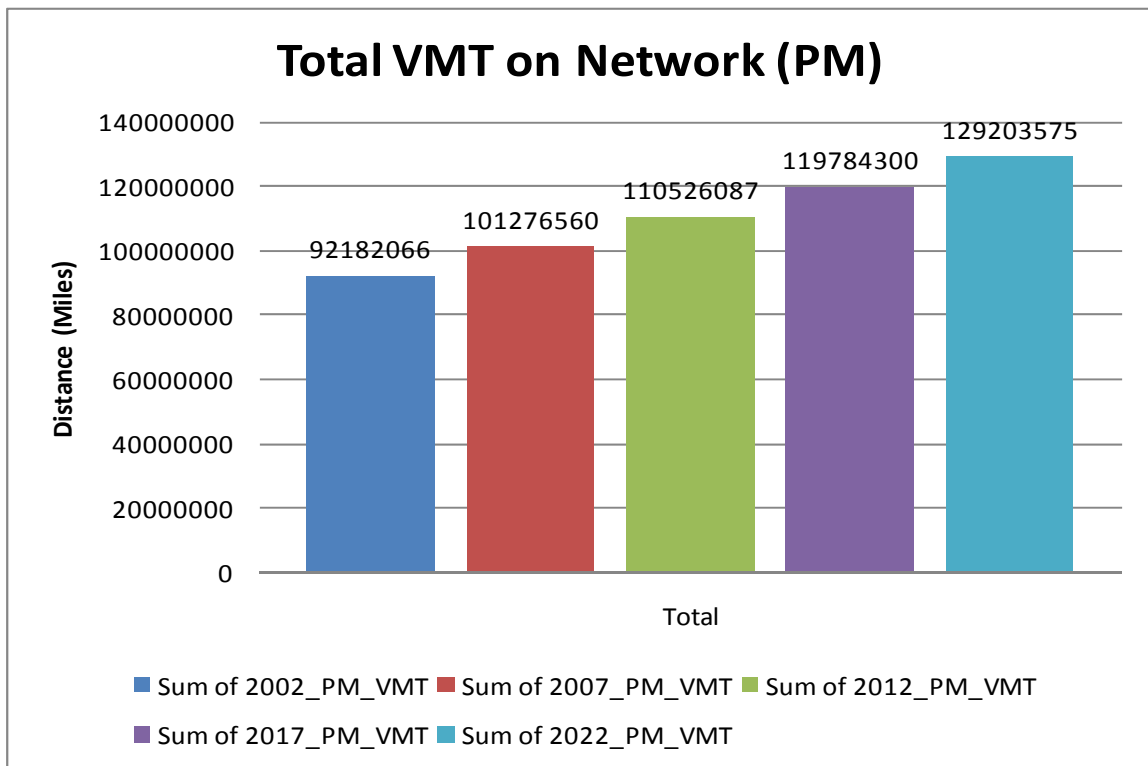


Figure 15: Total VMT in PM period (3-7) B1

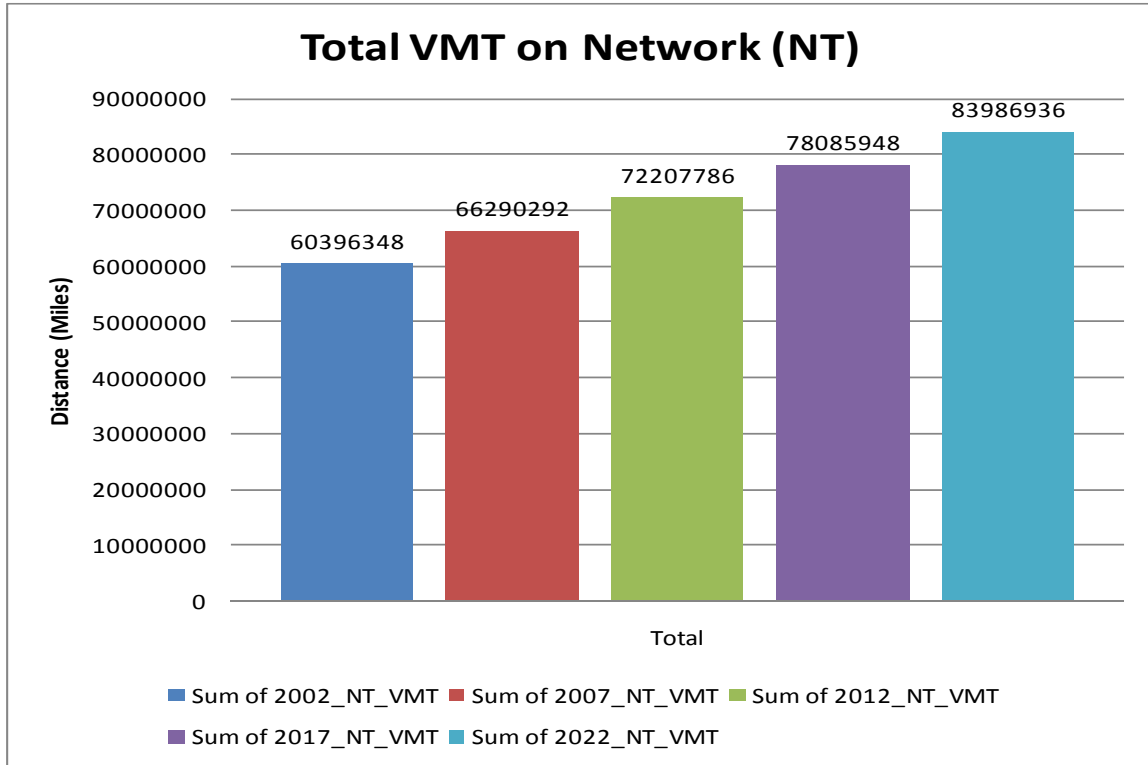


Figure 16: Total VMT in NT period (7P-6A) B1

Table 5: Percent change in VMT from BC (2002) B1

	2007	2012	2017	2022
AM	9.92	19.93	30.10	40.37
MD	9.97	20.01	30.01	40.28
PM	9.87	19.90	29.94	40.16
NT	9.76	19.56	29.29	39.06

Flow on Major Links

This section shows the flow on major corridors between New York City and New Jersey. The following links are included in this analysis: George Washington Bridge, Goethals Bridge, Holland Tunnel, Lincoln Tunnel, Outer Bridge Crossing and the Verrazano-Narrows Bridge. The figures show the flow on each link for all travel periods for all scenarios. Each major crossing is divided into an eastbound link and a westbound link as shown in the figures. A legend is included to distinguish scenarios. For all links listed in this section the eastbound direction is the peak travel direction during the AM period and the westbound direction is the peak travel direction during the PM period.

For the AM peak travel period, the eastbound link of the George Washington Bridge has the highest flow for all scenarios. This link is followed by the eastbound link of the Verrazano-Narrows Bridge, then the westbound link of the George Washington Bridge and the eastbound link of the Lincoln Tunnel. The flow on the eastbound link of the George Washington Bridge shows an increase from approximately 42000 vehicles/period

in 2002 to nearly 60000 vehicles/period in 2022, a 40 percent increase in flow. The flow on the eastbound link of the Verrazano- Narrows Bridge increases from approximately 40000 vehicles/period in 2002 to 54000 vehicles/period in 2022, which is a 36 percent increase. However the results show that crossings with smaller capacity such as the Holland Tunnel, Lincoln Tunnel, and the Goethals Bridge increase at rates around 20 percent and have much lower total flows than the George Washington or Verrazano. From these results it seems that as crossings with lower capacity such as the three just mentioned reach capacity, it appears that more travelers decide to enter New York City via different routes using the George Washington Bridge or Verrazano-Narrows Bridge during the AM peak period.

The PM peak travel period shows similar results in the opposite direction, with the westbound links now having a higher in general flow than the eastbound links. The George Washington Bridge has the highest flow in the westbound direction for all scenarios during the PM travel period, followed by the Verrazano-Narrows Bridge westbound. , The flow on westbound links of the George Washington and the Verrazano crossings increase 40 percent from 2002 to 2022. Increases of 24 percent on the Holland Tunnel, 23 percent on the Lincoln Tunnel and 15 percent on the Goethals Bridge were seen from 2002 to 2022. Similar to the AM travel period these results suggest as the Holland Tunnel, Lincoln Tunnel and Goethals Bridge reach near capacity, travelers are electing to take different routes home via the George Washington Bridge and the Verrazano-Narrows Bridge.

Figures for Flow on Major Links

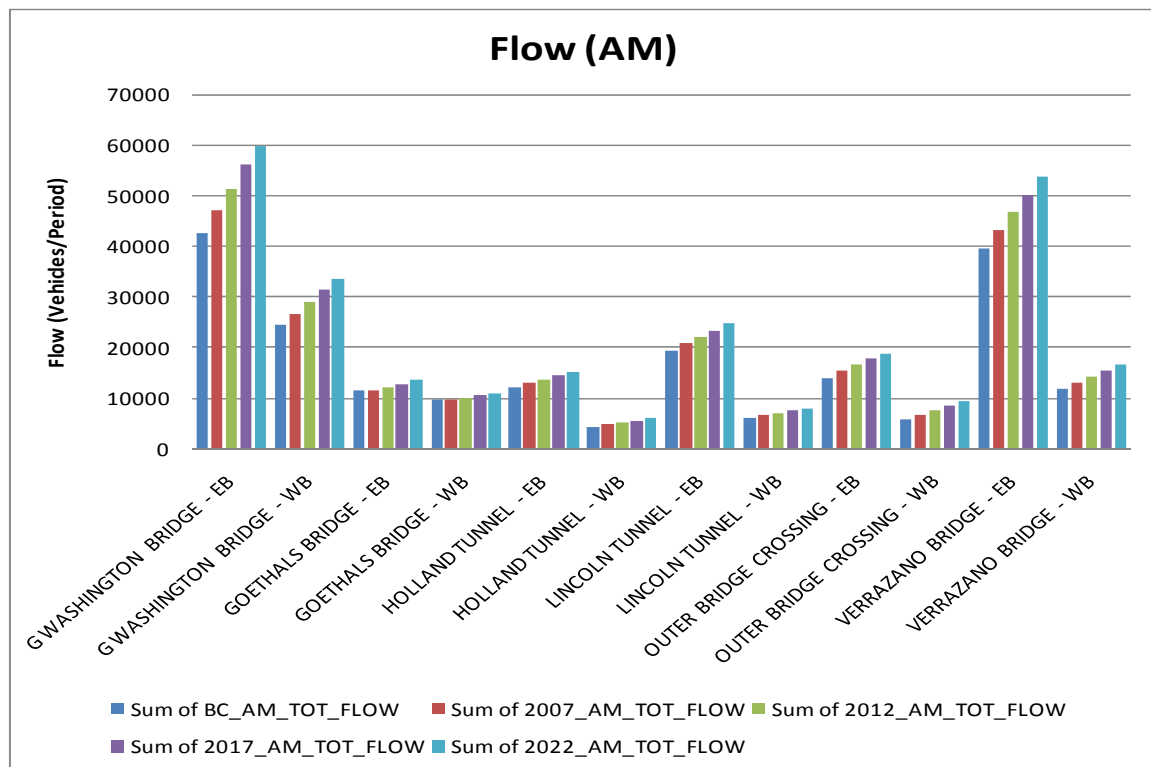


Figure 17: Flow on major links AM period (6AM-10AM) B1

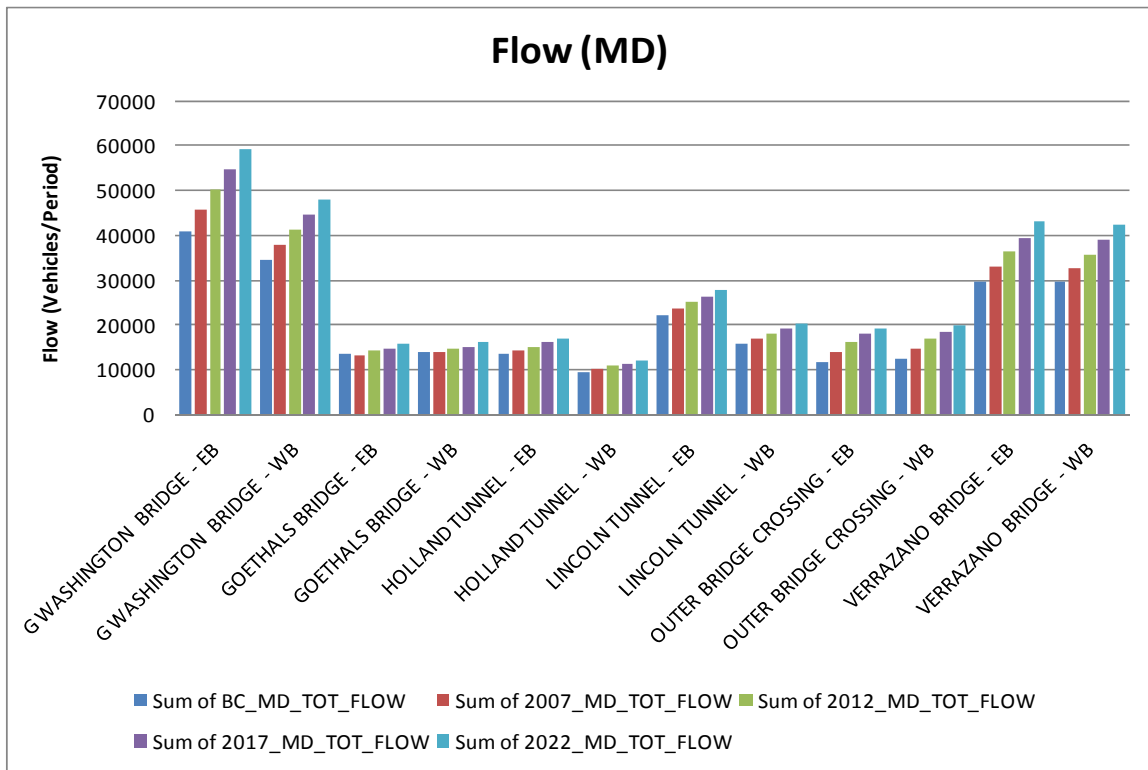


Figure 18: Flow on major links MD period (10A-3P) B1

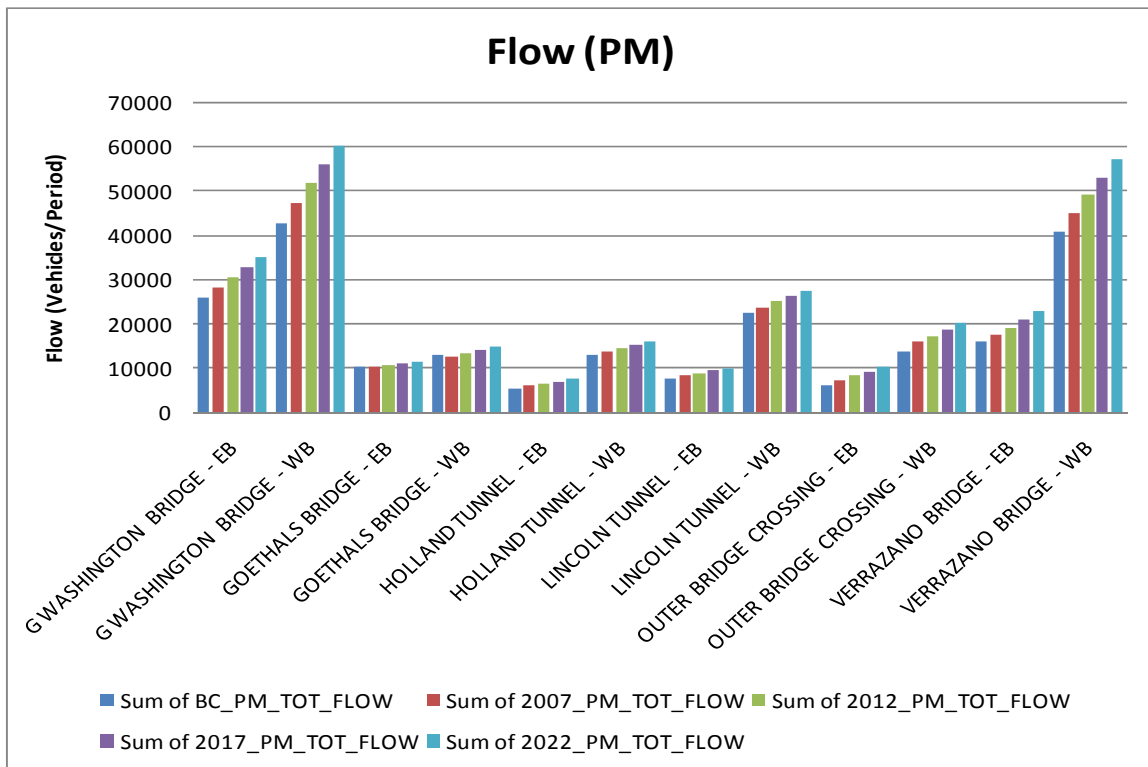


Figure 19: Flow on major links PM period (3-7) B1

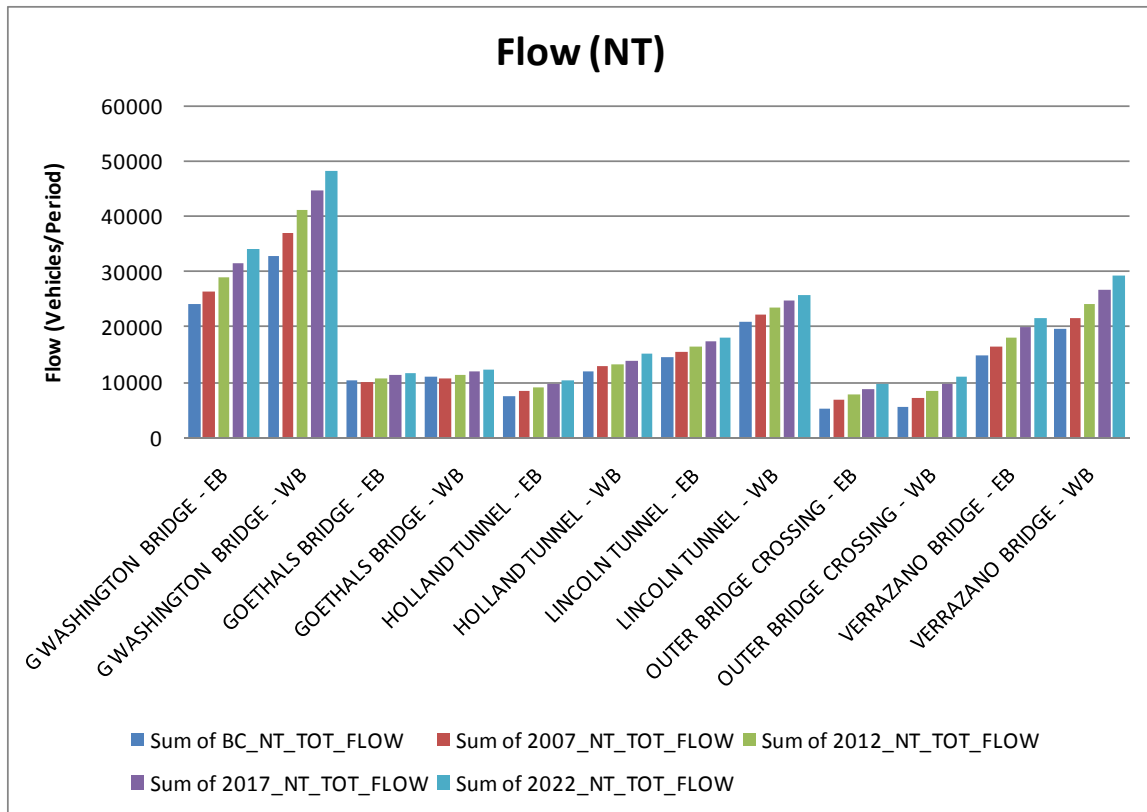


Figure 20: Flow on major links NT period (7P-6A) B1

Link-Level Delay

This section of the report shows how each scenario impacted travel times on vital links during the AM and PM peak travel periods. Five color-themed maps were produced for each scenario including the base case for the AM and PM periods. These images can be found in the appendix of this report (Figure 153 - Figure 162).

To understand the images and the analysis provided in this section, the construction of these images will be briefly discussed. Ten images were produced for this scenario (B1) *Impact of truck demand changes* in order to provide an understanding of how future scenarios impact vital links in the network. Five images were produced for the AM peak travel period; one for the base case and four for each of the scenarios outlined in the scenario description (S1-S4). The same was done for the PM peak travel period. A short description of each scenario is presented below.

- Base Case (2002) – no change
- Scenario One (2007) – five year projection
- Scenario Two (2012) – ten year projection
- Scenario Three (2017) – fifteen year projection
- Scenario Four (2022) – twenty year projection

First the delay on each link was calculated by taking the difference of the average travel time output by the NYBPM for each link and the free flow travel time of that link. This data was taken from the output that the NYBPM model produced. A color-themed map was then created to give a visual of delay on the network. On each map a red, circled star represents the location of the Verrazano-Narrows Bridge. The color-theme that was used to represent the delay ranges from green, representing the lowest delay to red, representing the highest delay. Each map has its own corresponding legend with the exact magnitude of delay represented by each color.

First the Base Case scenario map was examined to get an idea of where significant delay existed on the network before the traffic volume was increased. As the Base Case map shows, the link with the highest delay is the Holland Tunnel, colored orange to represent 20 to 24 minute delays in Figure 153. Other major delays in the region are on the Lincoln Tunnel, showing 8 to 12 minutes delays and several links along the New Jersey Turnpike. The NJ Turnpike from Exit 14-15E shows delays in the 12 to 16 minute range. The Verrazano-Narrows shows only up to 8 minute average delays before any capacity reduction occurs.

For each future year scenario cars were increased 2 percent each year and trucks from the selected O-D pairs discussed in the report were increased 5 percent. Figure 154 through Figure 162 are the delay images (AM and PM) for Scenario One through Scenario Four, respectively. During each future scenario the average delay on links throughout the New York Metropolitan Area increases. However the maps show the links that are the most affected. The major Manhattan crossings are the most impacted links on the network. Links including the Verrazano-Bridge, Holland Tunnel, Lincoln Tunnel, George Washington Bridge, Goethals Bridge and Outer Crossings Bridge all begin to reach capacity by the 2017 year scenario. Delays in Scenario 3 are anywhere between 25 to 70 minutes on these links and the delay on these links jumps to over 70 minutes during Scenario 4 (2022), the twenty year projection. The New Jersey Turnpike also shows major increases in delay for each future year scenario. These vital links of the region reach capacity causing major congestion and delays throughout the network. Figure 157 and Figure 162 are the AM and PM 20 year delay maps. These images clearly show the links most affected by the increase in traffic volume. These major delays are on vital links in the network causing major congestion to backup throughout the region.

3.2 B2: Impacts of changes in tolls

Total Vehicle Miles Traveled

Figure 22 through Figure 42 and Table 6 through Table 9 in this section show the total vehicle miles traveled for each five-mile buffer zone around the Verrazano-Narrows Bridge and the percent change in total VMT from the base case for each scenario. As previously stated, the model uses four time periods: AM peak (6AM – 10AM), midday (10AM – 3PM), PM peak (3PM – 7PM), and night (7PM – 6AM). For each period there are separate figures, tables and analysis of results. For each analysis the change in VMT is compared to the base case (BC) scenario.

AM Period

During the AM peak period (6AM – 10AM) the most significant changes are seen within the five mile radius in Scenario One and Scenario Two (refer to page 14). S1 is a change in toll collection on the bridge from the westbound direction to the eastbound direction, S2 is a switch to a bi-directional toll collection with half of the toll collected in the westbound direction and half the toll collected in the eastbound direction. S3 involves doubled the current toll in the westbound direction. The VMT dropped approximately 1.76 percent during S1 and 1.73 percent during S2 within the five mile radius around the bridge as shown in Table 6. This indicates that there was only a slight change in VMT within close proximity to the bridge as a result of the toll changes. The reduction in VMT as a result of the change in tolls dissipates further away from the bridge.

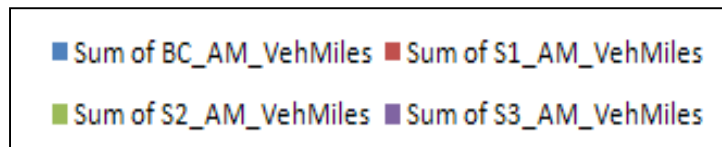


Figure 21: Legend for total VMT in AM period (6AM-10AM)

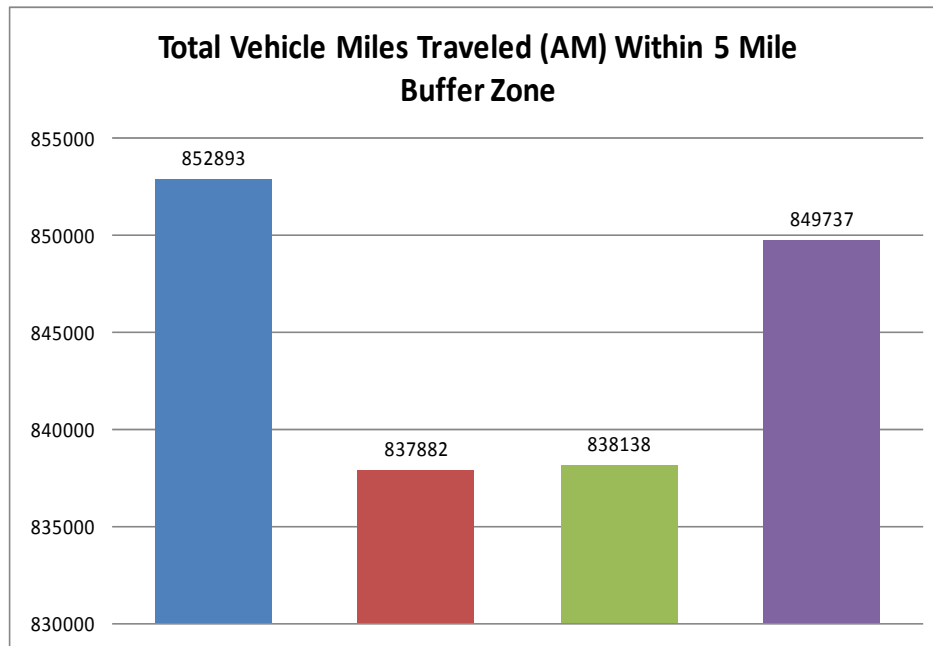


Figure 22: Total VMT in AM period (6AM-10AM) within 5 mile buffer zone

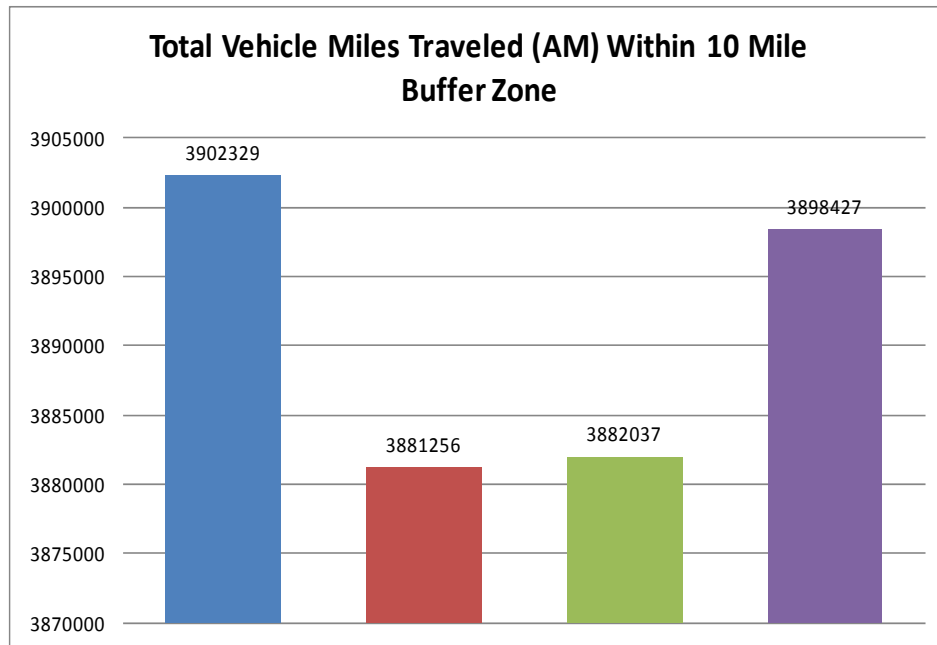


Figure 23: Total VMT in AM period (6AM-10AM) within 10 mile buffer zone

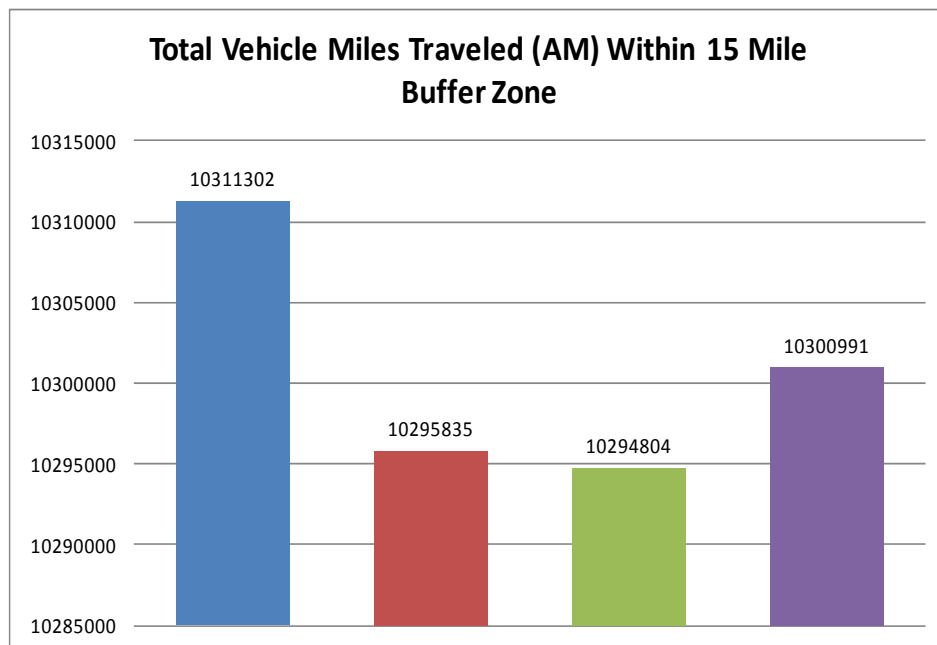


Figure 24: Total VMT in AM period (6AM-10AM) within 15 mile buffer zone

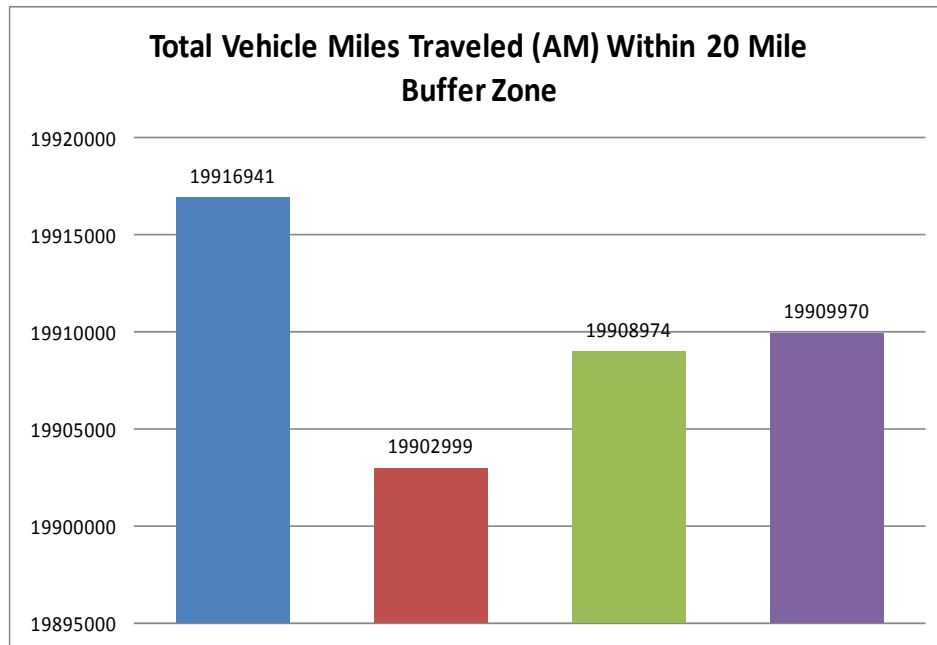


Figure 25: Total VMT in AM period (6AM-10AM) within 20 mile buffer zone

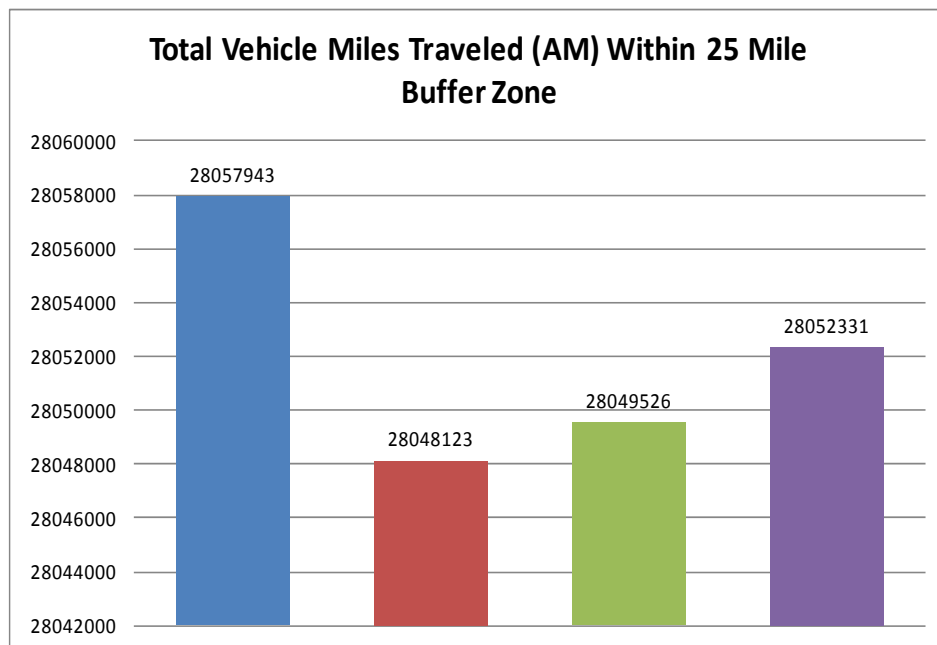


Figure 26: Total VMT in AM period (6AM-10AM) within 25 mile buffer zone

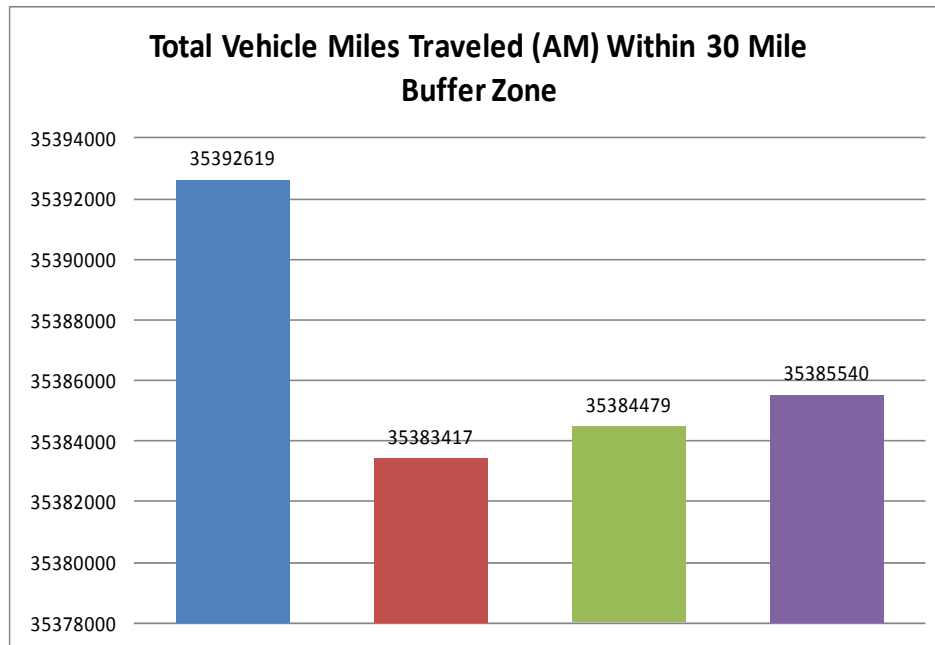


Figure 27: Total VMT in AM period (6AM-10AM) within 30 mile buffer zone

Table 6: Percent Change in VMT from BC (AM)

Distance	S1	S2	S3
5	-1.76	-1.73	-0.37
10	-0.54	-0.52	-0.10
15	-0.15	-0.16	-0.10
20	-0.07	-0.04	-0.04
25	-0.03	-0.03	-0.02
30	-0.02	-0.02	-0.02

MD Period

During the midday period (10AM – 3PM) the total vehicle miles traveled are fairly constant for each scenario in both directions and Table 7 shows there are no major changes due to a change of the toll collection policy. The total vehicle miles traveled are greater than in the AM peak period for all scenarios within every buffer zone, the midday period, however, is one hour longer than the AM peak period.

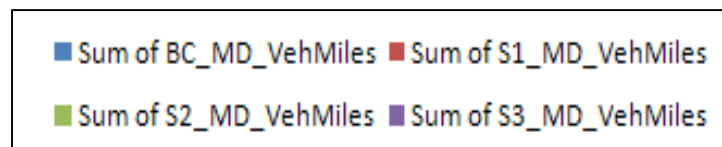


Figure 28: Legend for total VMT in MD period (10AM-3PM)

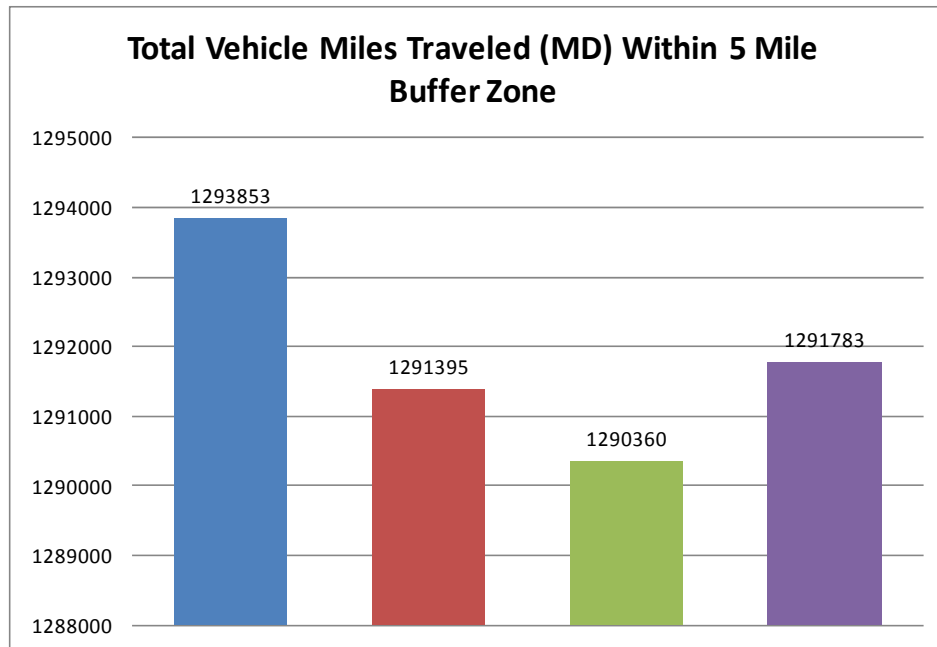


Figure 29: Total VMT in MD period (10AM-3PM) within 5 mile buffer zone

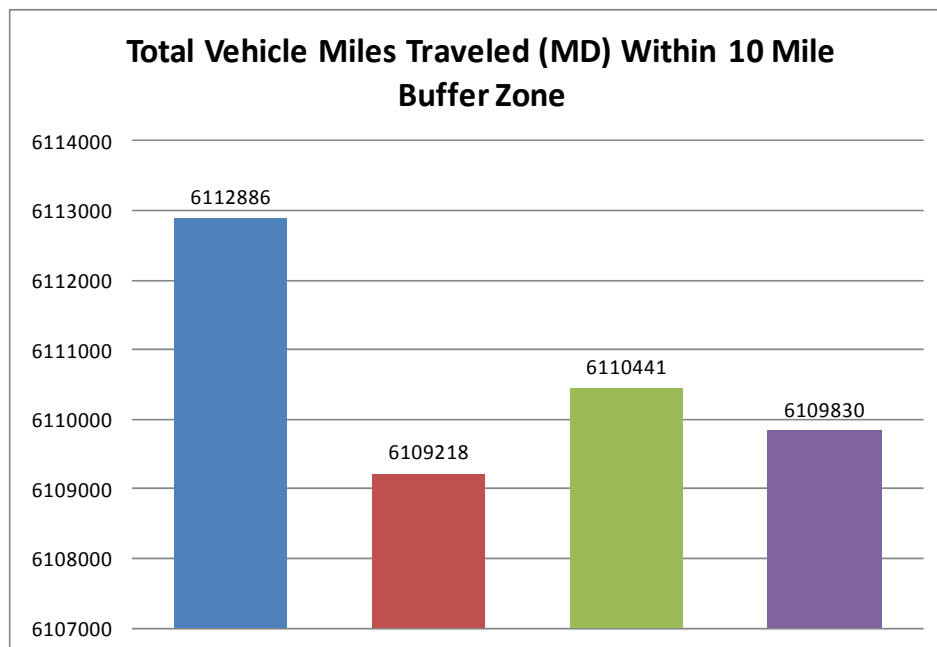


Figure 30: Total VMT in MD period (10AM-3PM) within 10 mile buffer zone

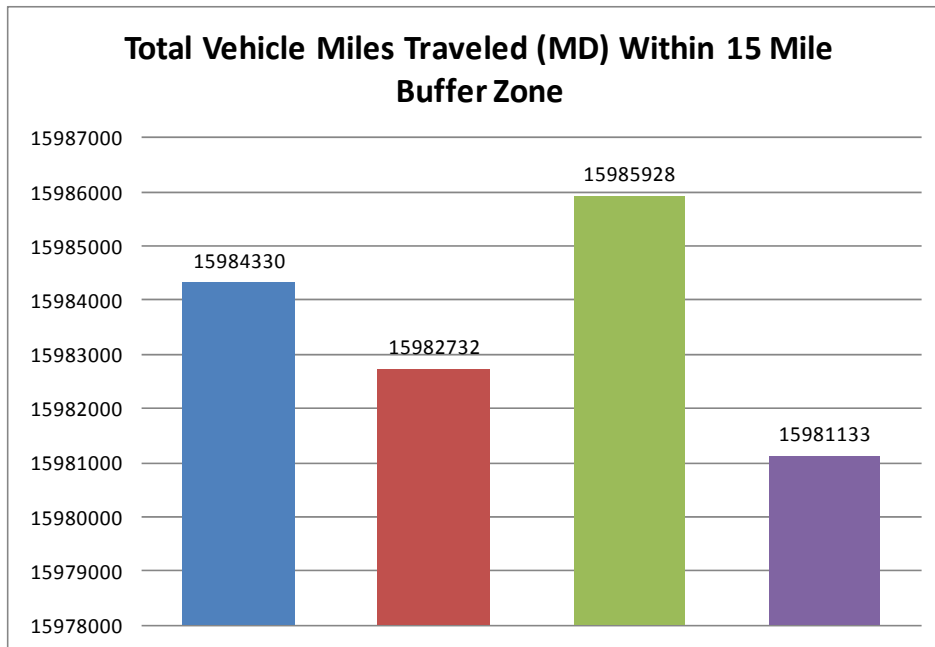


Figure 31: Total VMT in MD period (10AM-3PM) within 15 mile buffer zone

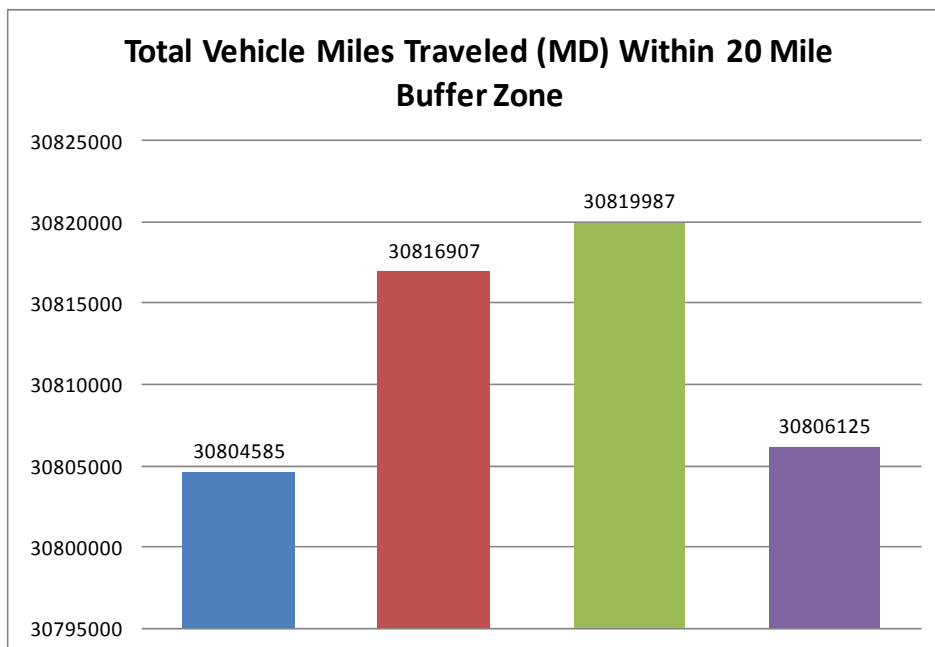


Figure 32: Total VMT in MD period (10AM-3PM) within 20 mile buffer zone

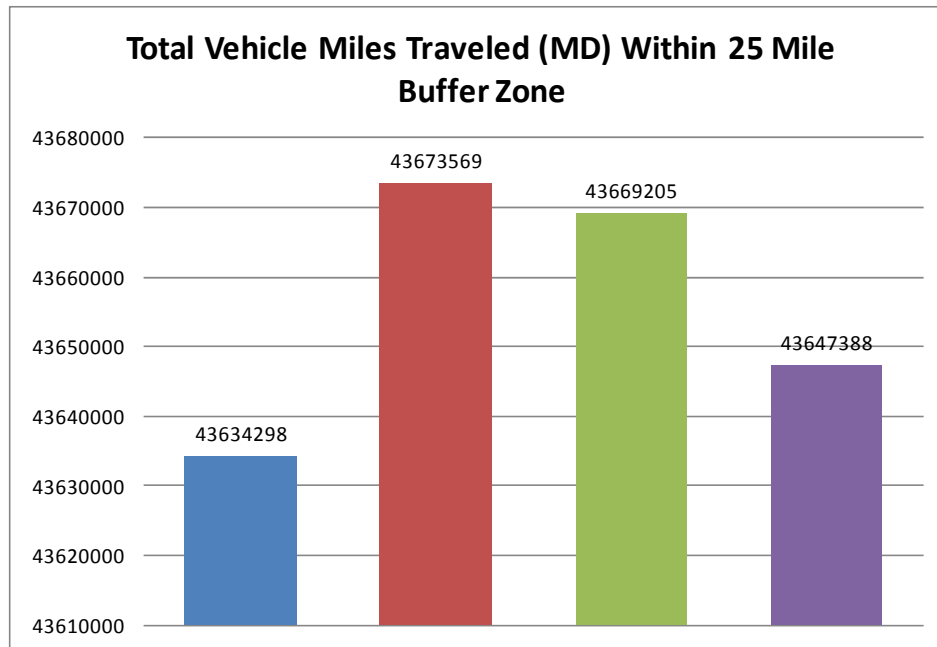


Figure 33: Total VMT in MD period (10AM-3PM) within 25 mile buffer zone

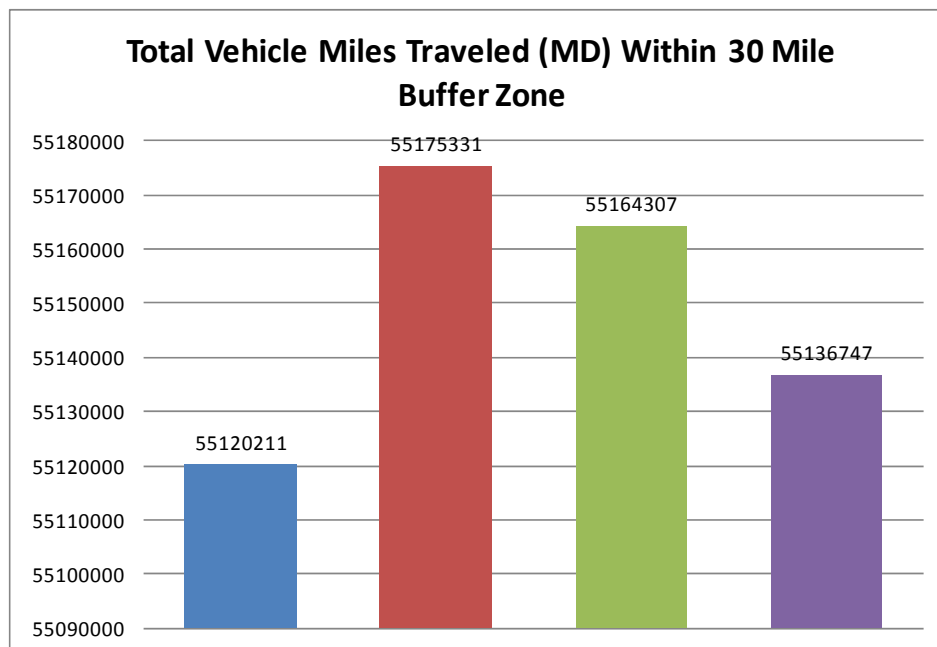


Figure 34: Total VMT in MD period (10AM-3PM) within 30 mile buffer zone

Table 7: Percent Change in VMT from BC (MD)

Distance	S1	S2	S3
5	-0.19	-0.27	-0.16
10	-0.06	-0.04	-0.05
15	-0.01	0.01	-0.02
20	0.04	0.05	0.00
25	0.09	0.08	0.03
30	0.10	0.08	0.03

PM Period

Similar to the MD peak period there are no major changes in total VMT during the PM peak period (3PM – 7PM). The highest reduction is observed in scenarios S2 and S3 within a 5-mile radius of the bridge, showing that change in tolls affects primarily the westbound direction of the bridge traffic. The total vehicle miles traveled are fairly constant for each scenario in both directions and Table 8 shows there are no major changes due to a change of the toll collection policy.

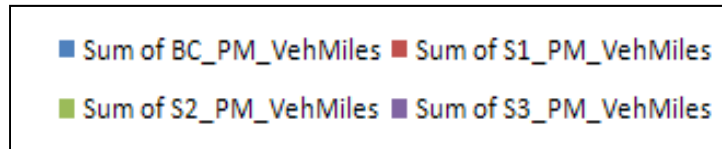


Figure 35: Legend for total VMT in PM period (3PM-7PM)

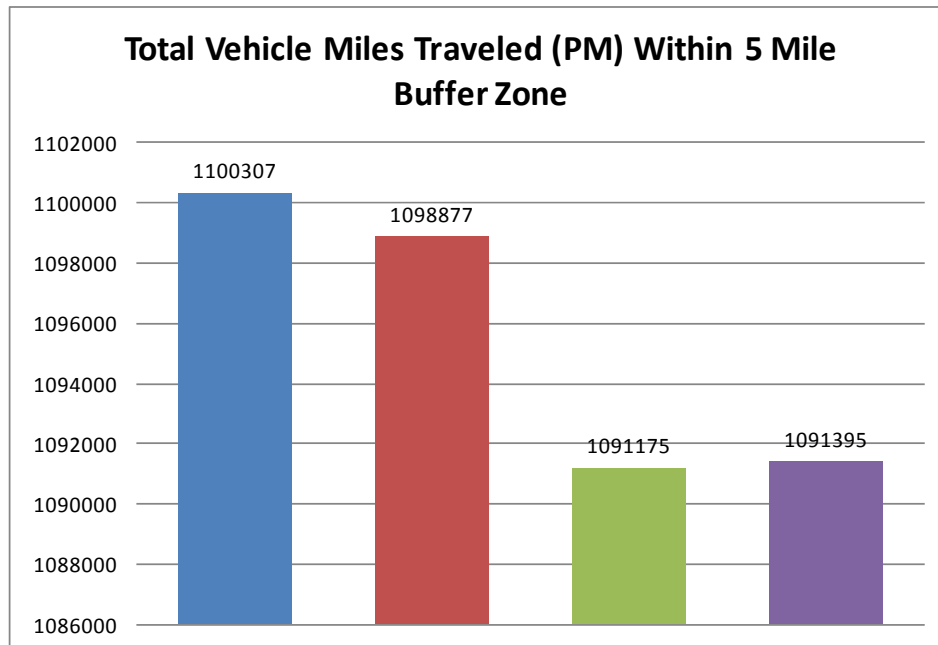


Figure 36: Total VMT in PM period (3PM-7PM) within 5 mile buffer zone

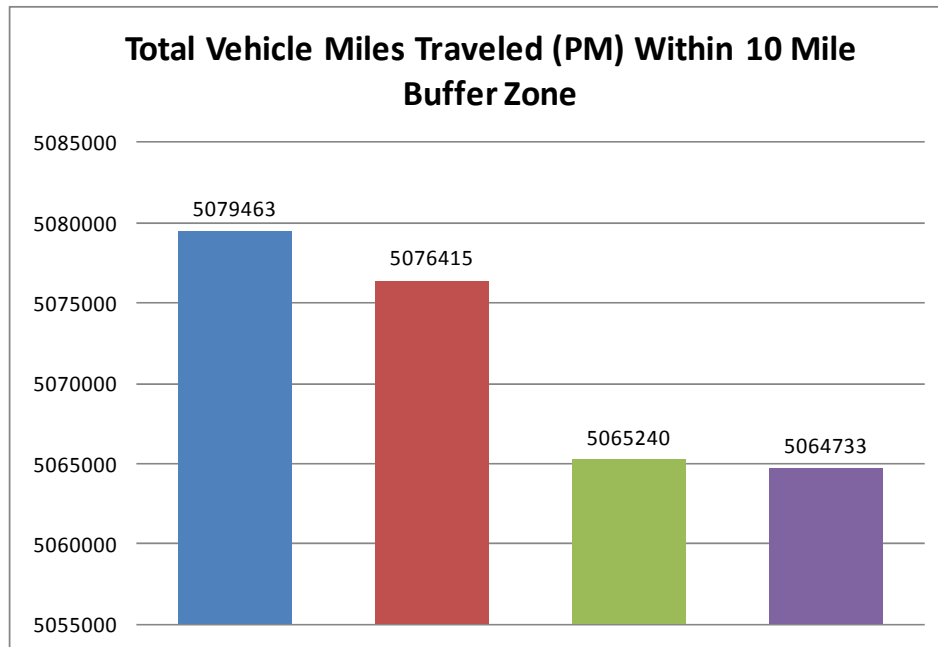


Figure 37: Total VMT in PM period (3PM-7PM) within 10 mile buffer zone

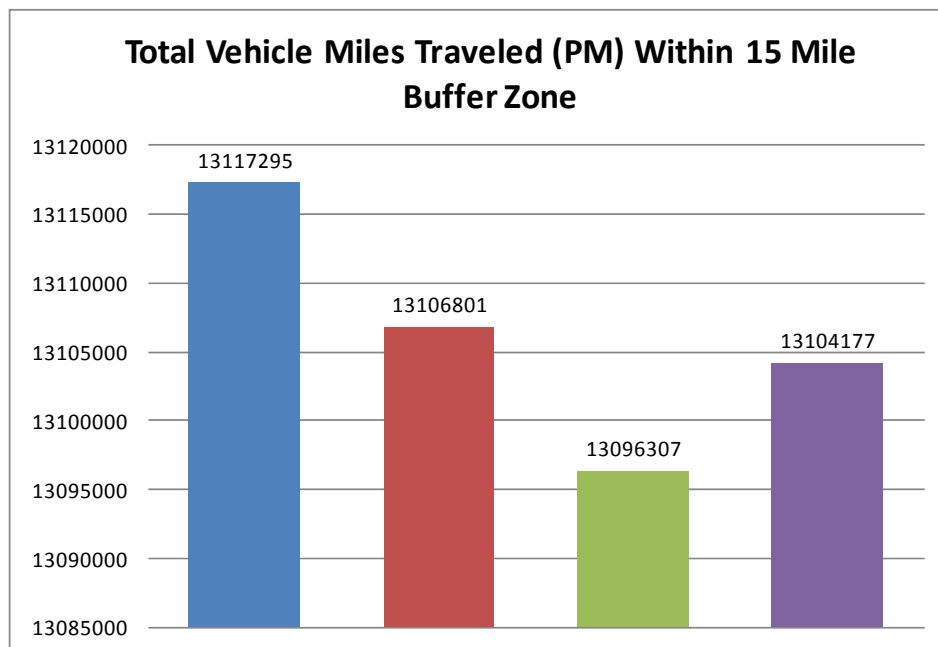


Figure 38: Total VMT in PM period (3PM-7PM) within 15 mile buffer zone

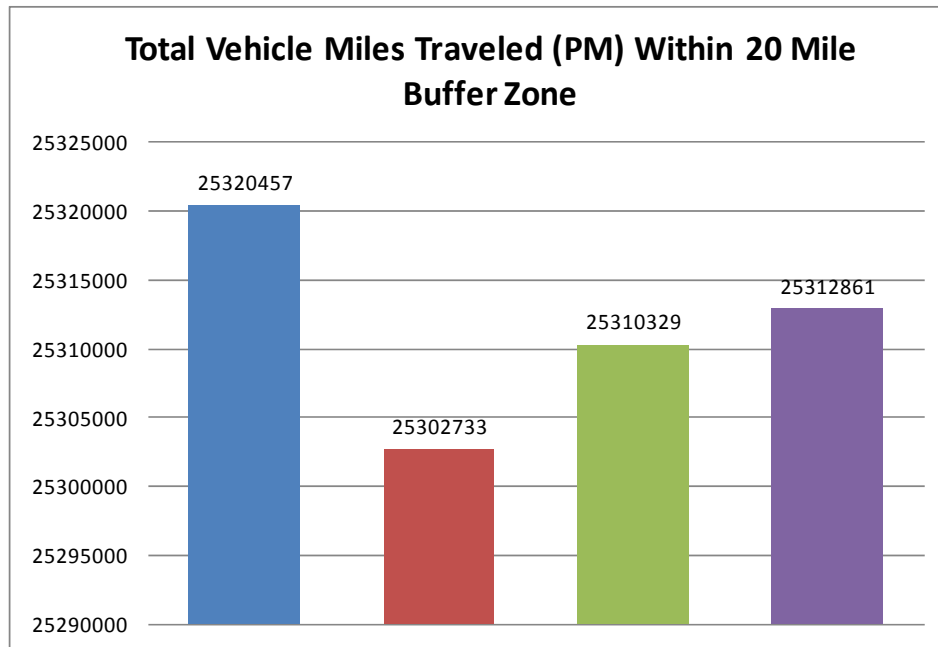


Figure 39: Total VMT in PM period (3PM-7PM) within 20 mile buffer zone

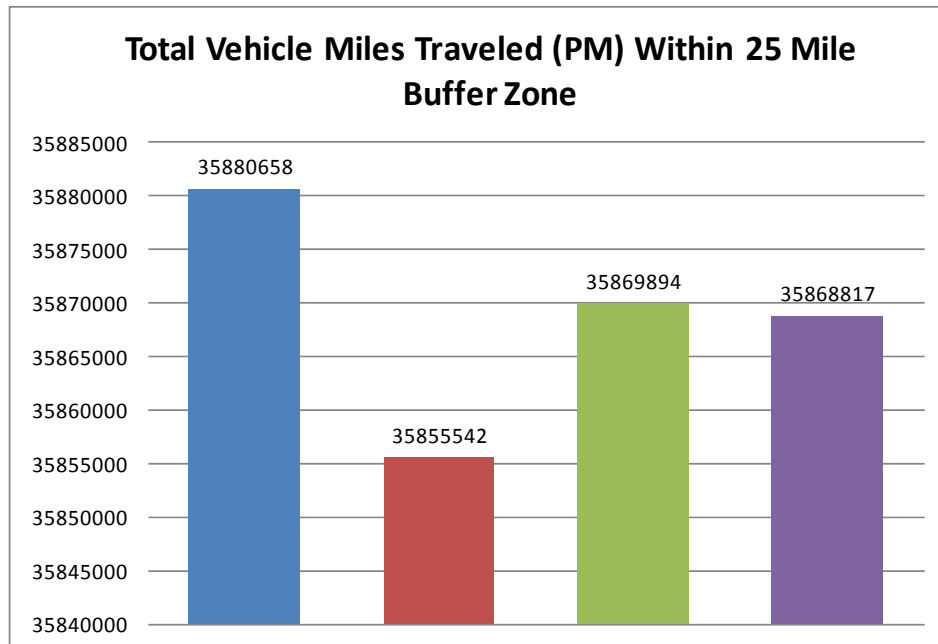


Figure 40: Total VMT in PM period (3PM-7PM) within 25 mile buffer zone

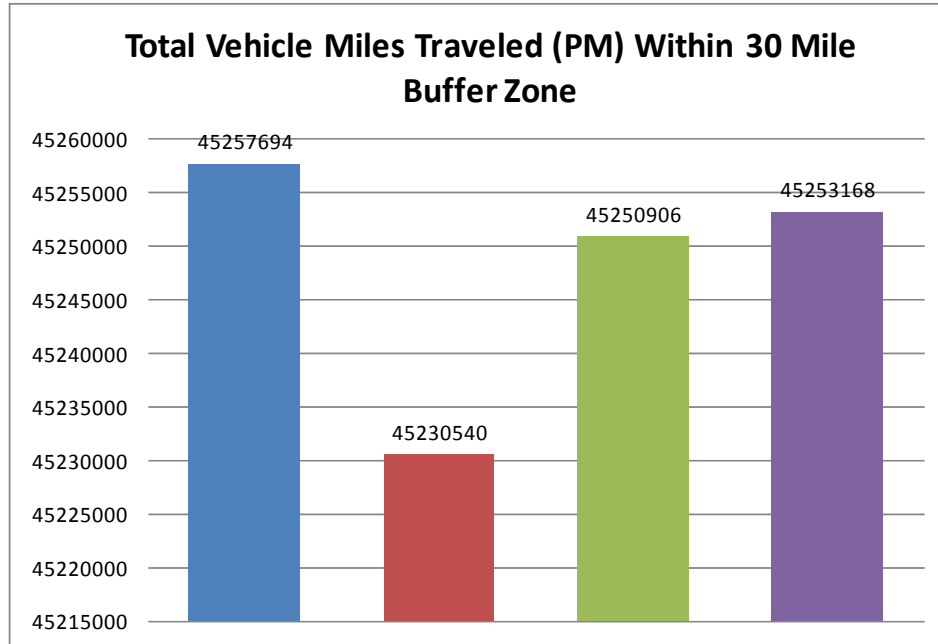


Figure 41: Total VMT in PM period (3PM-7PM) within 30 mile buffer zone

Table 8: Percent Change in VMT from BC (PM)

Distance	S1	S2	S3
5	-0.13	-0.83	-0.81
10	-0.06	-0.28	-0.29
15	-0.08	-0.10	-0.10
20	-0.07	-0.04	-0.03
25	-0.07	-0.03	-0.03
30	-0.06	-0.01	-0.01

NT Period

The night time (7PM – 6AM) results are very constant throughout all three scenarios and the base case. There is practically no major change in VMT as shown by Table 9.

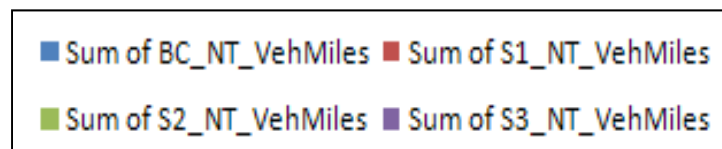


Figure 42: Legend for total VMT in NT period (7PM -6AM)

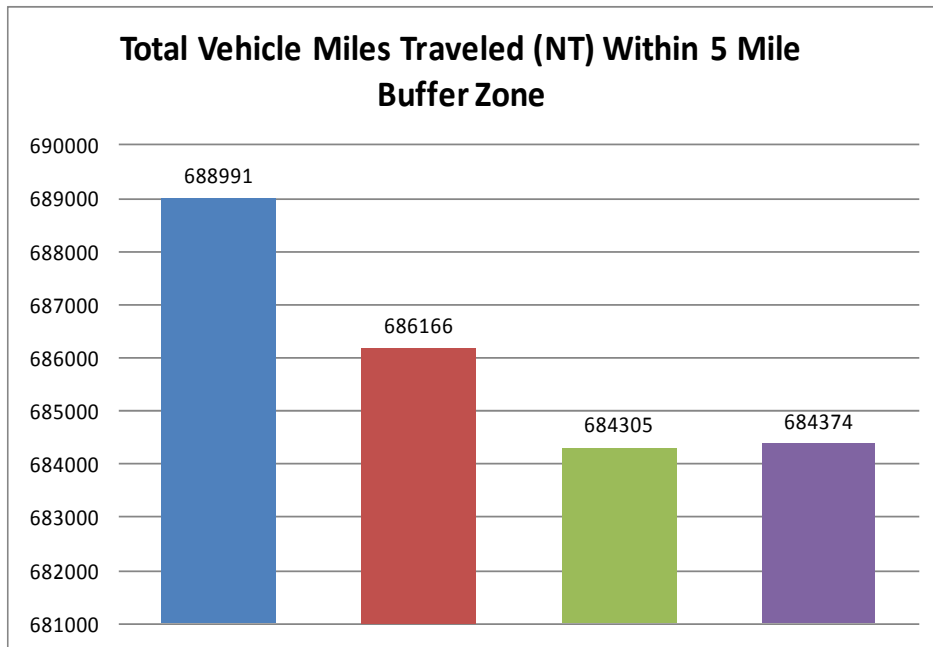


Figure 43: Total VMT in NT period (7PM -6AM) within 5 mile buffer zone

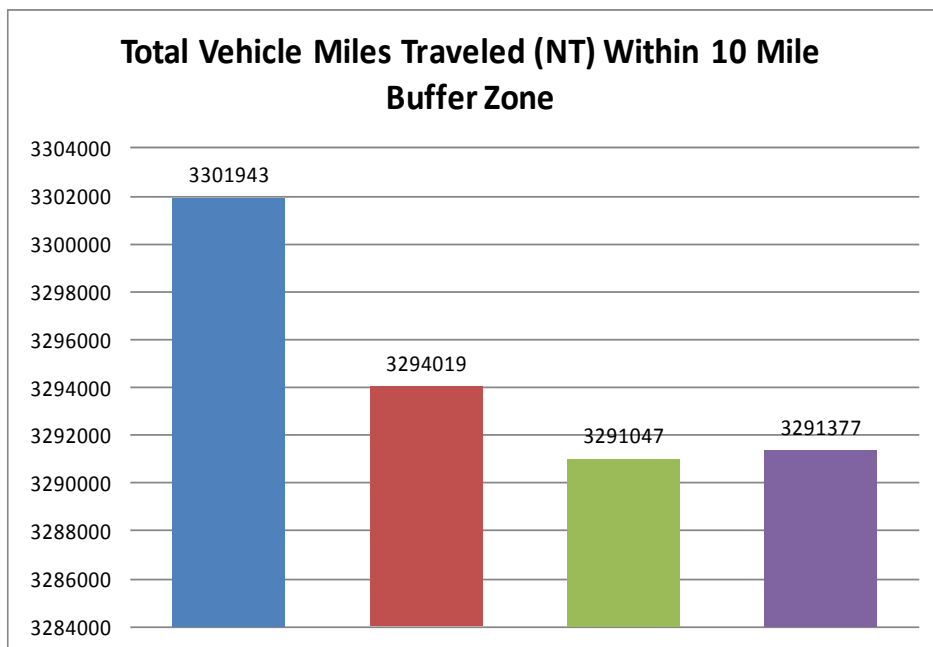


Figure 44: Total VMT in NT period (7PM -6AM) within 10 mile buffer zone

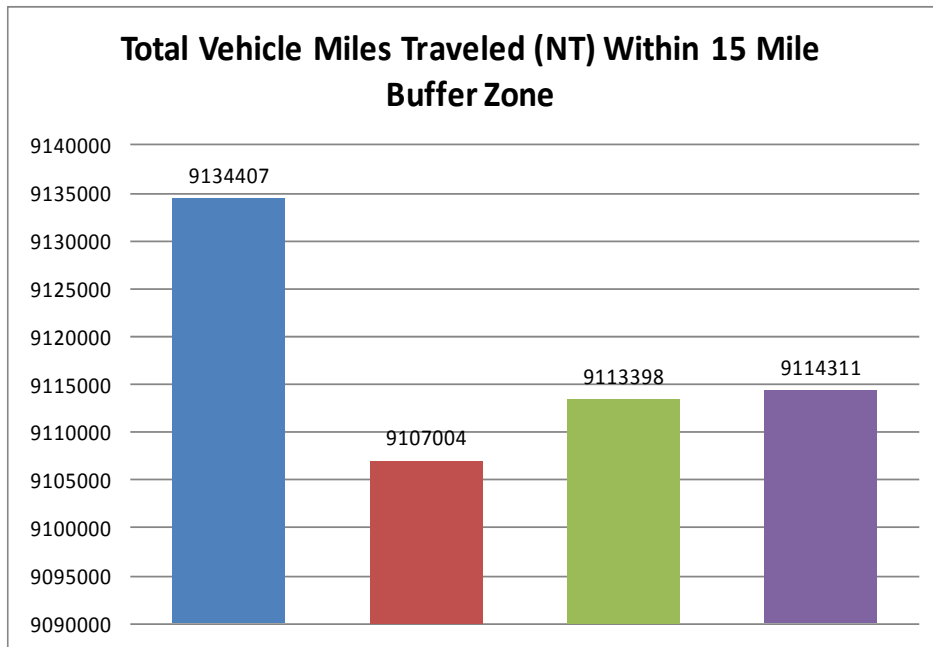


Figure 45: Total VMT in NT period (7PM -6AM) within 15 mile buffer zone

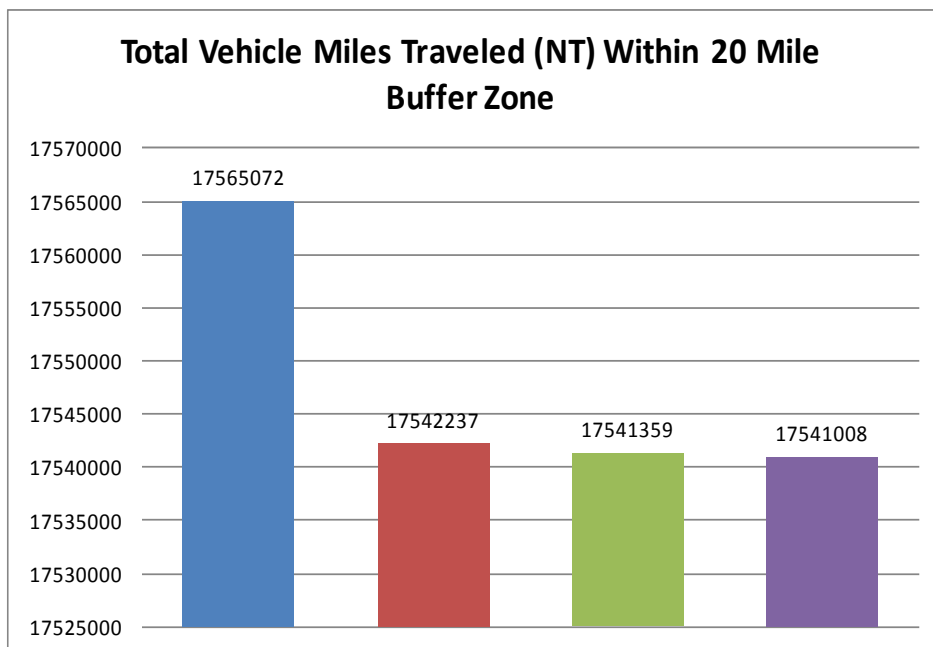


Figure 46: Total VMT in NT period (7PM -6AM) within 20 mile buffer zone

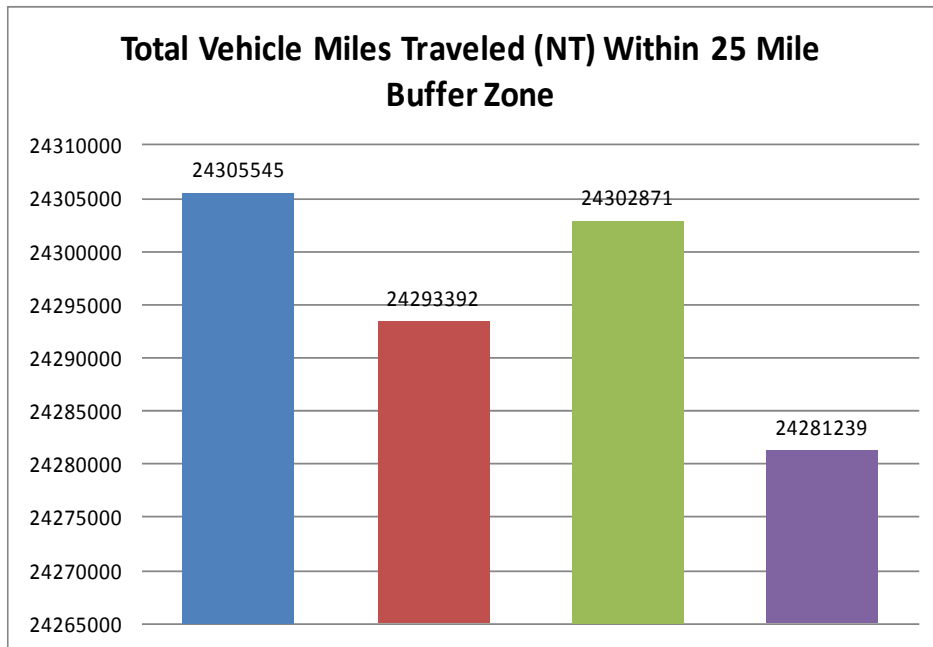


Figure 47: Total VMT in NT period (7PM -6AM) within 25 mile buffer zone

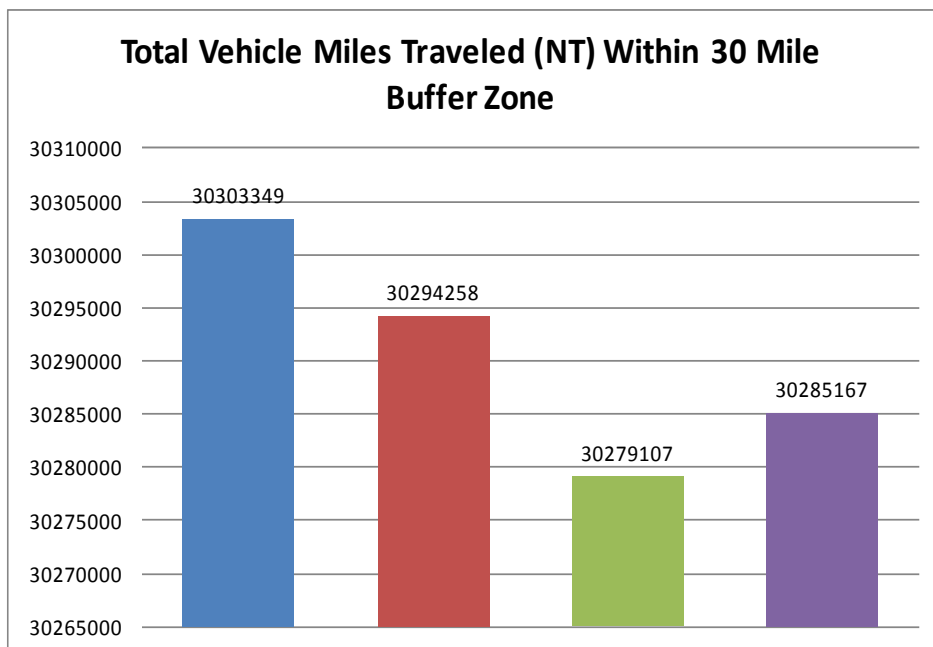


Figure 48: Total VMT in NT period (7PM -6AM) within 30 mile buffer zone

Table 9: Percent Change in VMT from BC (NT)

Distance	S1	S2	S3
5	-0.41	-0.68	-0.67
10	-0.24	-0.33	-0.32
15	-0.30	-0.23	-0.22
20	-0.13	-0.13	-0.13
25	-0.05	-0.11	-0.10
30	-0.03	-0.08	-0.06

Total Vehicle Hours Traveled

Figure 50 through Figure 70 and Table 10 through Table 13 show the total vehicle hours traveled within each five mile buffer around the Verrazano-Narrows Bridge. The figures show the total VHT for each scenario and within each five mile band, while the tables show the percent change from the base case scenario in each direction. The total vehicle hours show how each scenario impacts the total time travelers are on the road. The five mile bands will help show how far around the Verrazano the scenarios impacted total VHT.

AM Period

During the AM period a significant increase in VHT occurs in S1 and S2 within the five mile radius. Scenario 1 was a change in the toll collection from the westbound direction to the eastbound direction and Scenario 2 was a change to a bi-directional toll collection on the Verrazano-Narrows Bridge. As Table 10 shows, within five miles of the bridge, the VHT increased 6.47 percent during S1 and 6.51 percent during S2. There is no a significant impact for Scenario 3, doubling the current toll for the AM peak period. Significant increases in VHT are only seen for Scenario 1 and Scenario 2 because toll collection is shifted to the peak travel direction (eastbound) on the bridge. Although doubling the toll is a drastic change, the effects of this change are not felt in the AM travel period.

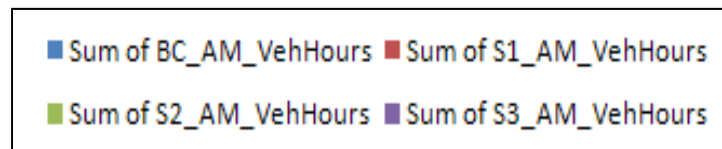


Figure 49: Legend for total VHT in AM period (6AM-10AM)

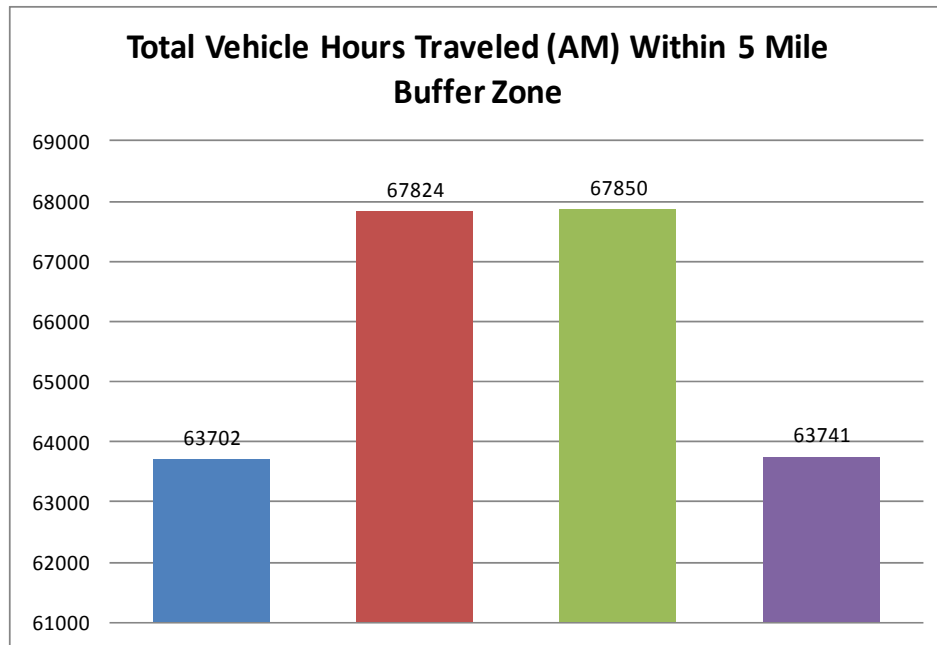


Figure 50: Total VHT in AM period (6AM-10AM) within 5 mile buffer zone

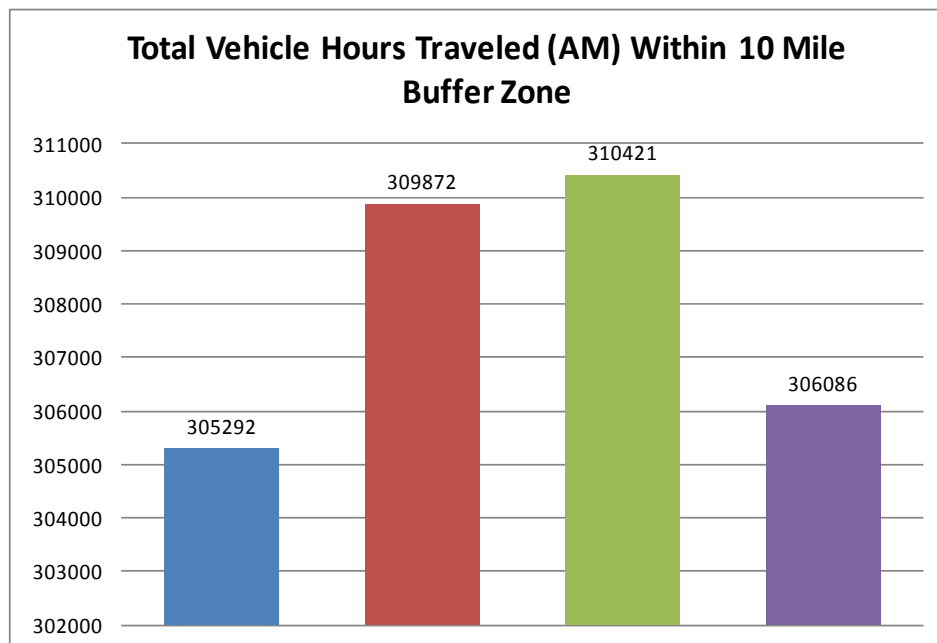


Figure 51: Total VHT in AM period (6AM-10AM) within 10 mile buffer zone

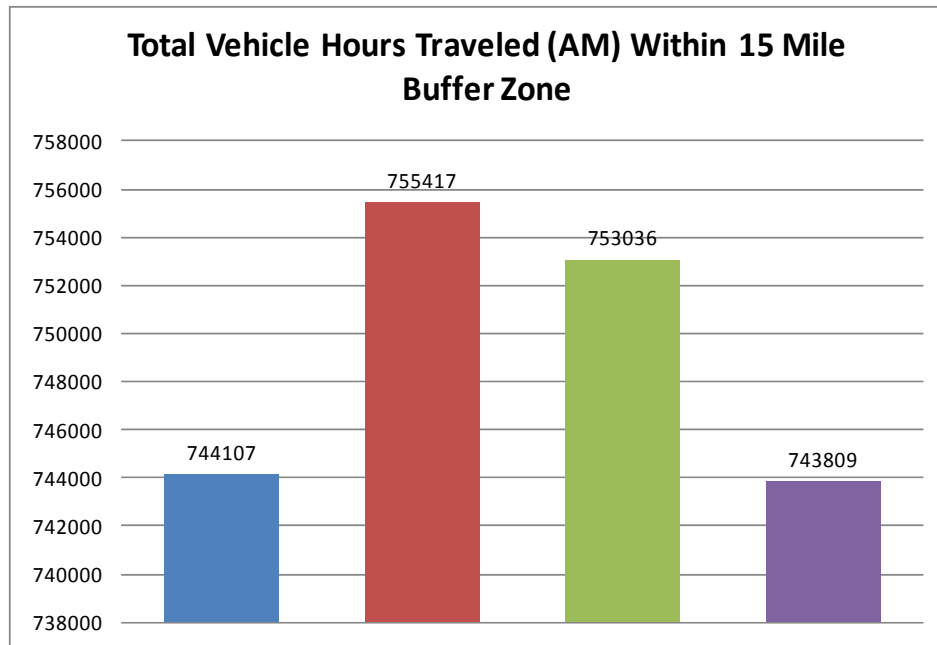


Figure 52: Total VHT in AM period (6AM-10AM) within 15 mile buffer zone

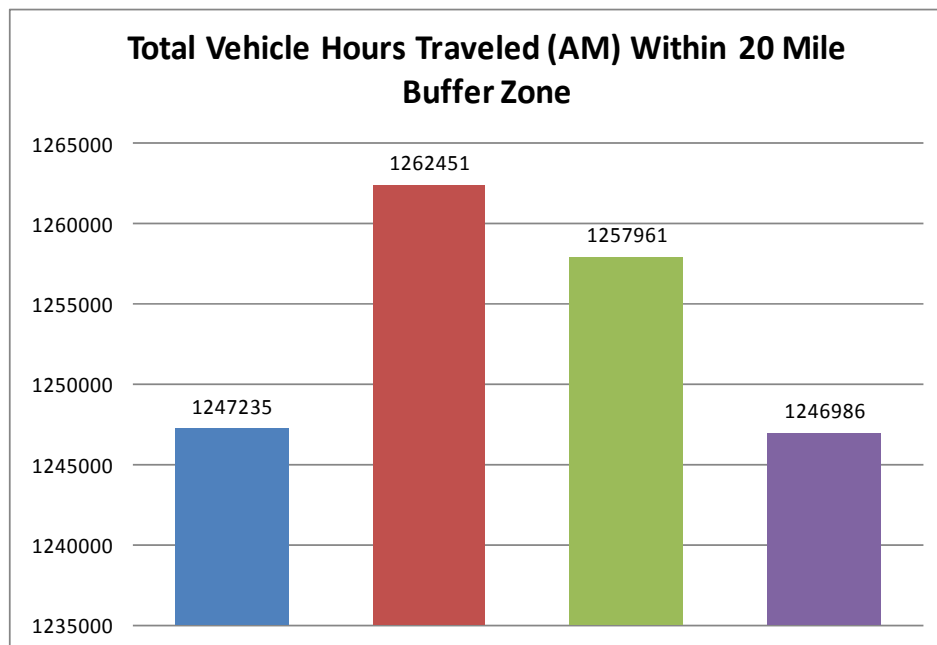


Figure 53: Total VHT in AM period (6AM-10AM) within 20 mile buffer zone

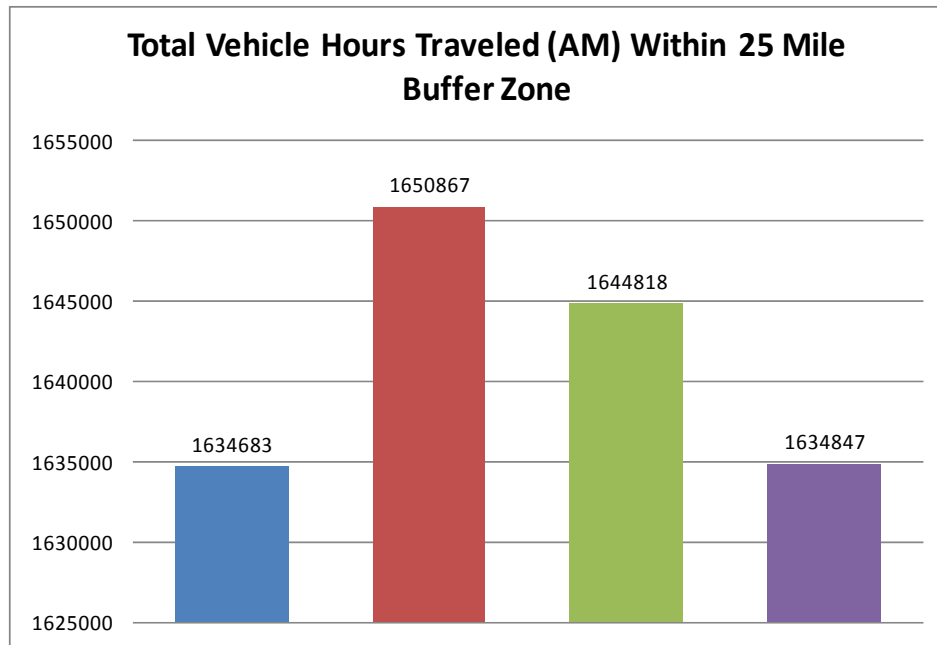


Figure 54: Total VHT in AM period (6AM-10AM) within 25 mile buffer zone

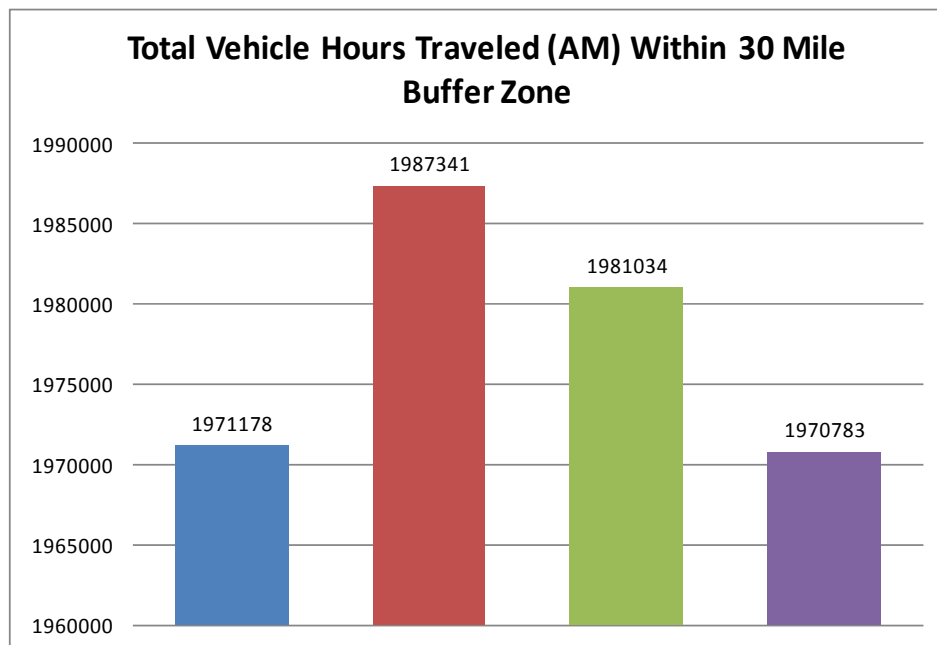


Figure 55: Total VHT in AM period (6AM-10AM) within 30 mile buffer zone

Table 10: Percent Change in VHT from BC (AM)

Distance	S1	S2	S3
5	6.47	6.51	0.06
10	1.50	1.68	0.26
15	1.52	1.20	-0.04
20	1.22	0.86	-0.02
25	0.99	0.62	0.01
30	0.82	0.50	-0.02

MD Period

During the midday period (10AM – 3PM) there is no significant change in VHT for each scenario. The total hours traveled for each scenario during the midday period are higher than any other travel period, however this is due to the fact that the midday period is one-hour longer than the AM peak period and the PM peak period.

Table 11 highlights the changes in VHT during the midday period. The changes in toll collection policy for the three scenarios do not have a major impact on VHT within the region during the MD travel period.

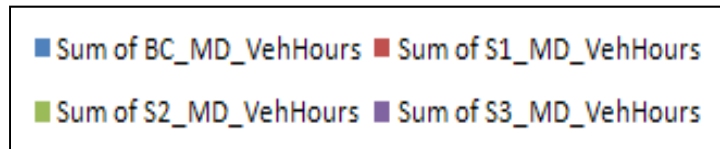


Figure 56: Legend for total VHT in MD period (10AM-3PM)

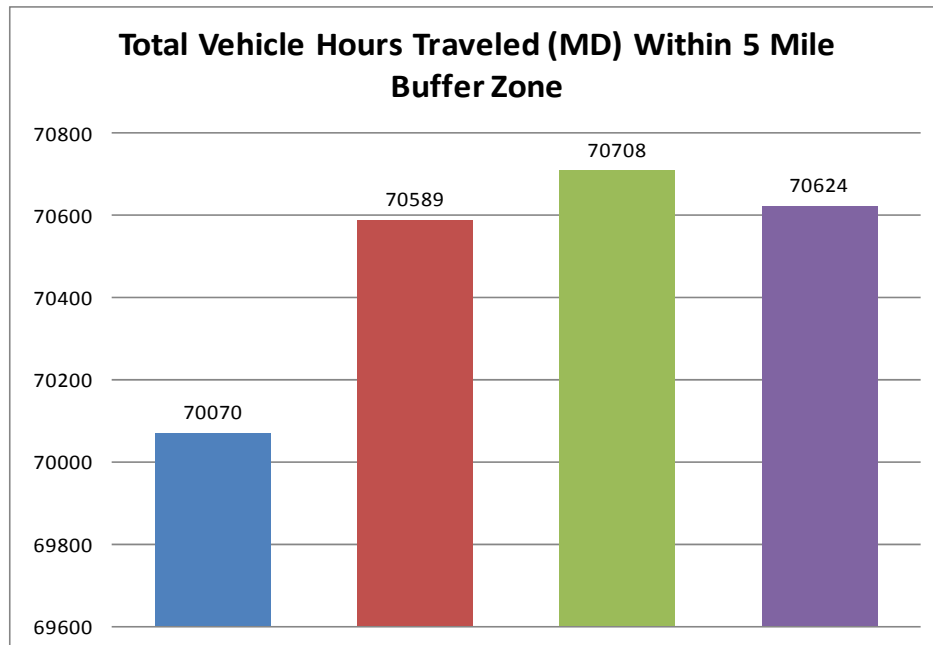


Figure 57: Total VHT in MD period (10AM-3PM) within 5 mile buffer zone

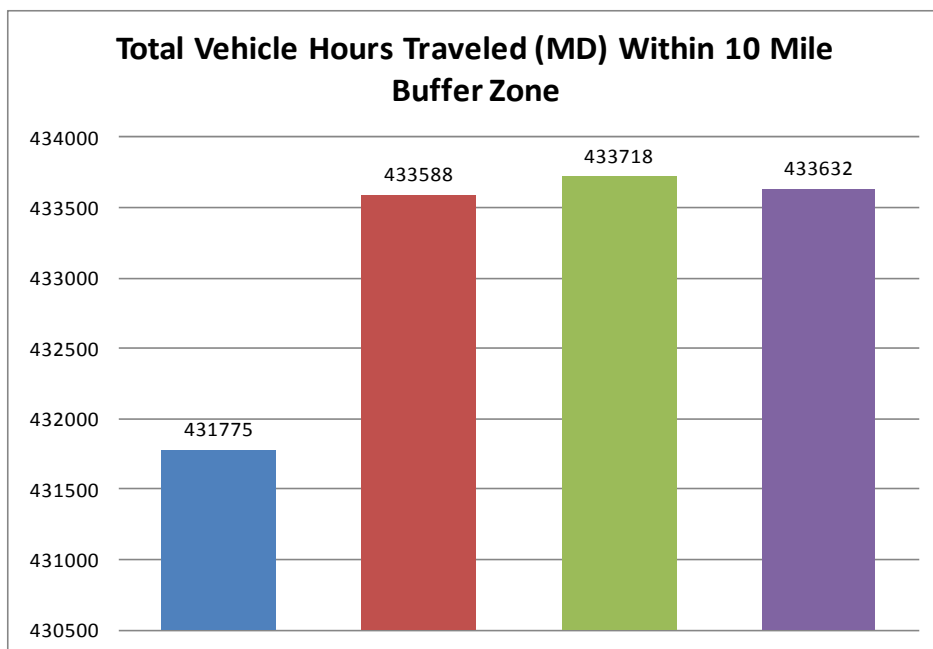


Figure 58: Total VHT in MD period (10AM-3PM) within 10 mile buffer zone

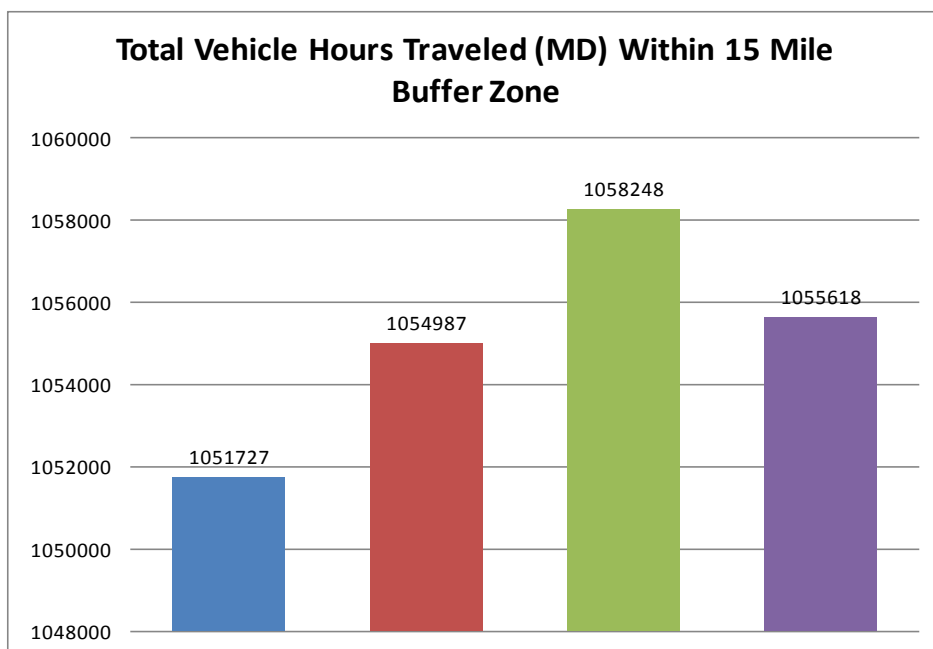


Figure 59: Total VHT in MD period (10AM-3PM) within 15 mile buffer zone

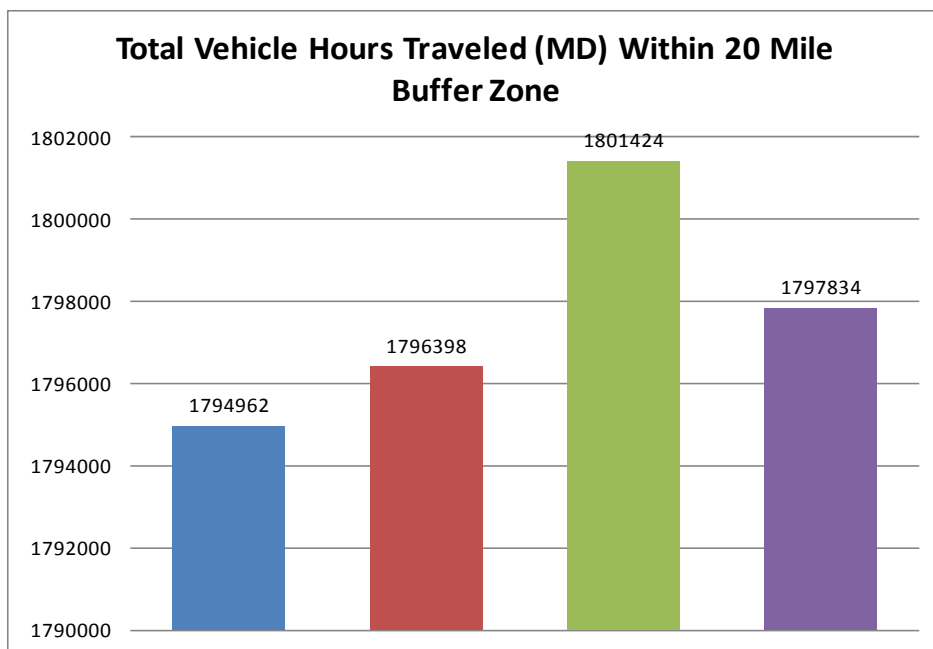


Figure 60: Total VHT in MD period (10AM-3PM) within 20 mile buffer zone

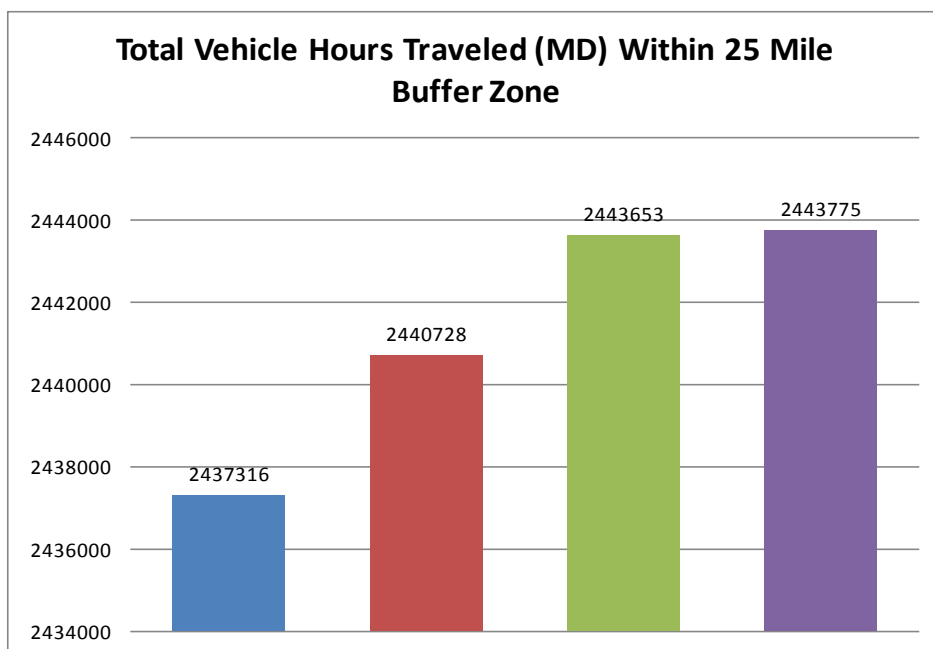


Figure 61: Total VHT in MD period (10AM-3PM) within 25 mile buffer zone

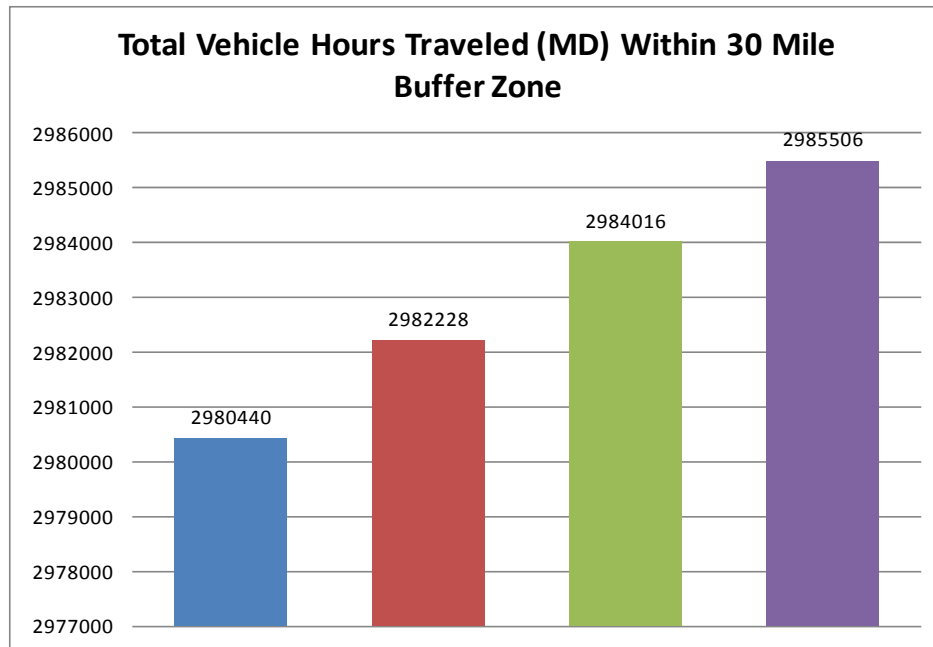


Figure 62: Total VHT in MD period (10AM-3PM) within 30 mile buffer zone

Table 11: Percent Change in VHT from BC (MD)

Distance	S1	S2	S3
5	0.74	0.91	0.79
10	0.42	0.45	0.43
15	0.31	0.62	0.37
20	0.08	0.36	0.16
25	0.14	0.26	0.26
30	0.06	0.12	0.17

PM Period

During the PM peak period (3PM-7PM) the total hours traveled have increased from the AM period but are still lower than the total hours traveled in the midday period as shown in the following figures. Table 12 shows that there are some significant changes in VHT during two scenarios in this period. Scenario 2 is a change to a bi-directional toll collection on the Verrazano-Narrows Bridge and resulted in a 2.41 percent increase of VHT within a five mile radius of the bridge. Scenario 3, doubling the current tolls on the Verrazano Bridge caused similar increases in VHT. There is a 2.15 percent increase on links within five miles of the bridge.

Table 12 shows that the changes just discussed caused the only significant increases in total vehicle hours traveled during the PM peak period. These changes all occurred on links within five miles of the bridge. Opposite to the AM results, the two scenarios that showed significant increases in VHT (S2 and S3) had toll collection in the westbound direction which is the peak travel direction on the bridge during the PM travel period.

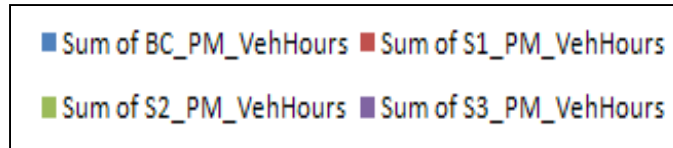


Figure 63: Legend for total VHT in PM period (3PM-7PM)

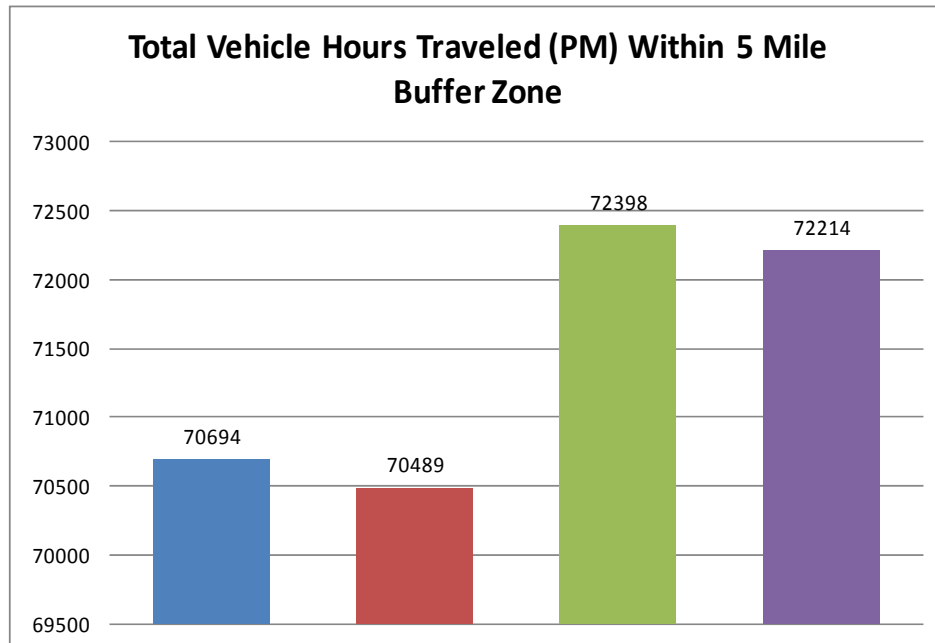


Figure 64: Total VHT in PM period (3PM-7PM) within 5 mile buffer zone

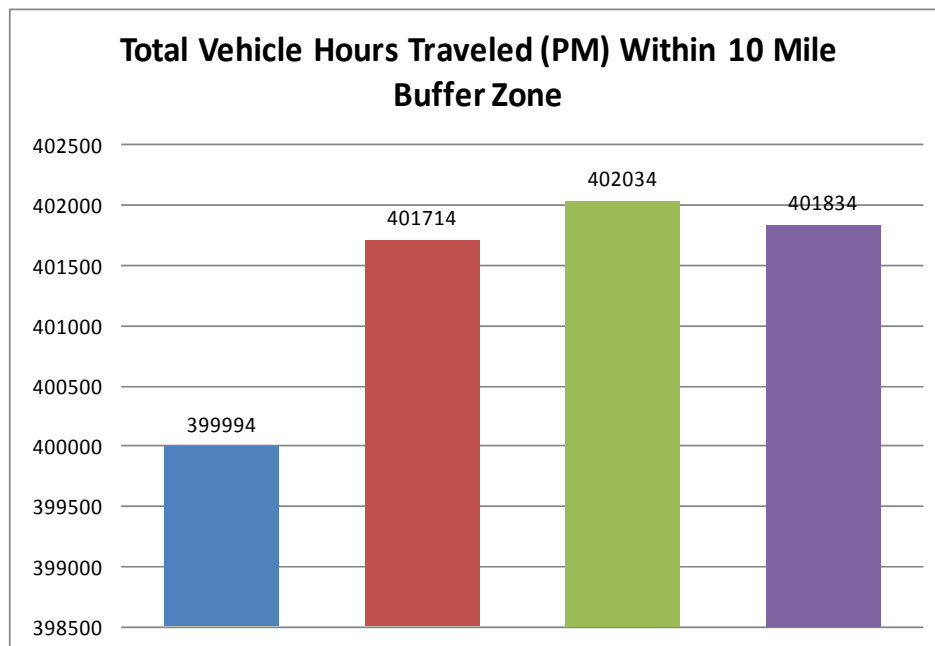


Figure 65: Total VHT in PM period (3PM-7PM) within 10 mile buffer zone

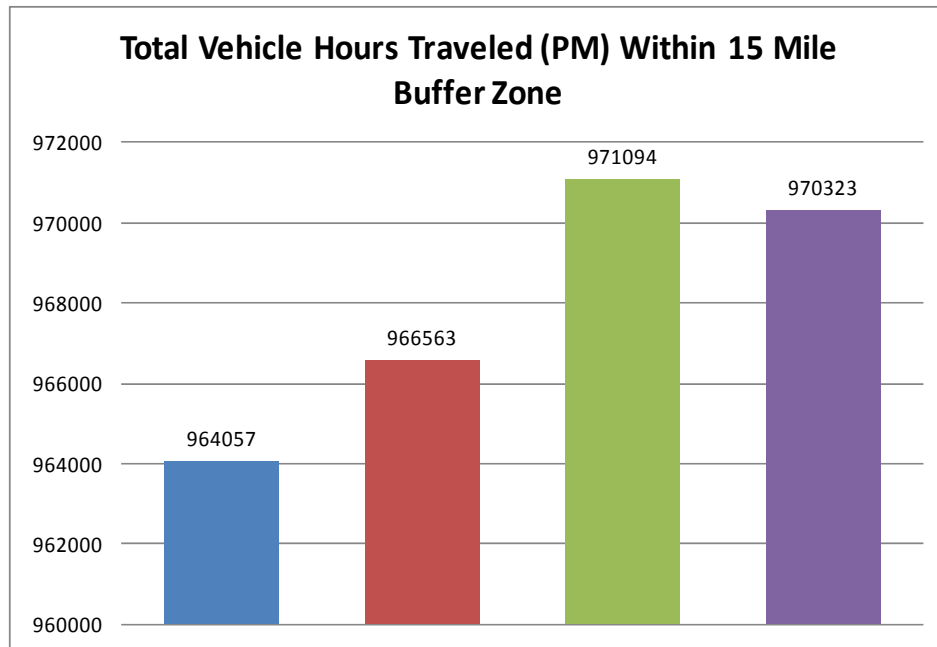


Figure 66: Total VHT in PM period (3PM-7PM) within 15 mile buffer zone

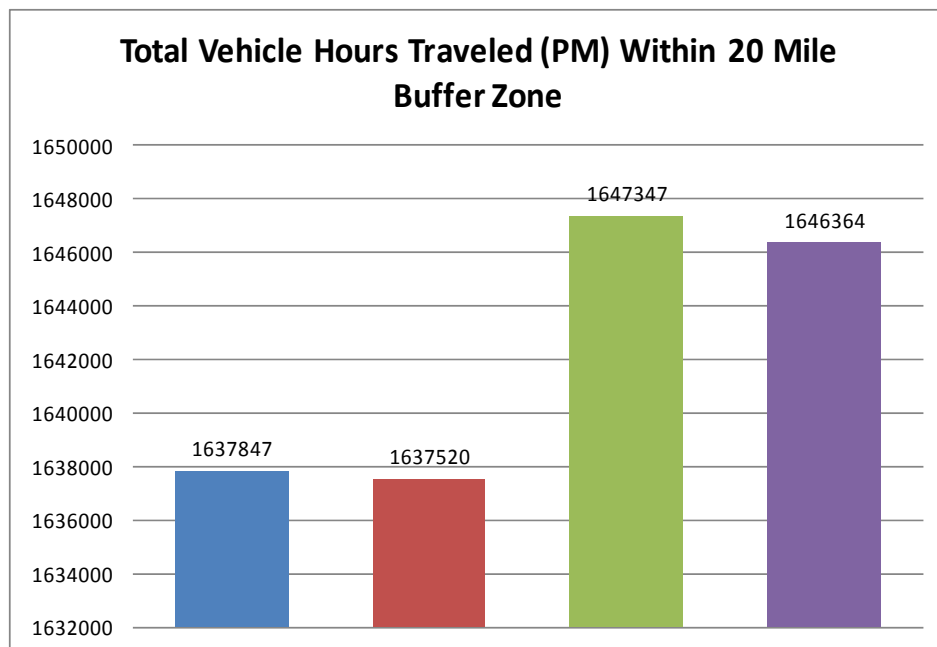


Figure 67: Total VHT in PM period (3PM-7PM) within 20 mile buffer zone

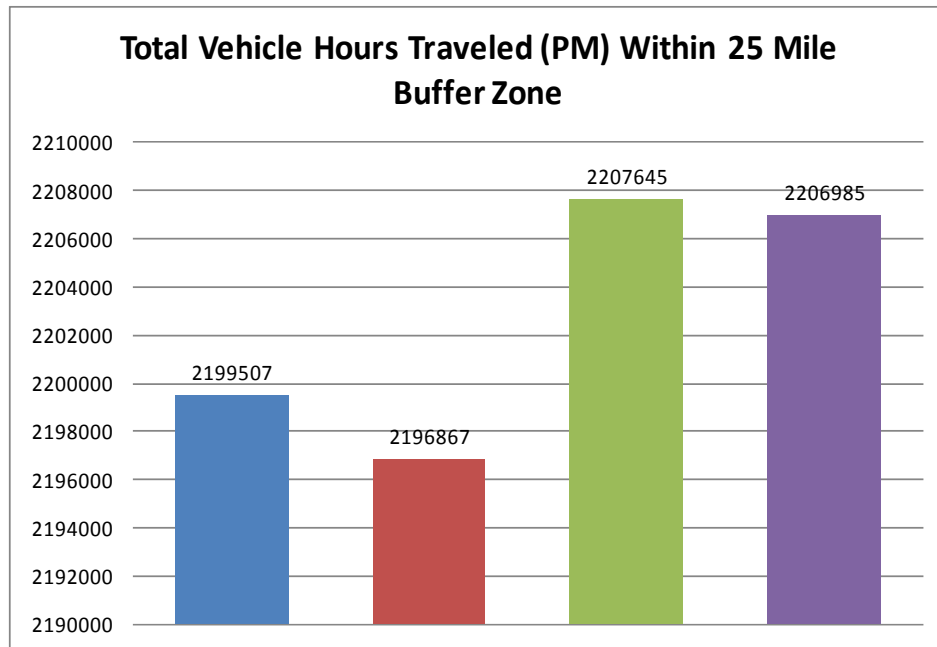


Figure 68: Total VHT in PM period (3PM-7PM) within 25 mile buffer zone

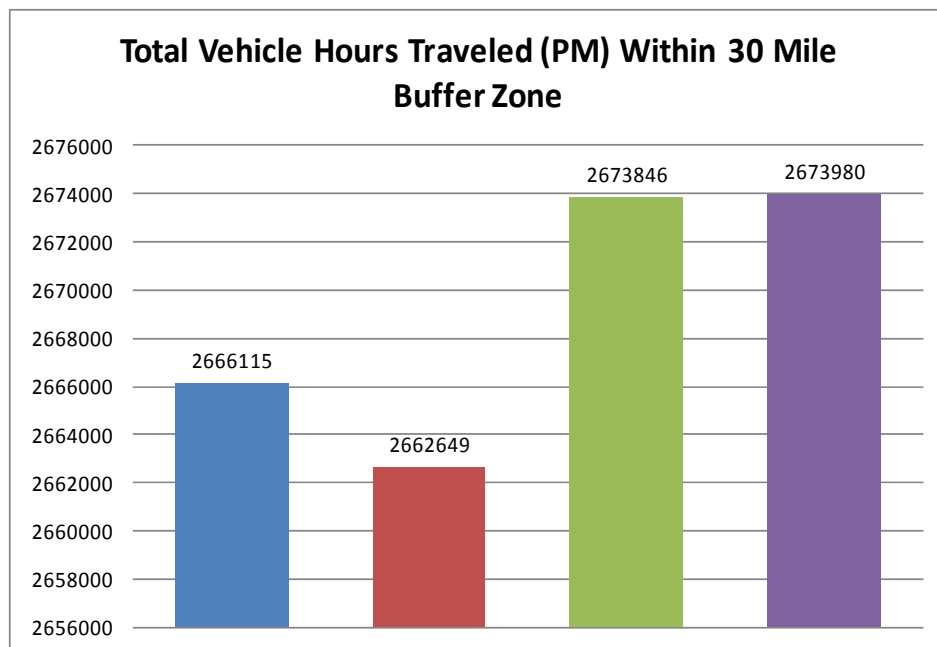


Figure 69: Total VHT in PM period (3PM-7PM) within 30 mile buffer zone

Table 12: Percent Change in VHT from BC (PM)

Distance	S1	S2	S3
5	-0.29	2.41	2.15
10	0.43	0.51	0.46
15	0.26	0.73	0.65
20	-0.02	0.58	0.52
25	-0.12	0.37	0.34
30	-0.13	0.29	0.29

NT Period

There are no significant changes in vehicle hours traveled during this travel period. The following figures show that the total VHT are much lower than the other three travel periods and

Table 13 shows that there is no significant increase or decrease in VHT.

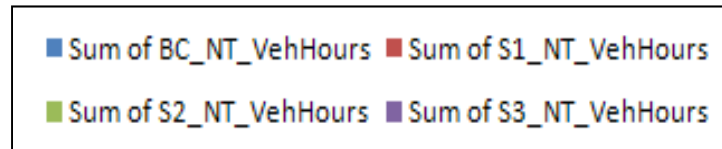


Figure 70: Legend for total VHT in NT period (7PM -6AM)

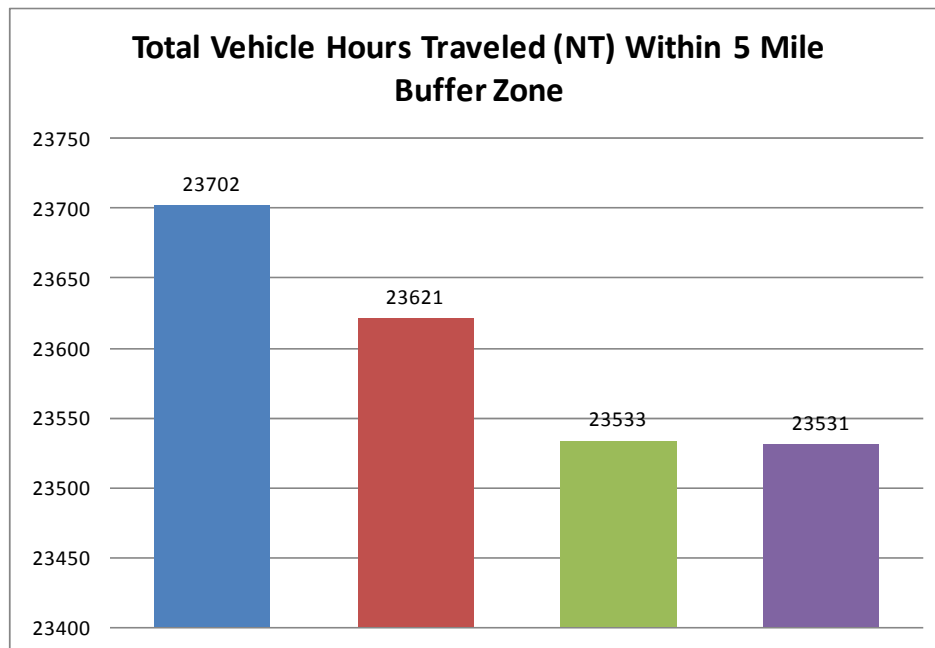


Figure 71: Total VHT in NT period (7PM -6AM) within 5 mile buffer zone

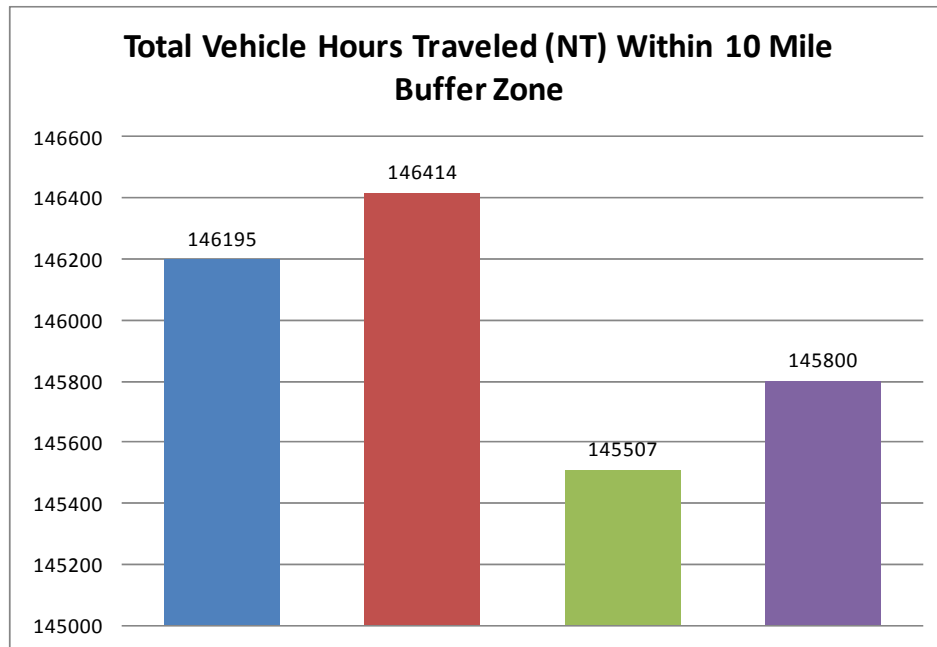


Figure 72: Total VHT in NT period (7PM -6AM) within 10 mile buffer zone

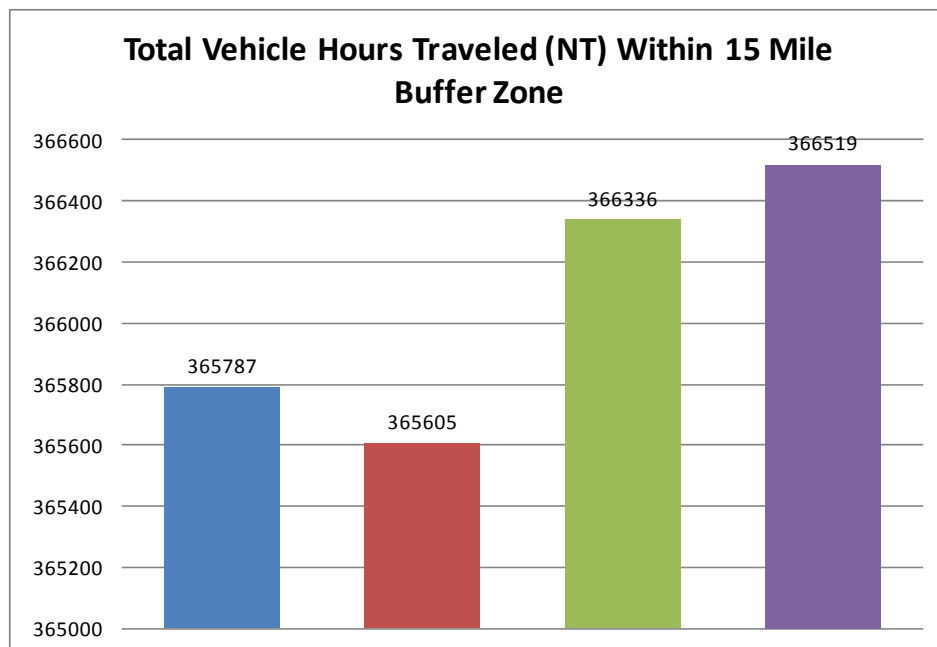


Figure 73: Total VHT in NT period (7PM -6AM) within 15 mile buffer zone

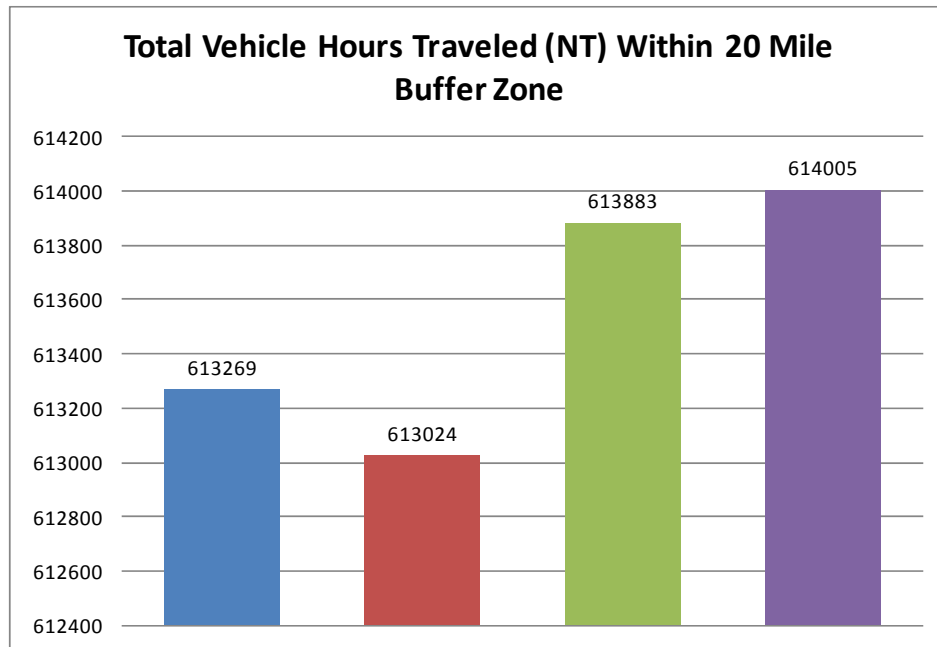


Figure 74: Total VHT in NT period (7PM -6AM) within 20 mile buffer zone

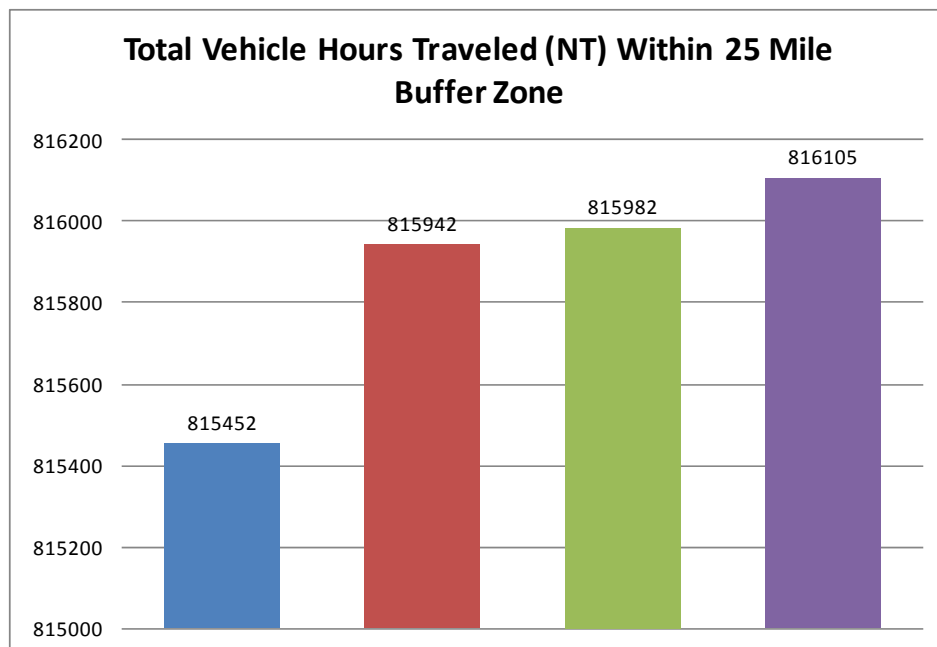


Figure 75: Total VHT in NT period (7PM -6AM) within 25 mile buffer zone

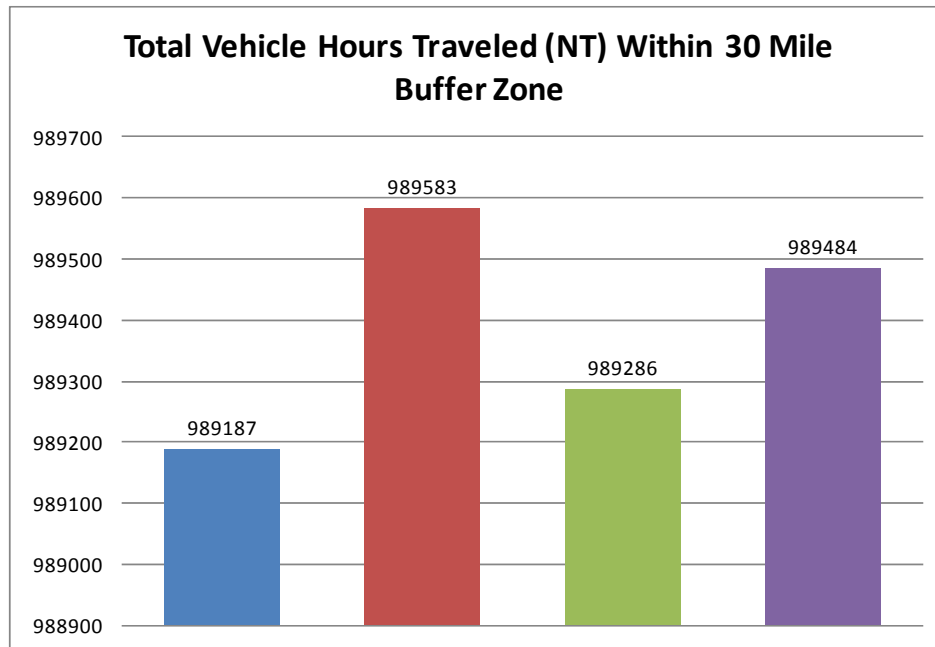


Figure 76: Total VHT in NT period (7PM -6AM) within 25 mile buffer zone

Table 13: Percent Change in VHT from BC (NT)

Distance	S1	S2	S3
5	-0.34	-0.71	-0.72
10	0.15	-0.47	-0.27
15	-0.05	0.15	0.20
20	-0.04	0.10	0.12
25	0.06	0.06	0.08
30	0.04	0.01	0.03

Total Delay per Band

Figure 77 through Figure 80 and Table 14 through Table 17 show the total delay experienced within each five mile buffer around the Verrazano-Narrows Bridge. The delay represents a more direct impact faced by travelers from the change in toll policy on the Verrazano-Narrows Bridge. The figures show the total delay in hours for each scenario and within each buffer zone around the bridge. The tables show the percent changes in delay from the base case scenario. The total delay was calculated by multiplying the average delay on each link by the total flow on that link.

AM Period

During the AM period (6AM-10AM) there are major increases in delay for a number of scenarios. Within the five mile radius S1 and S2 both have drastic and immediate impacts to travelers as shown in Table 14. The total delay when the toll collection is

changed to the eastbound direction (S1) increases 11.83 percent. Similarly S2, a bi-directional toll collection causes an 11.93 percent increase in total delay on links within five miles of the bridge.

Scenario 1 and Scenario 2 have the most impact on the total delay and the impact of these scenarios can be felt within the thirty-mile radius. The highlighted cells in Table 14 indicate the significant changes in delay. When a toll collection is implemented in the eastbound direction during the AM peak travel period the effects can be felt within the thirty-mile radius.

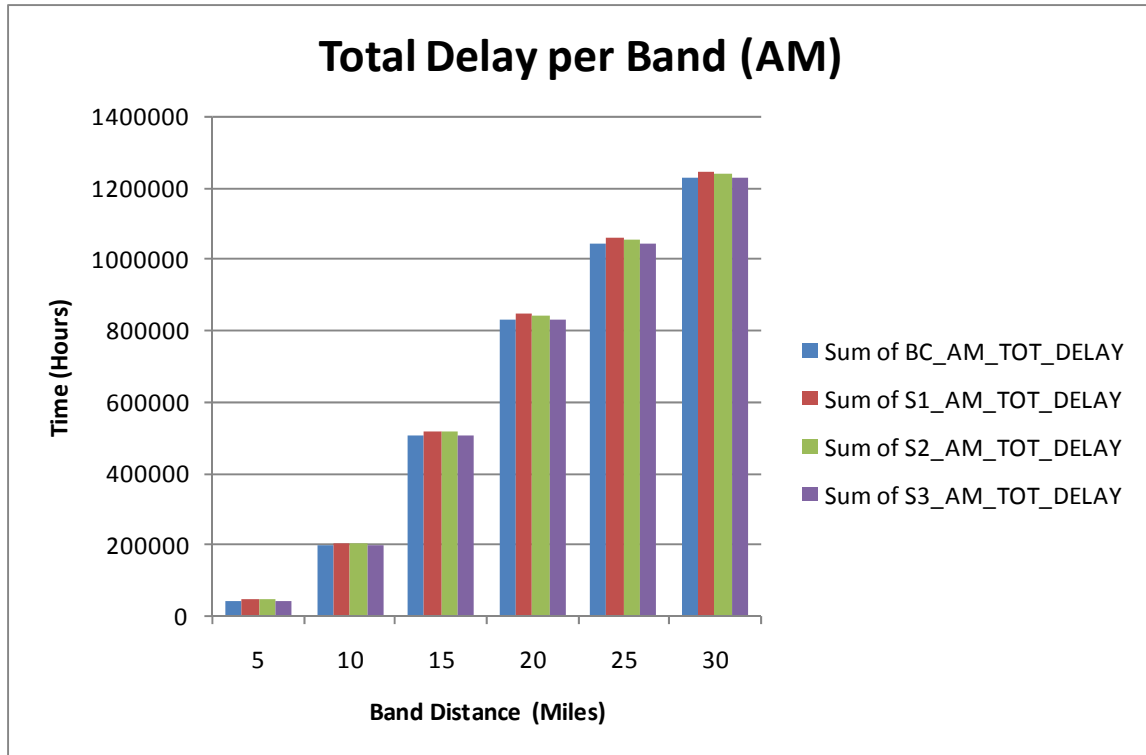


Figure 77: Total delay in AM period (6AM -10AM)

Table 14: Percent change in total delay from BC (AM)

Distance	S1	S2	S3
5	11.83	11.93	0.39
10	2.80	3.10	0.46
15	2.55	2.01	-0.06
20	2.09	1.44	-0.04
25	1.73	1.06	0.01
30	1.47	0.87	-0.04

MD Period

The impact on delay is not as significant during the midday period (10AM-3PM). As with the total VMT and the total VHT, the total midday delay is higher than the AM peak period and the PM peak period however as stated before this is due to the fact that the

duration of the MD period is one hour longer. Table 15 shows that the increases in delay are mainly limited to within the five mile radius around the bridge. Significant changes result from S1, S2, and S3. S1, the change in toll collection from the westbound direction to the eastbound direction, causes a 2.03 percent increase in total delay. S2, the change to bi-directional tolling on the bridge, causes a 2.39 percent increase in total delay and S3 doubles the current toll rates which causes a 1.98 percent increase in total delay. Here an increase in delay is seen in both directions unlike the trend in VHT and VMT for the MD travel period.

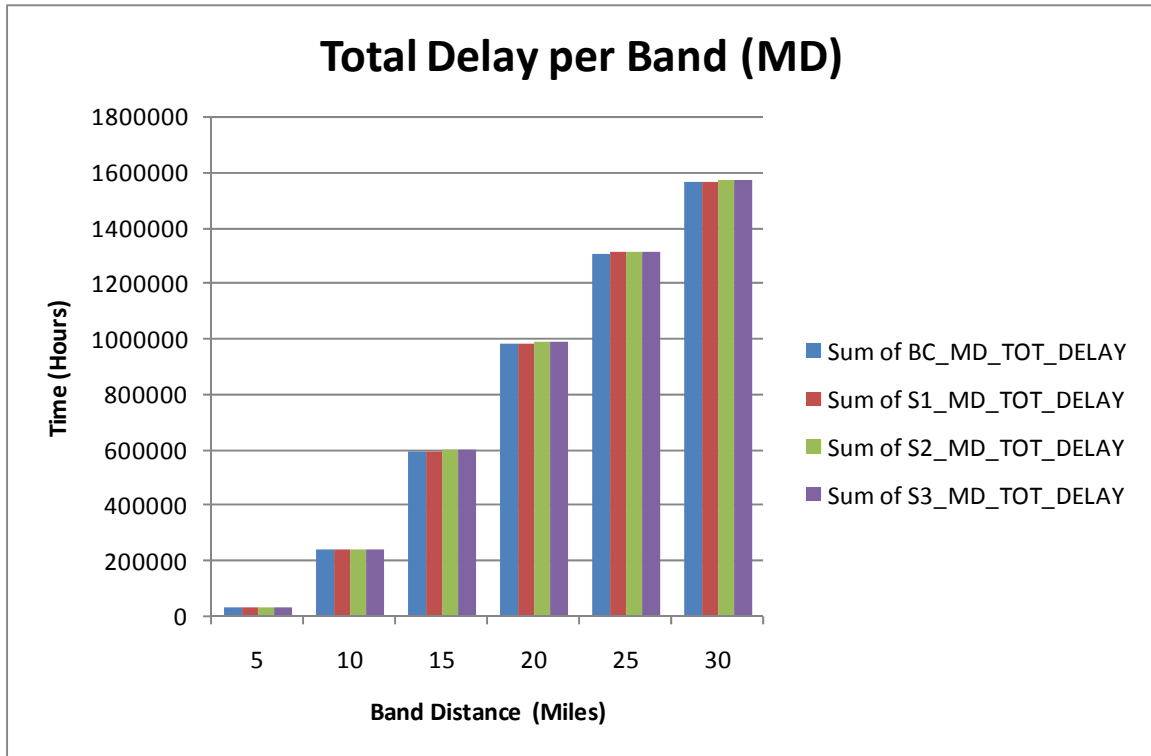


Figure 78: Total delay in MD period (10AM -3PM)

Table 15: Percent change in total delay from BC (MD)

Distance	S1	S2	S3
5	2.03	2.39	1.98
10	0.77	0.77	0.79
15	0.48	1.05	0.61
20	0.06	0.56	0.23
25	0.15	0.37	0.42
30	0.00	0.13	0.28

PM Period

During the PM peak period (3PM-7PM) major impacts on delay are seen under Scenario 2 and Scenario 3. Scenario 2 is change to bi-directional tolling on the bridge and Scenario 3 doubles the current toll rates. The peak travel direction on the bridge during

the PM period is westbound. Within the five mile radius S2 and S3 all have drastic and immediate impacts to travelers as shown in Table 16. The total delay when the toll collection changes to bi-directional collection on the bridge (S2) increases by 5.11 percent. Similarly S3, doubling the current toll rates causes a 4.56 percent increase in total delay on links within five miles of the bridge. Scenario 2 and Scenario 3 have the most impact on the total delay. Table 16 shows each highlighted cell for these two scenarios, which indicates some significant change in delay. An increase in delay is felt only when there is a policy change affecting the westbound direction (S2 and S3) which is the peak travel direction during the PM travel period.

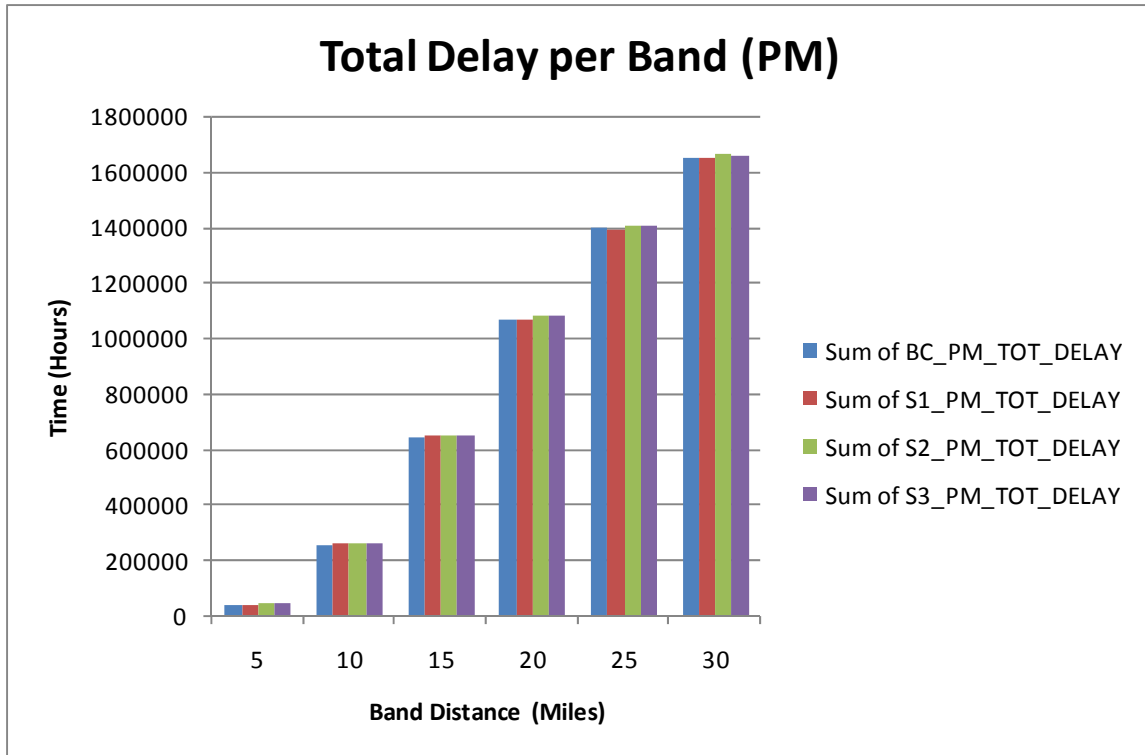


Figure 79: Total delay in PM period (3PM -7PM)

Table 16: Percent change in total delay from BC (PM)

Distance	S1	S2	S3
5	-0.52	5.11	4.56
10	0.69	0.95	0.87
15	0.44	1.21	1.08
20	-0.03	0.96	0.86
25	-0.19	0.62	0.58
30	-0.23	0.48	0.47

NT Period

As with VMT and VHT, the total delay was least affected during the night time travel period (7PM – 6AM). Some small changes in delay are seen in Scenario 2 and Scenario 3. The highlighted cells in Table 17 represent these percent changes in delay.

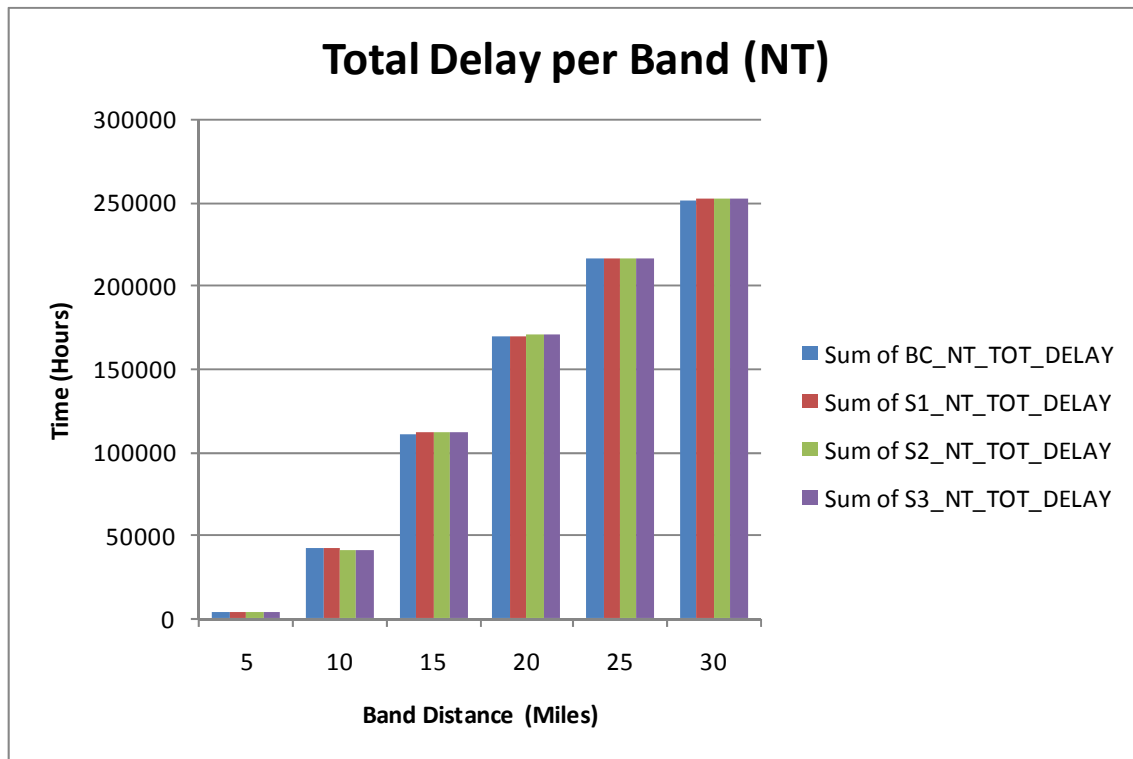


Figure 80: Total delay in NT period (7PM-6AM)

Table 17: Percent change in total delay from BC (NT)

Distance	S1	S2	S3
5	-0.39	-2.23	-2.25
10	0.74	-1.48	-0.77
15	0.26	0.84	1.01
20	0.07	0.59	0.65
25	0.37	0.41	0.46
30	0.25	0.18	0.22

Flow on Verrazano-Narrows Bridge

The next set of figures and tables shows the change in flow on the Verrazano-Narrows Bridge in both directions (eastbound and westbound) for the base case and the three scenarios (S1 – S3). The figures show the total flow per period for each scenario while the corresponding tables show the percent changes from the base case scenario for each capacity reducing scenario. Scenarios that have a noticeable impact on the flow over the Verrazano-Narrows Bridge are highlighted in the tables shown at the end of this section.

AM Period

During the AM peak period the flow on the Verrazano-Narrows Bridge was impacted the most by Scenario One and Scenario Two. S1 was a change in toll collection from the westbound direction to the eastbound direction and S2 was a change to a bi-directional

toll collection on the Verrazano-Bridge. Figure 81 shows that the total flow in the eastbound direction during the base case is approximately 40,000 vehicles throughout the AM period and the flow drops to nearly 38,000 vehicles (approximately -3.38 percent) during S1. Table 18 shows that Scenario Three only has a minor change in flow compared to the base case (approximately -.45 percent) in the eastbound direction. There are no major changes in flow in the westbound direction on the bridge. The total flow during the base case in the westbound direction is approximately 12,000 vehicles throughout the period. As expected, during the AM peak period the most impacted scenarios are those where a toll collection is implemented on the eastbound links of the Verrazano Bridge. This is the peak direction for commuters during the AM period.

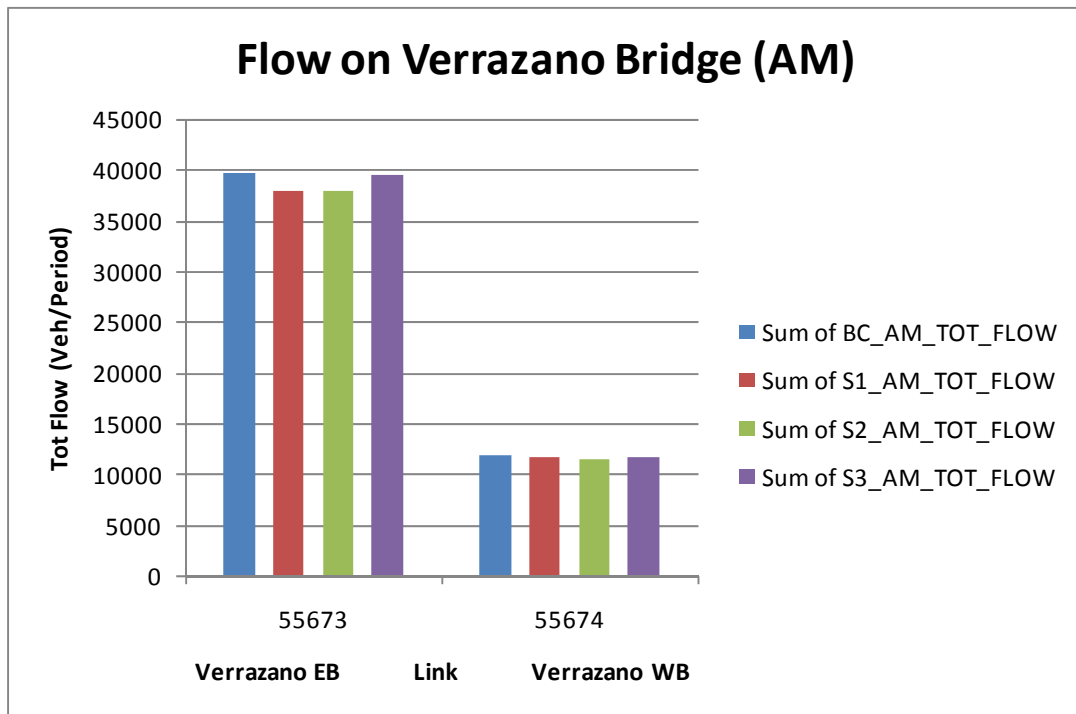


Figure 81: Flow on Verrazano in AM period (6-10)

Table 18: Percent change in flow from BC (AM)

(AB is the eastbound and BA is the westbound direction)

S1_AB	S2_AB	S3_AB
-3.38	-1.51	-0.45
S1_BA	S2_BA	S3_BA
-0.83	-1.21	-0.85

MD Period

During the midday period, none of the scenarios had a major impact on the change in flow throughout the travel period. The flow in the eastbound direction during the base case was around 29,800 vehicles. Figure 82 and Table 19 show that in the eastbound direction the change in flow remained within approximately 1 percent or below for all scenarios. The flow in the westbound direction during the base case was slightly lower than in the eastbound direction and there were no significant changes in flow due to any of the scenarios.

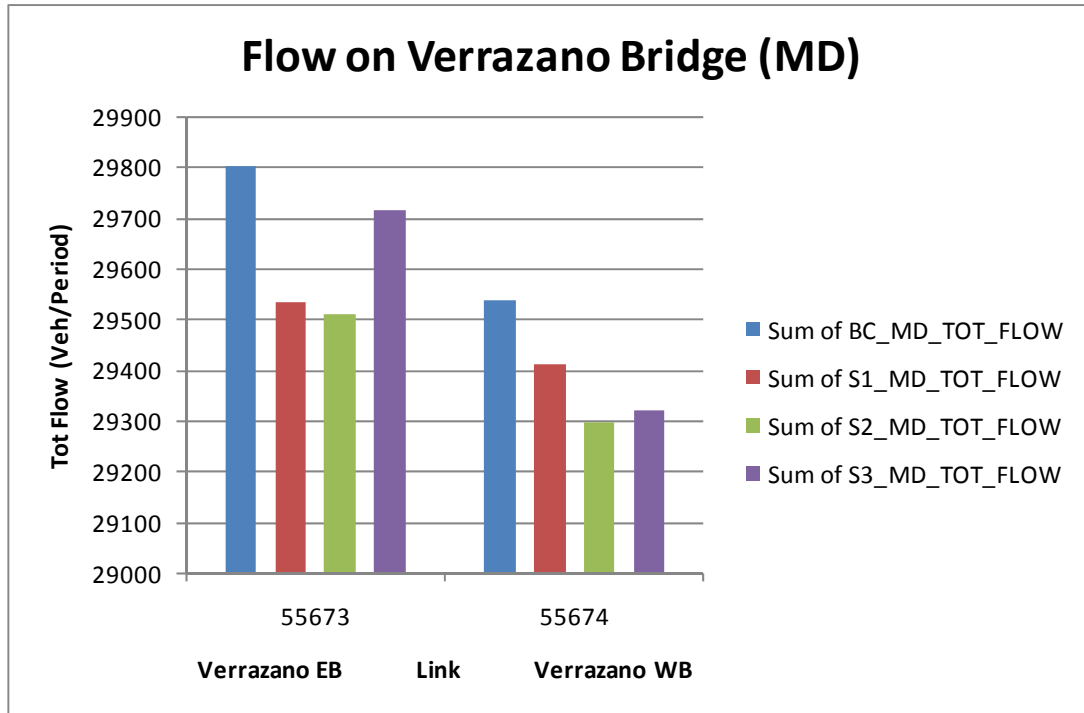


Figure 82: Flow on Verrazano in MD period (10A-3P)

Table 19: Percent change in flow from BC (MD)

(AB is the eastbound and BA is the westbound direction)

S1_AB	S2_AB	S3_AB
-0.92	-1.01	-0.3
S1_BA	S2_BA	S3_BA
-0.42	-0.76	-0.68

PM Period

During the PM peak period the flow on the Verrazano-Narrows Bridge was impacted the most by Scenario Two and Scenario Three in the westbound direction. S2 was a change to a bi-directional toll collection on the Verrazano Bridge and S3 doubled the current toll rates on the Verrazano Bridge. Figure 83 shows that the total flow in the eastbound direction during the base case is near 15,000 vehicles throughout the PM period and the

flow remains quite constant for all three of the scenarios. In the westbound direction the flow is slightly above 40,000 vehicles in the PM peak period. During S2 and S3, when changes in the tolling policy on the westbound link of the Verrazano are implemented the flow drops -2.54 percent and -2.60 percent, respectively. These results are reasonable since significant changes are seen on the westbound link which is the peak travel direction on the bridge during the PM peak period.

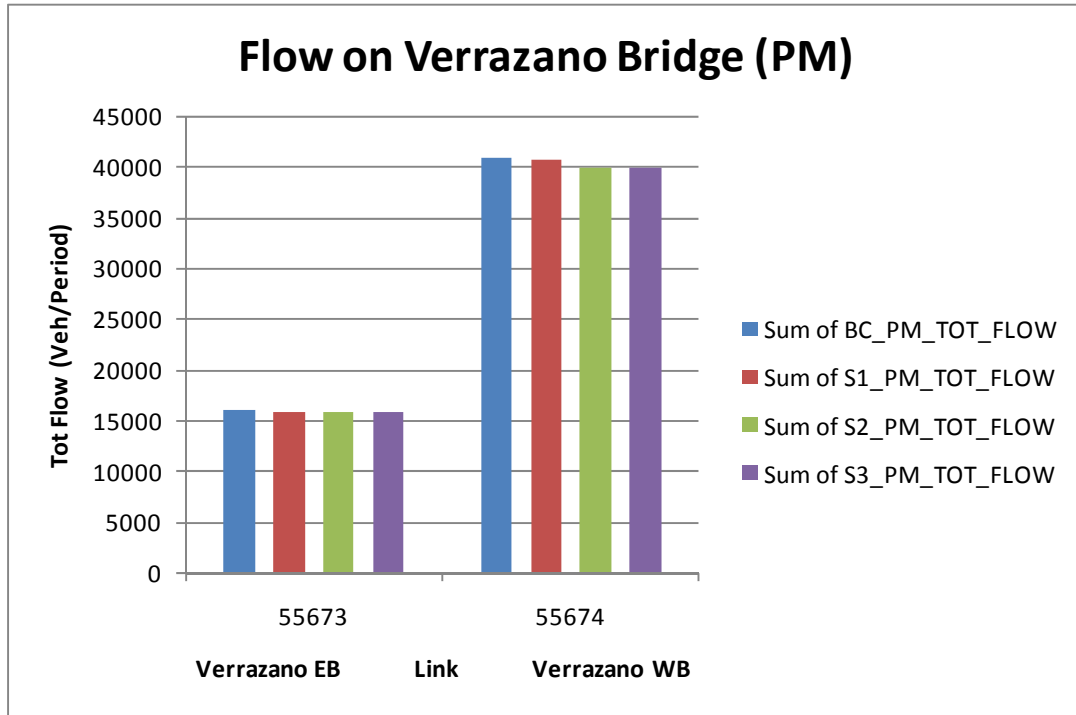


Figure 83: Flow on Verrazano in PM period (3PM-7PM)

Table 20: Percent change in flow from BC (PM)

(AB is the eastbound and BA is the westbound direction)

S1_AB	S2_AB	S3_AB
-0.41	-0.73	-0.84
S1_BA	S2_BA	S3_BA
-0.39	-2.54	-2.60

NT Period

Figure 84 and Table 21 show that none of the scenarios noticeably impact the flow during the night time period between 7 PM and 6 AM. The flow remains just under 15,000 vehicles throughout the period in the eastbound direction and just under 20,000 vehicles throughout the period in the westbound direction.

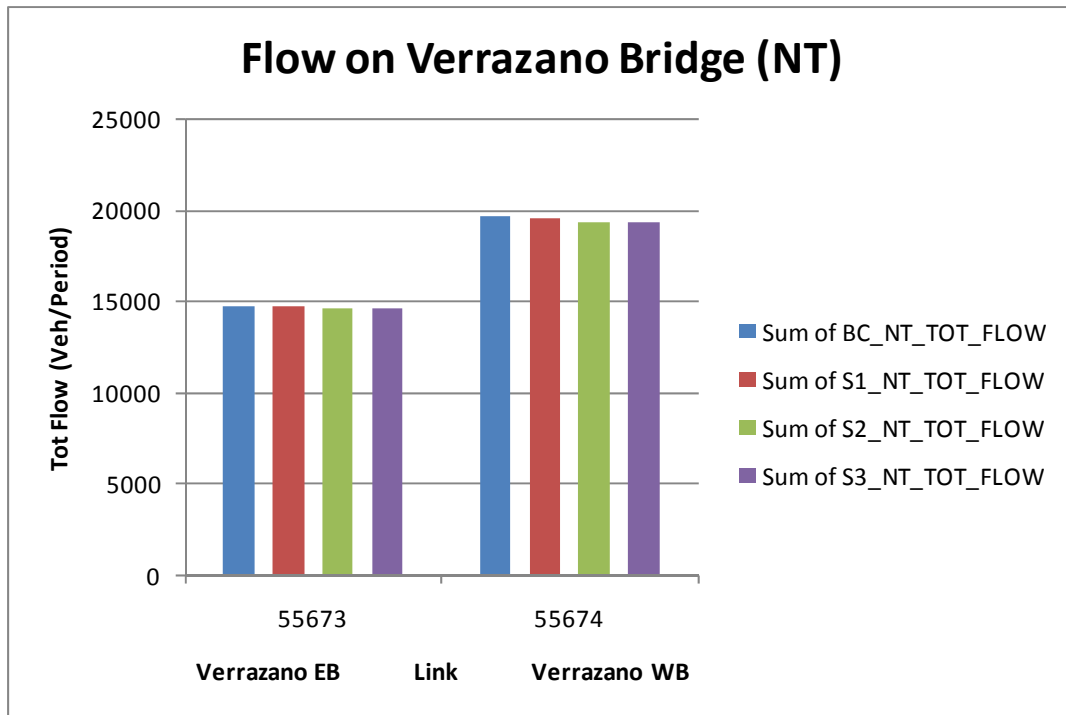


Figure 84: Flow on Verrazano in NT period (7PM-6AM)

Table 21: Percent change in flow from BC (NT)
(AB is the eastbound and BA is the westbound direction)

S1_AB	S2_AB	S3_AB
-0.50	-0.75	-0.61
S1_BA	S2_BA	S3_BA
-0.68	-0.85	-0.88

Link-Level Delay

This section of the report shows how each scenario impacted travel times on vital links during the AM and PM peak travel periods. Four color-themed maps were produced for each scenario including the base case for the AM and PM periods. These images can be found in the appendix of this report (Figure 163 - Figure 170).

To understand the images and the analysis provided in this section, the construction of these images will be briefly discussed. Eight images were produced for this scenario (B2) *Impacts of changes in tolls* in order to provide an understanding of how these changes impacted vital links in the network. Four images were produced for the AM peak travel period; one for the base case and one for each of the scenarios (S1-S3). The same was done for the PM peak travel period. A short description of each scenario is presented below.

- Base Case (BC) – no change
- Scenario One (S1) – eastbound toll
- Scenario Two (S2) – bi-directional toll
- Scenario Three (S3) – double current tolls

First the delay on each link was calculated by taking the difference of the average travel time output by the NYBPM for each link and the free flow travel time of that link. A color-themed map was then created to give a visual of delay on the network. On each map a red, circled star represents the location of the Verrazano-Narrows Bridge. The color-theme that was used to represent the delay ranges from green representing the lowest delay, to red representing the highest delay. Each map has its own corresponding legend with the exact magnitude of delay represented by each color.

First the Base Case scenario map was examined to get an idea of where significant delay existed on the network before any changes in tolling policy were made to the Verrazano-Narrows Bridge. As the Base Case map shows, the link with the highest delay is the Holland Tunnel, colored orange to represent 20 to 24 minute delays in Figure 153. Other major delays in the region are on the Lincoln Tunnel, showing 8 to 12 minute delays and several links along the New Jersey Turnpike. The NJ Turnpike from Exit 14-15E shows delays in the 12 to 16 minute range. The Verrazano-Narrows shows only up to 8 minute average delays before any toll changes occur.

Figure 163 through Figure 170 are the delay images (AM and PM) for Scenario One through Scenario Three. These images show the effects on other New York City crossings when the tolling policy on the Verrazano Narrows Bridge is changed.

During the AM peak travel period significant changes in delay on other major New York City crossings are seen when the toll is changed from the westbound direction to the eastbound direction on the Verrazano Bridge. Delays are seen because the toll is now in the peak travel direction. There is already some congestion on the Verrazano Bridge as the Base Case map shows, and placing the toll in the eastbound direction increases delay on the Verrazano along with other Manhattan Crossings. Figure 164 and Figure 165 are the images for delay in the AM during Scenario One and Scenario Two, respectively. These images show increases in delay on the Holland Tunnel, Lincoln Tunnel and the George Washington Bridge. No major changes in delay were observed for Scenario Three, doubling the toll rates in the westbound direction since traffic in the eastbound, peak travel direction is not affected by this change.

During the PM peak travel period significant changes in delay occur on other major New York City crossings during Scenario Two and Scenario Three. Scenario Three has the most impact in delay during the PM period. Scenario Three doubles the current toll rates in the westbound direction, which is the peak travel direction in the Verrazano-Narrows Bridge during the PM travel period. Figure 166 shows the image for delay in the PM for Scenario Three. These images show increases in delay on the Holland Tunnel, Lincoln Tunnel and the approach to George Washington Bridge.

3.3 B3: Impact of disruption of infrastructure

3.3.1 Regional Analysis

Total Vehicle Miles Traveled

The first set of figures and tables in this section show the total vehicle miles traveled for each five-mile buffer zone around the Verrazano-Narrows Bridge and the percent change in total VMT from the base case for each scenario. As previously stated, the model uses four time periods: AM peak (6AM – 10AM), midday (10AM – 3PM), PM peak (3PM – 7PM), and night (7PM – 6AM). For each period there are separate figures, tables and analysis of results. For each analysis the change in VMT is compared to the base case (BC) scenario.

AM Period

During the AM peak period (6AM – 10AM) the most significant changes are seen within the five mile radius in Scenario Five (S5) and Scenario Six (S6). S5 is a three lane reduction in the eastbound direction of the Verrazano and S6 is a three lane reduction in the eastbound and westbound direction of the bridge. The VMT dropped approximately 8.45 percent during S5 and 8.57 percent during S6 within the five mile radius around the bridge as shown by the highlighted cells in

Table 22. Although the capacity reduction between the two scenarios is significant, the difference in VMT is not major. This is because the westbound direction is not a peak direction in the AM period, thus most of the re-routing occurred in the peak eastbound direction. The results also show the decrease in the overall VMT within close proximity to the bridge. In the 20-, 25-, and 30-mile radius from the bridge the effect of traffic re-routing is captured, although no major changes are observed.

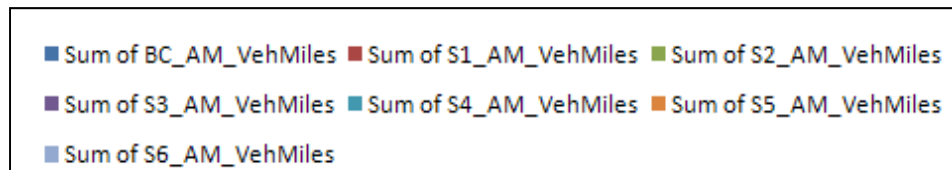


Figure 85: Legend for total VMT in AM period (6AM-10AM)

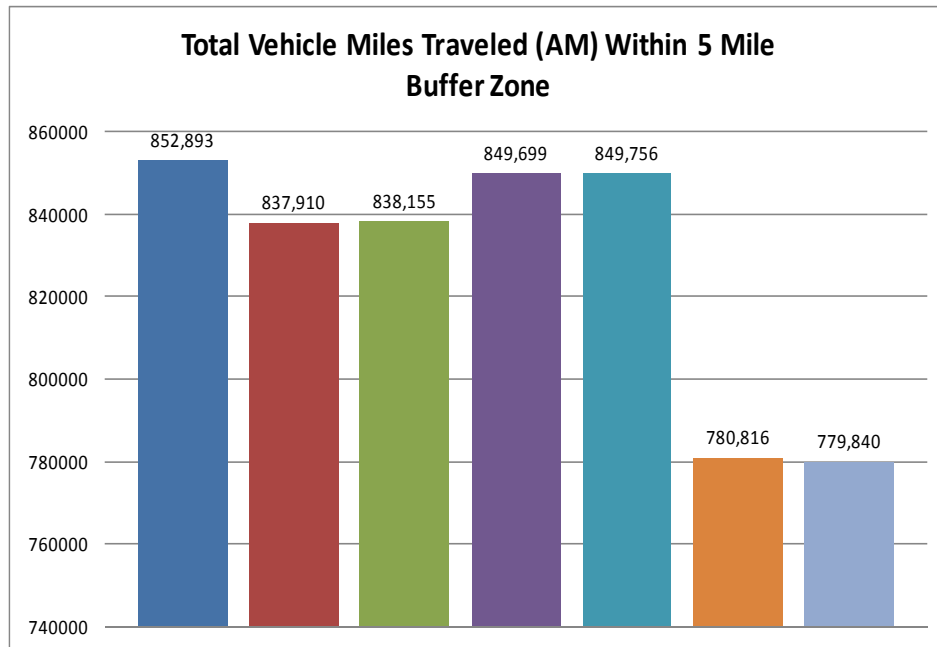


Figure 86: Total VMT in AM period (6AM-10AM) within 5 mile buffer zone

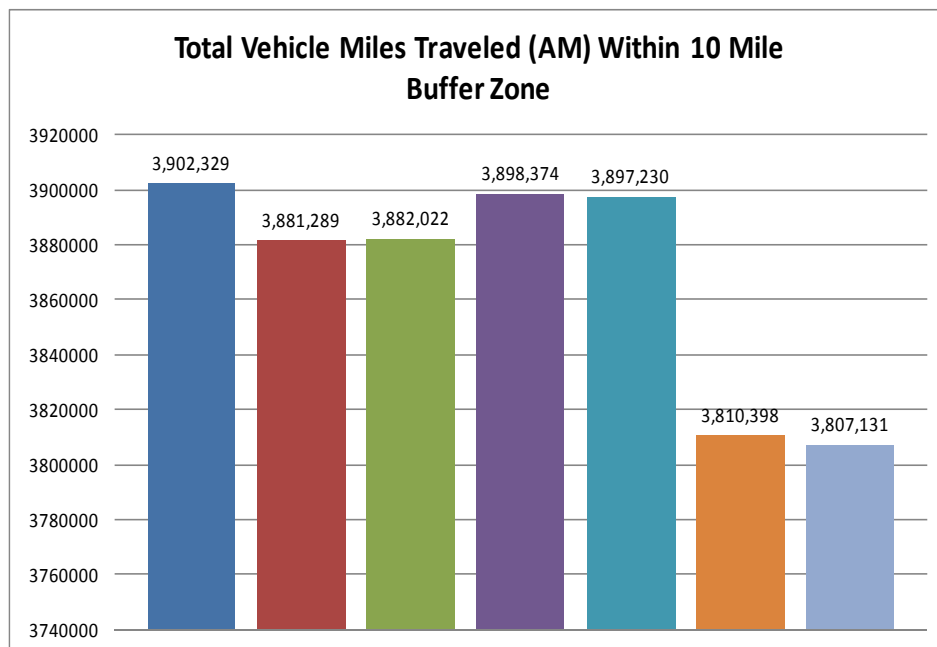


Figure 87: Total VMT in AM period (6AM-10AM) within 10 mile buffer zone

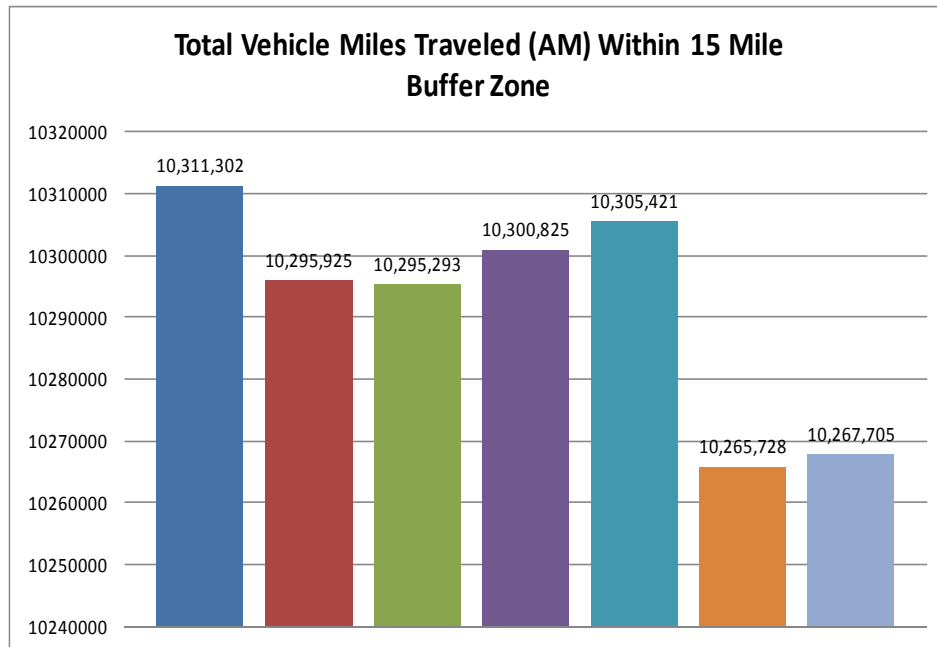


Figure 88: Total VMT in AM period (6AM-10AM) within 15 mile buffer zone

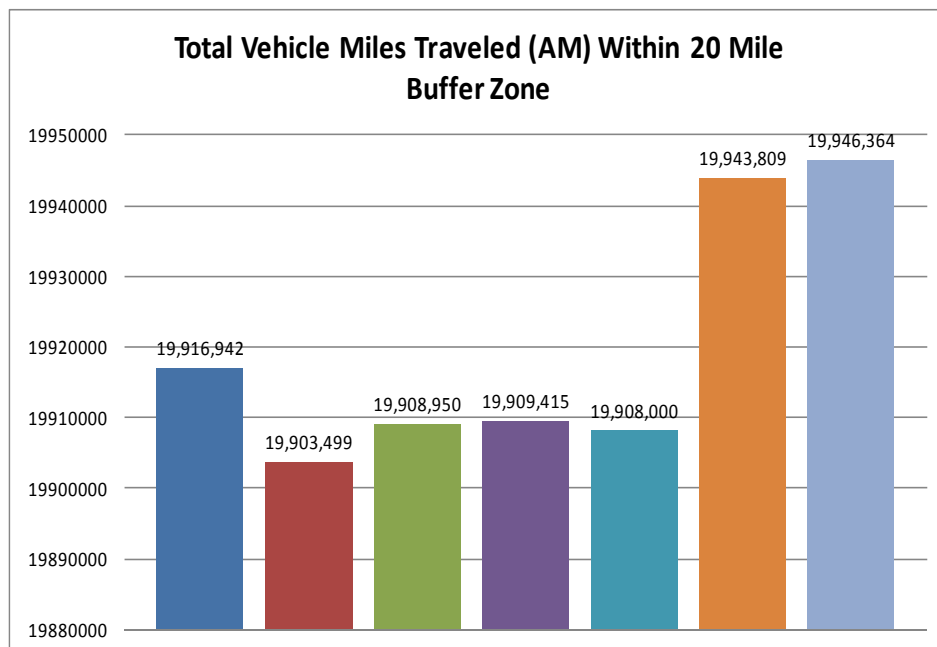


Figure 89: Total VMT in AM period (6AM-10AM) within 20 mile buffer zone

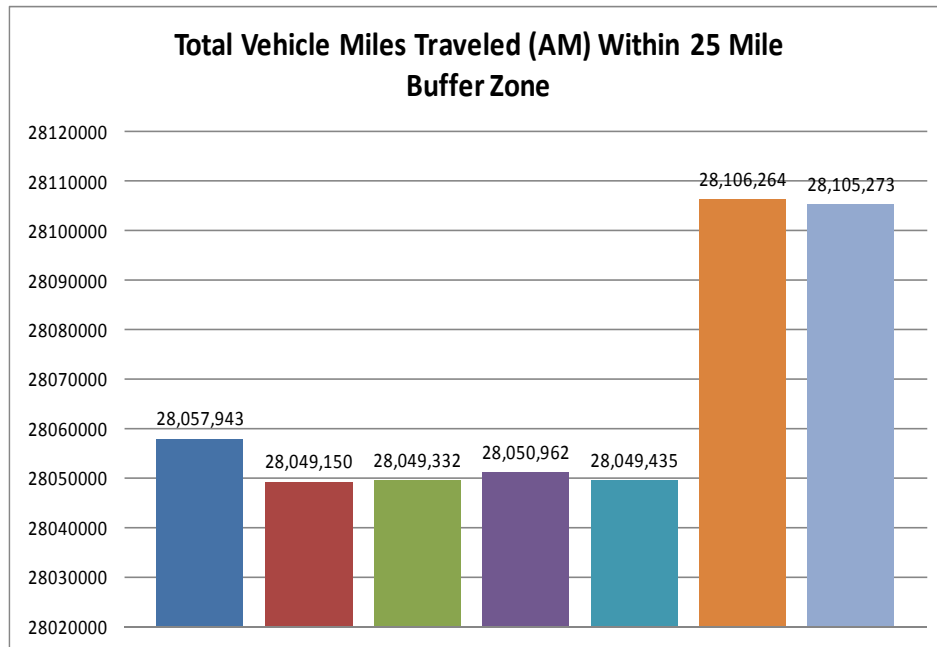


Figure 90: Total VMT in AM period (6AM-10AM) within 25 mile buffer zone

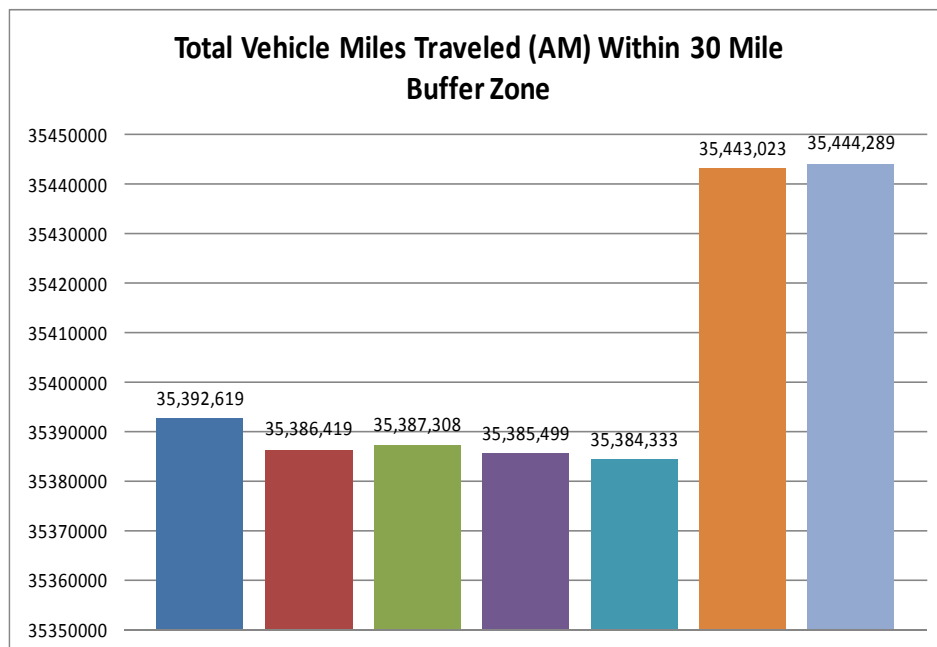


Figure 91: Total VMT in AM period (6AM-10AM) within 30 mile buffer zone

Table 22: Percent Change in VMT from BC (AM)

Distance	S1	S2	S3	S4	S5	S6
5	-1.76	-1.73	-0.37	-0.37	-8.45	-8.57
10	-0.54	-0.52	-0.10	-0.13	-2.36	-2.44
15	-0.15	-0.16	-0.10	-0.06	-0.44	-0.42
20	-0.07	-0.04	-0.04	-0.04	0.13	0.15
25	-0.03	-0.03	-0.02	-0.03	0.17	0.17
30	-0.02	-0.02	-0.02	-0.02	0.14	0.15

MD Period

During the midday period (10AM – 3PM) the total vehicle miles traveled are fairly constant for each scenario in both directions and Table 23 shows there are no major changes due to any of the capacity reducing scenarios. The total vehicle miles traveled are greater than in the AM peak period for all scenarios within every buffer zone, the midday period, however, is one hour longer than the AM peak period.

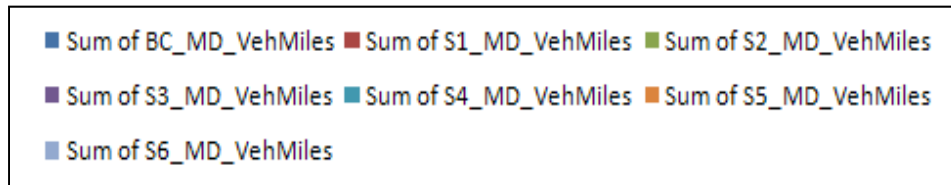


Figure 92: Legend for total VMT in MD period (10AM-3PM)

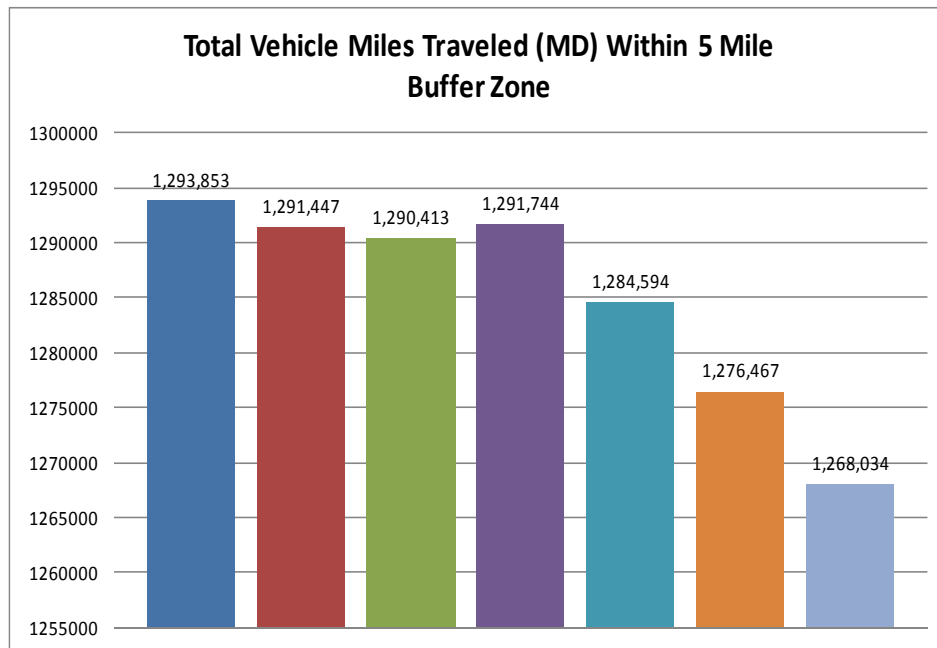


Figure 93: Total VMT in MD period (10AM-3PM) within 5 mile buffer zone

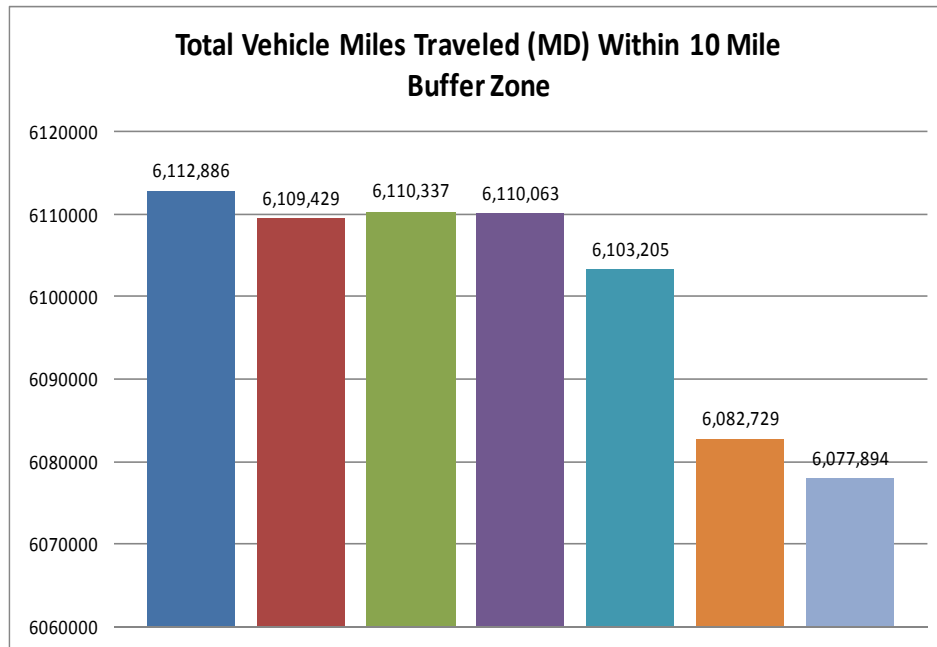


Figure 94: Total VMT in MD period (10AM-3PM) within 10 mile buffer zone

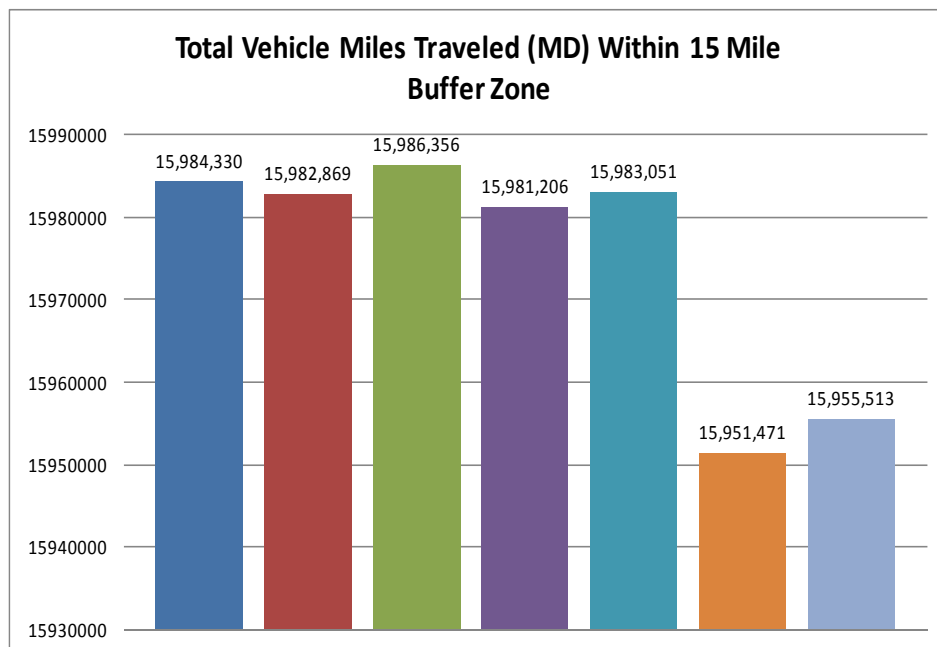


Figure 95: Total VMT in MD period (10AM-3PM) within 15 mile buffer zone

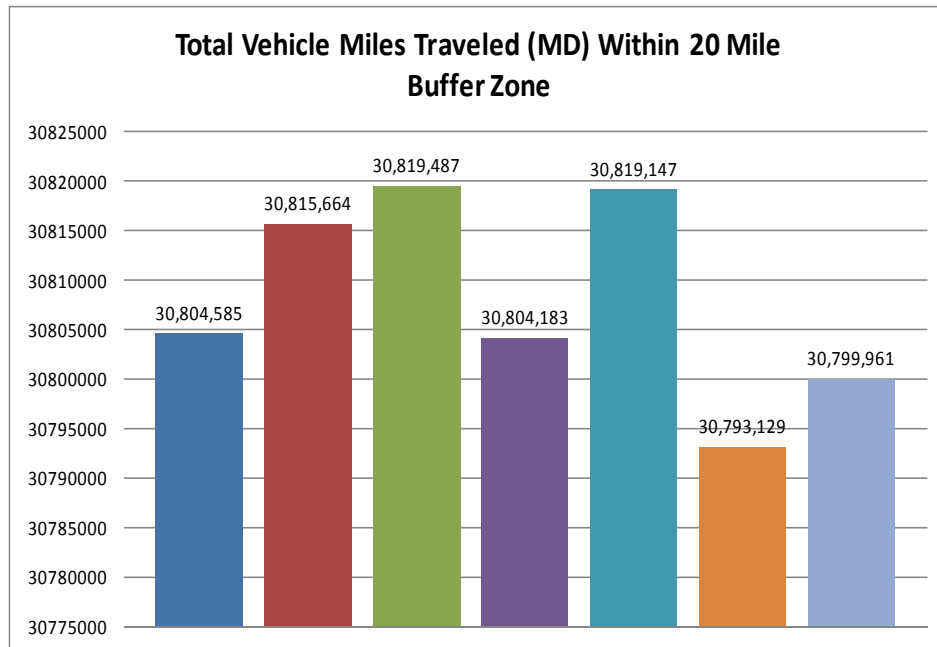


Figure 96: Total VMT in MD period (10AM-3PM) within 20 mile buffer zone

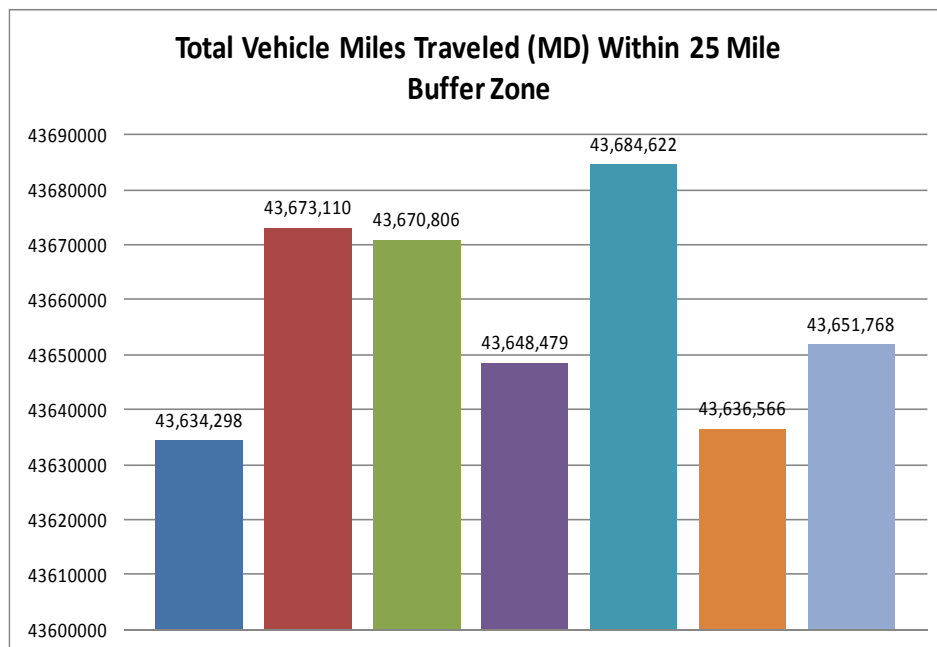


Figure 97: Total VMT in MD period (10AM-3PM) within 25 mile buffer zone

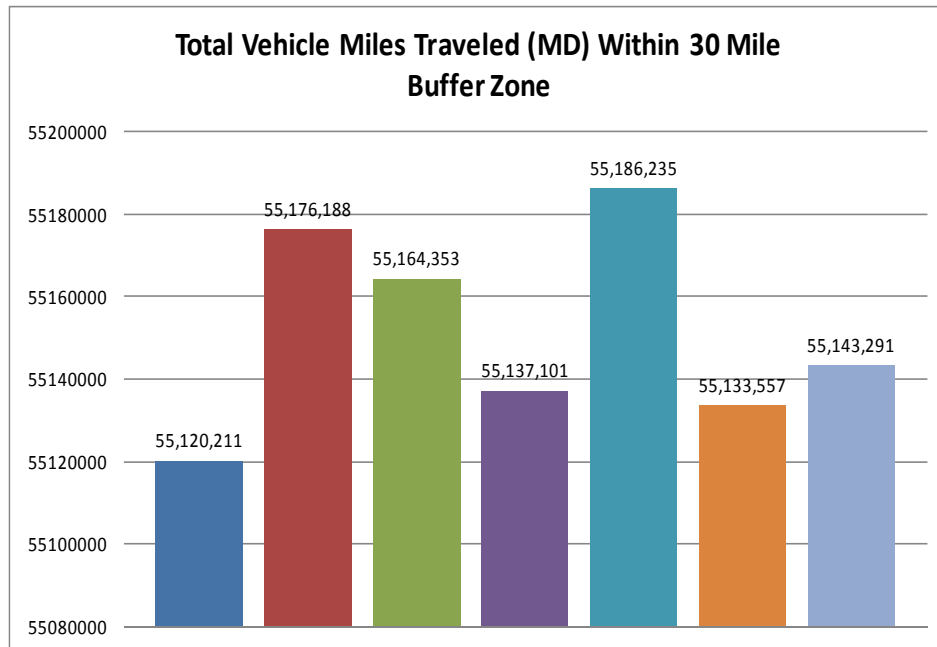


Figure 98: Total VMT in MD period (10AM-3PM) within 30 mile buffer zone

Table 23: Percent Change in VMT from BC (MD)

Distance	S1	S2	S3	S4	S5	S6
5	-0.19	-0.27	-0.16	-0.72	-1.34	-2.00
10	-0.06	-0.04	-0.05	-0.16	-0.49	-0.57
15	-0.01	0.01	-0.02	-0.01	-0.21	-0.18
20	0.04	0.05	0.00	0.05	-0.04	-0.02
25	0.09	0.08	0.03	0.12	0.01	0.04
30	0.10	0.08	0.03	0.12	0.02	0.04

PM Period

During the PM peak period (3PM – 7PM) the most significant changes are seen within the five mile radius as was the case during the AM travel period, except the changes are now seen in Scenario Four and Scenario Six. S4 is a three lane reduction in the westbound direction of the Verrazano Bridge and S6 is a three lane reduction in the eastbound and westbound direction of the bridge. The VMT dropped approximately 4.75 percent during S4 and 4.85 percent during S6 within the five mile radius around the bridge as shown by the highlighted cells in

Table 24. The westbound direction is the one mostly impacted during the PM period. When there is a large capacity reduction to the bridge in the peak travel direction, commuters alter their travel path.

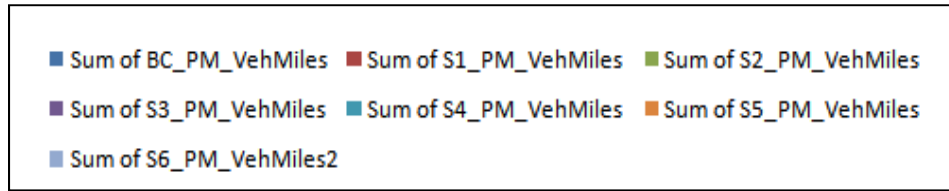


Figure 99: Legend for total VMT in AM period (6PM-10PM)

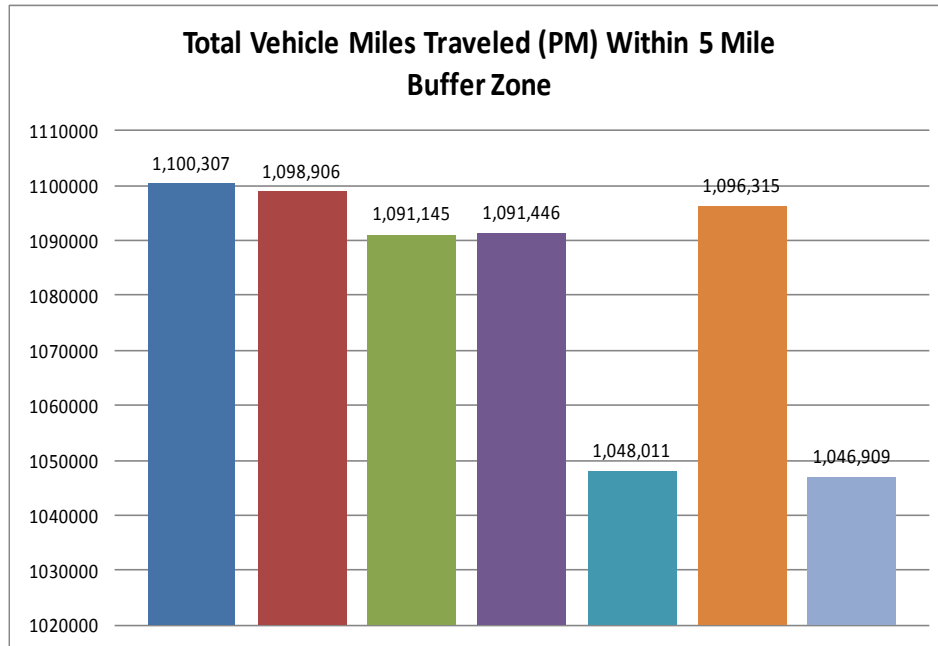


Figure 100: Total VMT in PM period (6PM-10PM) within 5 mile buffer zone

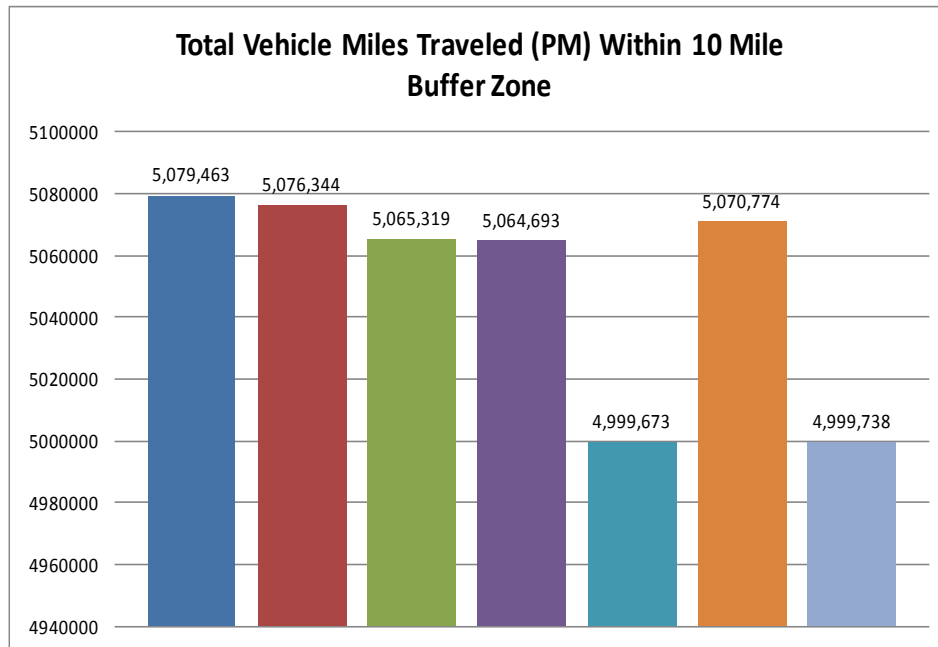


Figure 101: Total VMT in PM period (6PM-10PM) within 10 mile buffer zone

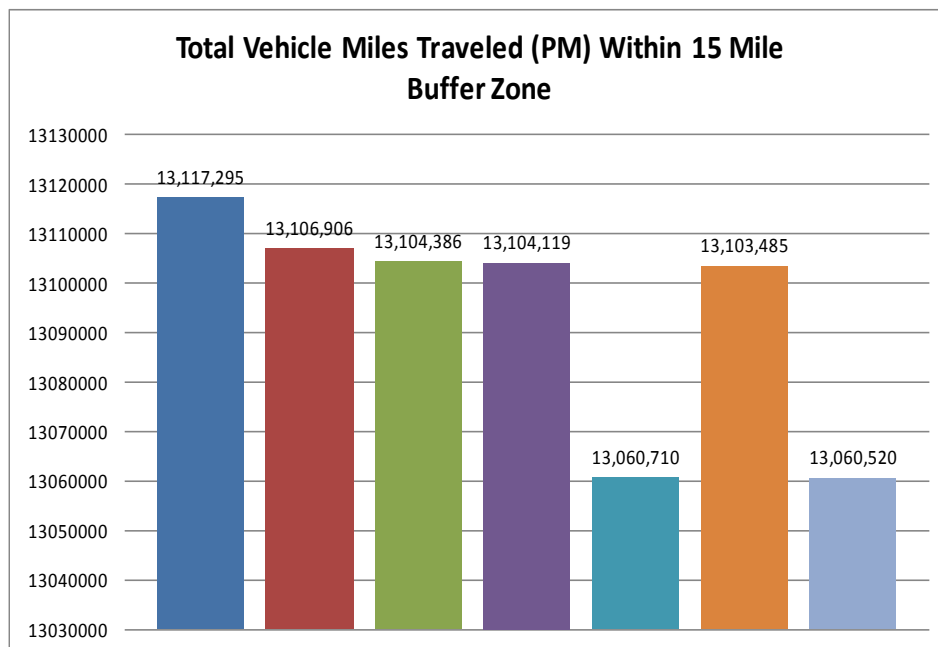


Figure 102: Total VMT in PM period (6PM-10PM) within 15 mile buffer zone

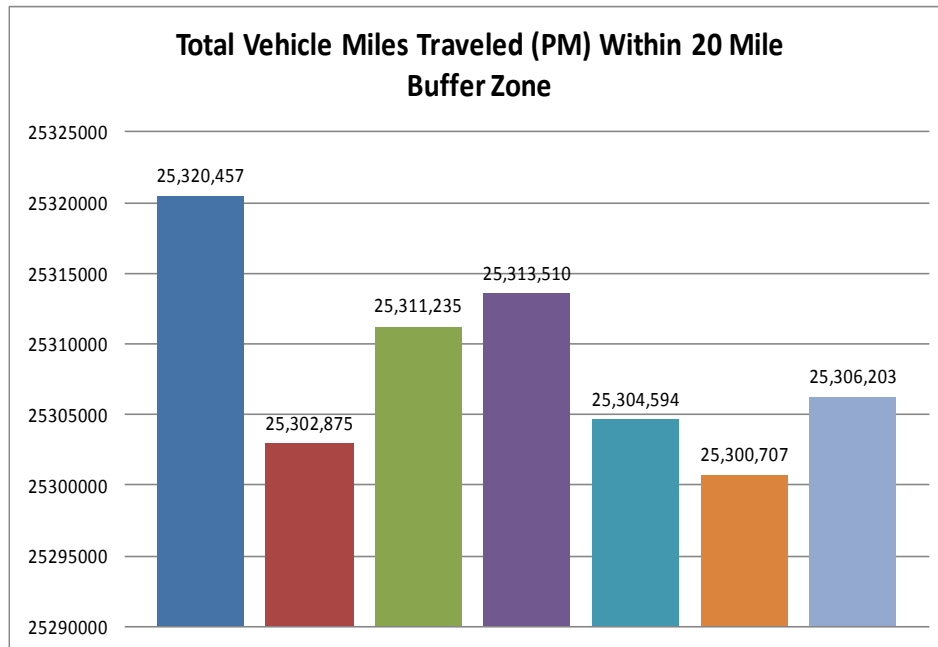


Figure 103: Total VMT in PM period (6PM-10PM) within 20 mile buffer zone

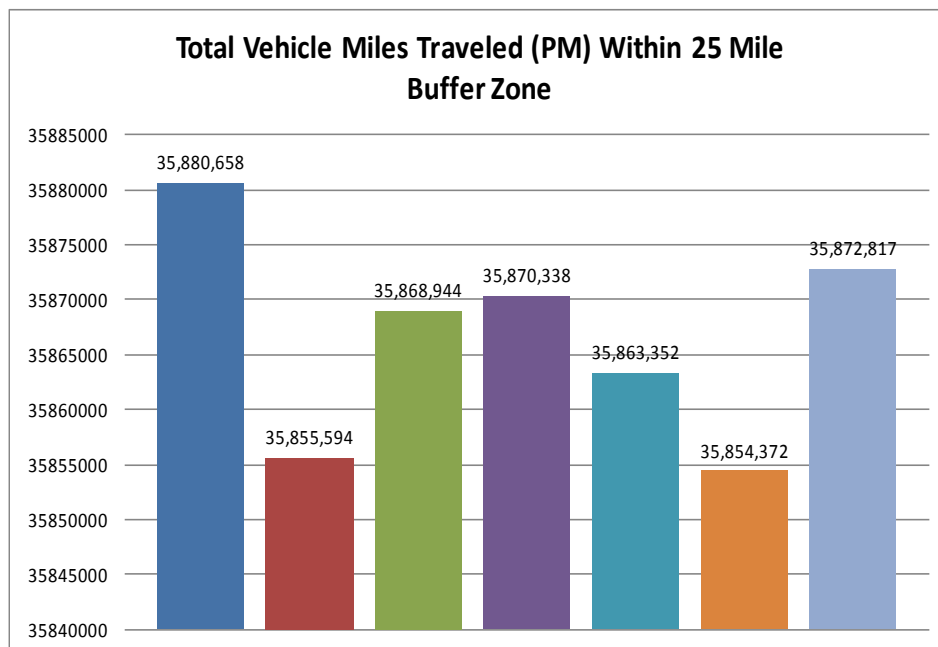


Figure 104: Total VMT in PM period (6PM-10PM) within 25 mile buffer zone

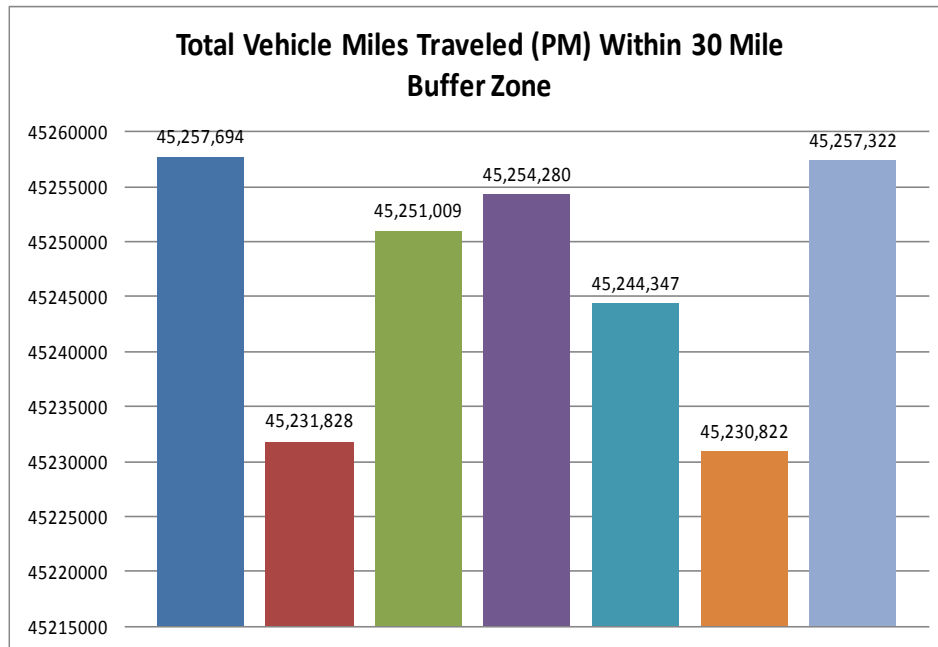


Figure 105: Total VMT in PM period (6PM-10PM) within 30 mile buffer zone

Table 24: Percent Change in VMT from BC (PM)

Distance	S1	S2	S3	S4	S5	S6
5	-0.13	-0.83	-0.81	-4.75	-0.36	-4.85
10	-0.06	-0.28	-0.29	-1.57	-0.17	-1.57
15	-0.08	-0.10	-0.10	-0.43	-0.11	-0.43
20	-0.07	-0.04	-0.03	-0.06	-0.08	-0.06
25	-0.07	-0.03	-0.03	-0.05	-0.07	-0.02
30	-0.06	-0.01	-0.01	-0.03	-0.06	0.00

NT Period

The night time (7PM – 6AM) results are very constant throughout all six scenarios and the base case. There is practically no change in VMT as shown in

Table 25.

It is difficult to distinguish a change in traffic patterns solely looking at total vehicle miles traveled in the area. There is a minimal amount of change in the total VMT for each of the six scenarios. The largest changes were seen during the two peak travel periods (AM and PM) and only within the five mile radius around the bridge. Outside of the five mile radius, the six Verrazano capacity reducing scenarios have little effect on the overall VMT.

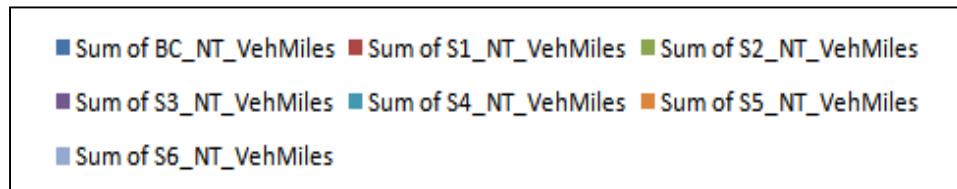


Figure 106: Legend for total VMT in NT period (10AM-3PM)

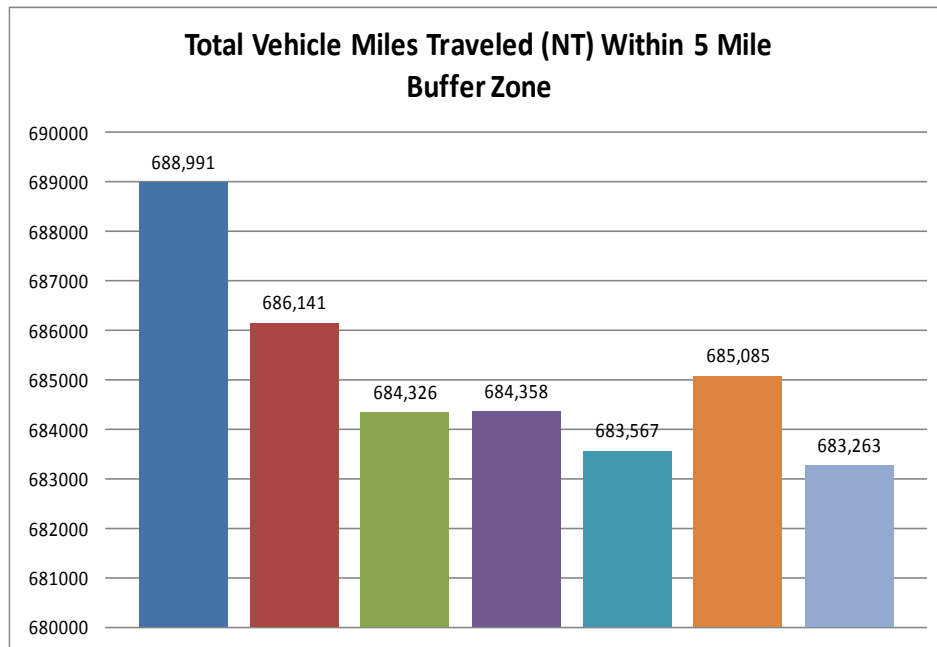


Figure 107: Total VMT in NT period (10AM-3PM) within 5 mile buffer zone

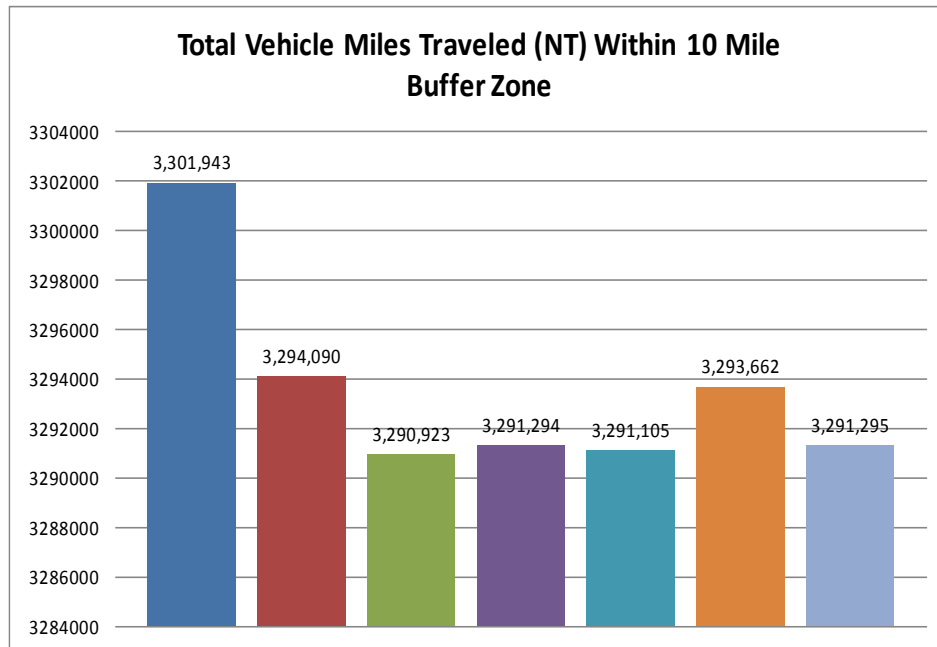


Figure 108: Total VMT in NT period (10AM-3PM) within 10 mile buffer zone

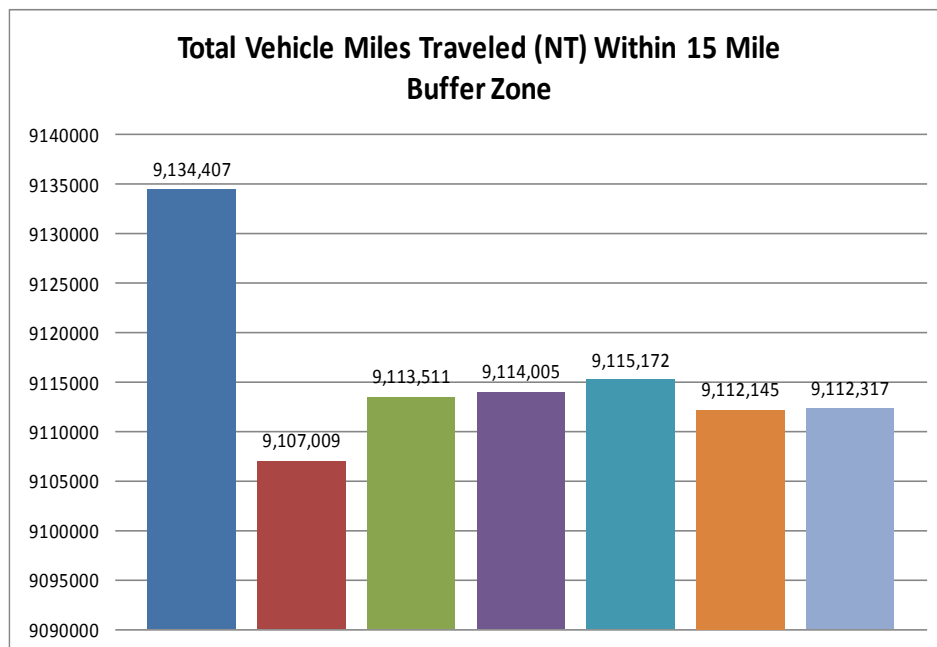


Figure 109: Total VMT in NT period (10AM-3PM) within 15 mile buffer zone

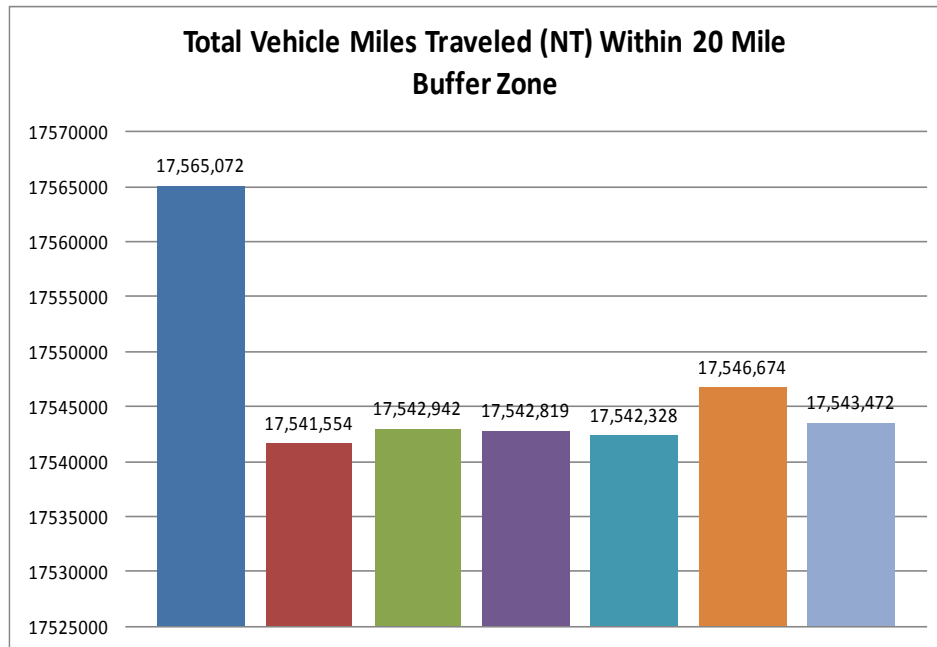


Figure 110: Total VMT in NT period (10AM-3PM) within 20 mile buffer zone

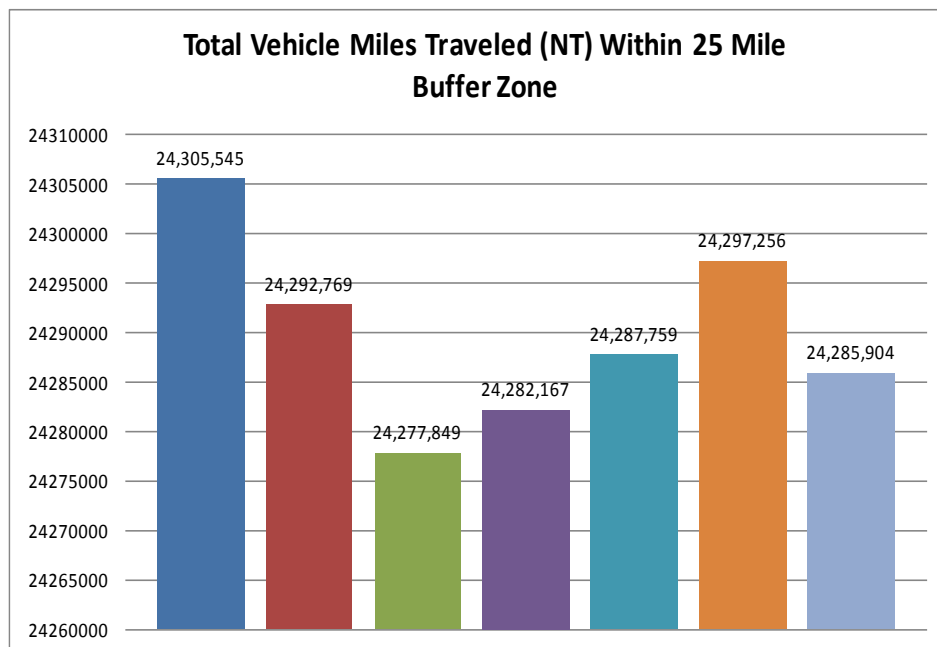


Figure 111: Total VMT in NT period (10AM-3PM) within 25 mile buffer zone

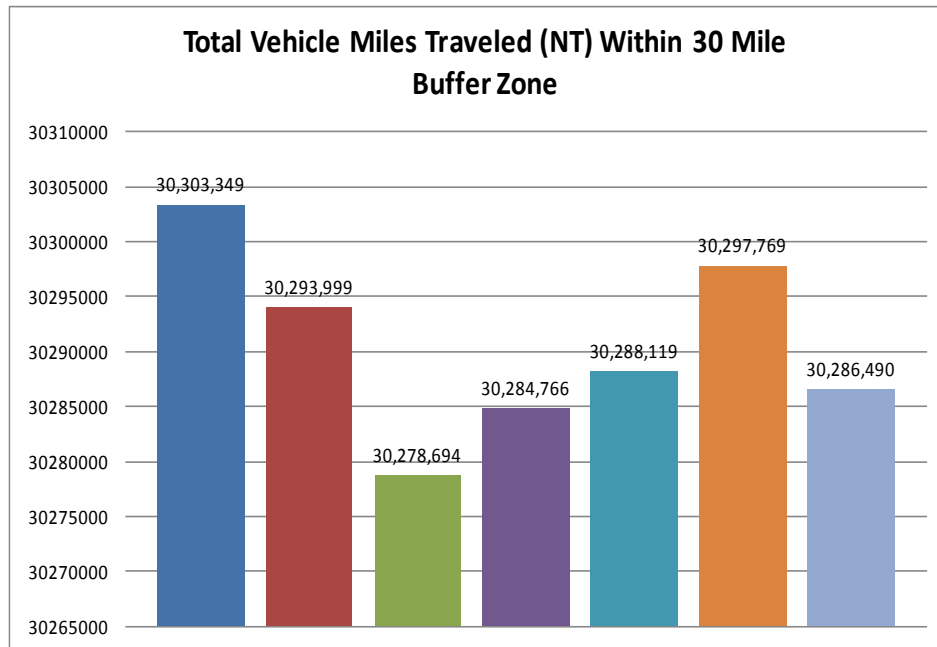


Figure 112: Total VMT in NT period (10AM-3PM) within 30 mile buffer zone

Table 25: Percent Change in VMT from BC (NT)

Distance	S1	S2	S3	S4	S5	S6
5	-0.41	-0.68	-0.67	-0.79	-0.57	-0.83
10	-0.24	-0.33	-0.32	-0.33	-0.25	-0.32
15	-0.30	-0.23	-0.22	-0.21	-0.24	-0.24
20	-0.13	-0.13	-0.13	-0.13	-0.10	-0.12
25	-0.05	-0.11	-0.10	-0.07	-0.03	-0.08
30	-0.03	-0.08	-0.06	-0.05	-0.02	-0.06

Total Vehicle Hours Traveled

This set of figures and tables shows the total vehicle hours traveled within each five mile buffer around the Verrazano-Narrows Bridge. The figures show the total VHT for each scenario and within each band, while the tables show the percent change from the base case scenario in each direction. The total vehicle hours show how each scenario impacts the total time travelers are on the road. The five mile bands will help show how far around the Verrazano the scenarios impacted total VHT.

AM Period

During the AM period a drastic increase in VHT occurs in Scenario 5 and Scenario 6 within the five mile radius. Scenario 5 was a three lane reduction in the eastbound direction and Scenario 6 was a three lane reduction in both the eastbound and westbound directions on the Verrazano-Narrows Bridge. As

Table 26 shows, within five miles of the bridge, the VHT increased 36.21 percent during S5 and 35.67 percent during S6. As the table shows S5 and S6 have a significant impact on VHT stretching out to the twenty mile radius around the Verrazano. At this distance the percent increase in VHT is 4.89 percent during S5 and 4.84 percent during S6. Capacity reduction increases the congestion levels on the bridge and its access network. Few vehicles re-route, as indicated from the VMT analysis. Nevertheless, the capacity reduction causes a bottleneck on the bridge which causes overall delays on the network.

Also, during Scenario 1 and Scenario 2 significant changes in VHT occur within the five mile buffer. Scenario 1 is a one lane reduction in the eastbound direction and increases VHT by 6.84 percent. Scenario 2 is a one lane reduction in both the eastbound and the westbound direction and increases VHT by 6.86.

Table 26 highlights all of the cells mentioned, showing the most significant changes in VHT during the AM peak period. The only scenarios that cause no significant impact on VHT are S3 and S4 which both do not include a reduction in the eastbound direction. A one lane reduction in the eastbound direction seems to impact the total VHT only within close proximity to the bridge while the three lane reduction impacts the change in VHT up to twenty miles around the bridge.

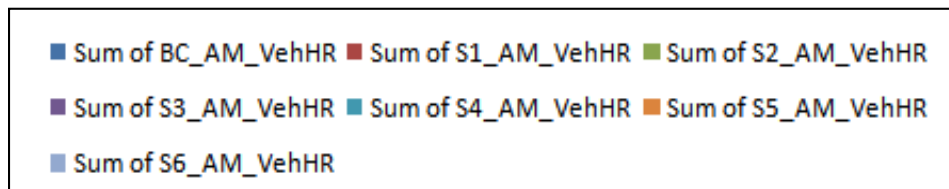


Figure 113: Legend for total VHT in AM period (6AM -10AM)

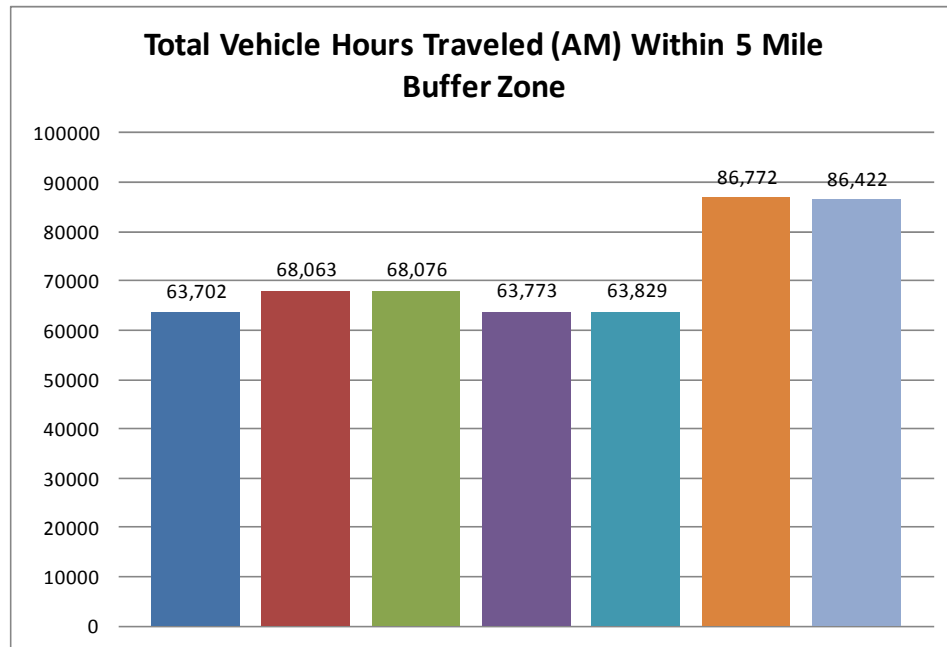


Figure 114: Total VHT in AM period (6AM -10AM) within 5 mile buffer zone

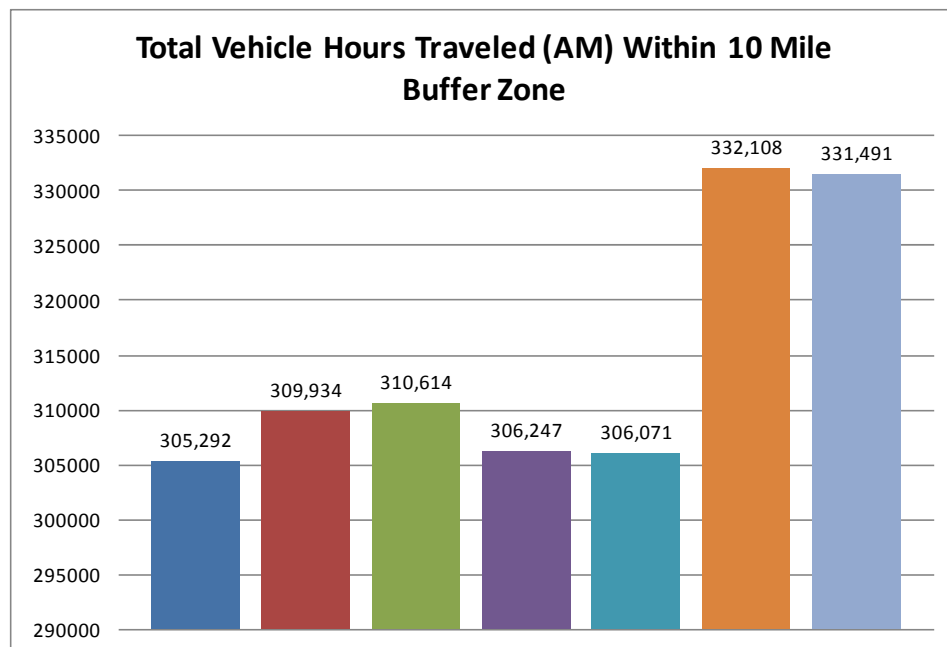


Figure 115: Total VHT in AM period (6AM -10AM) within 10 mile buffer zone

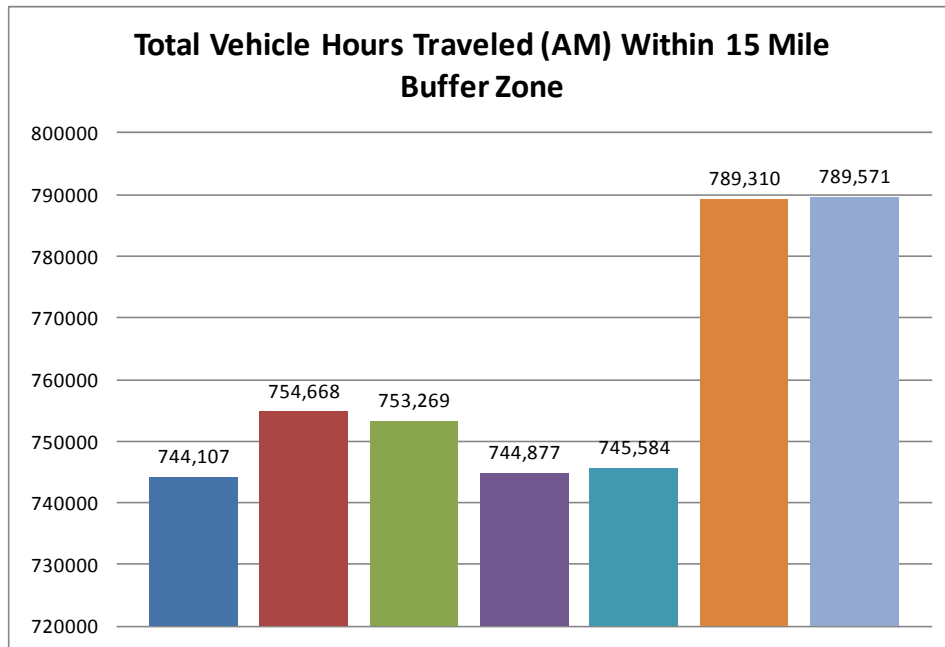


Figure 116: Total VHT in AM period (6AM -10AM) within 15 mile buffer zone

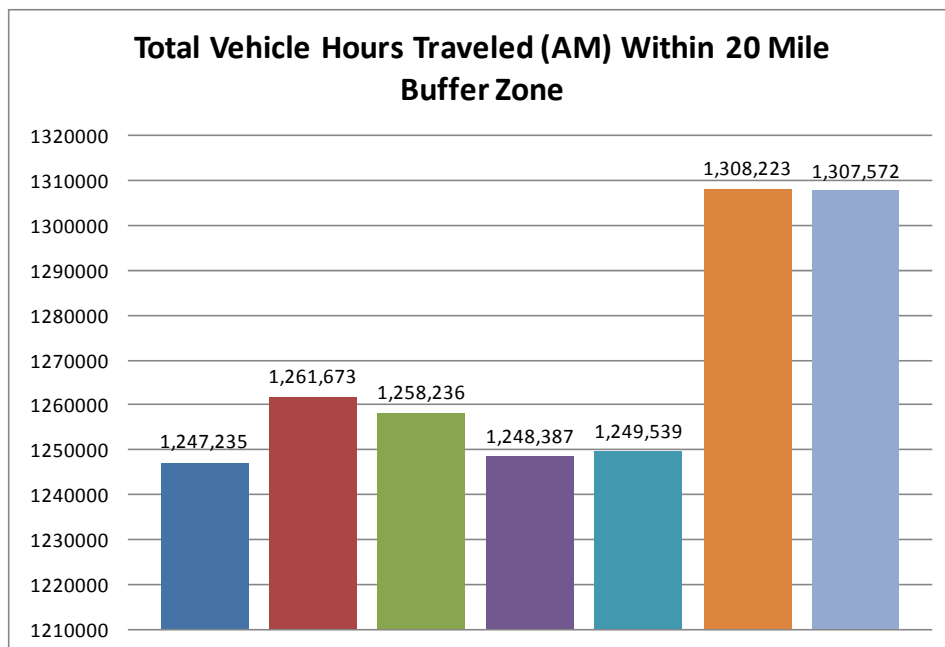


Figure 117: Total VHT in AM period (6AM -10AM) within 20 mile buffer zone

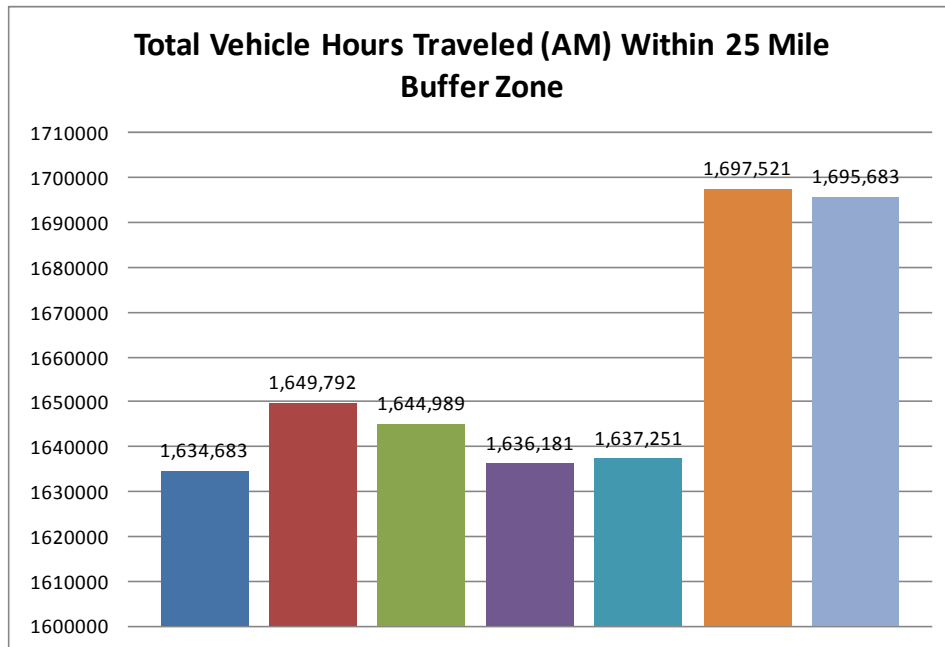


Figure 118: Total VHT in AM period (6AM -10AM) within 25 mile buffer zone

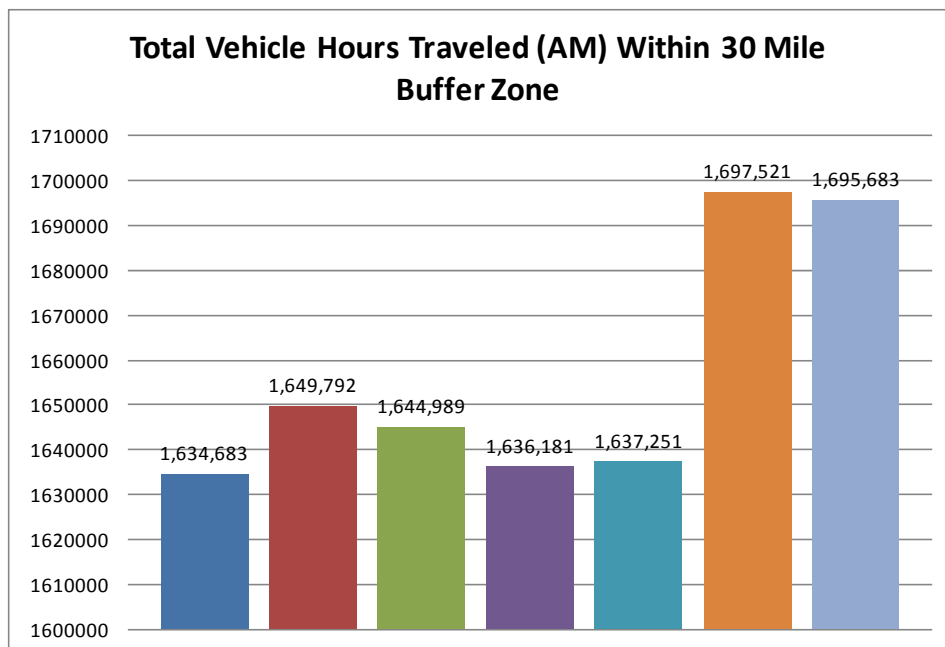


Figure 119: Total VHT in AM period (6AM -10AM) within 30 mile buffer zone

Table 26: Percent change in total VHT from BC (AM)

Distance	S1	S2	S3	S4	S5	S6
5	6.84	6.86	0.11	0.20	36.21	35.67
10	1.52	1.74	0.31	0.25	8.78	8.58
15	1.42	1.23	0.10	0.20	6.07	6.11
20	1.16	0.88	0.09	0.18	4.89	4.84
25	0.92	0.63	0.09	0.16	3.84	3.73
30	0.76	0.50	0.05	0.13	3.16	3.10

MD Period

During the midday period (10AM – 3PM) there is not a significant change in VHT for each scenario. The following figures show that the total hours traveled for each scenario are higher than any other travel period, however this is due to the fact that the midday period is one-hour longer than the AM peak period and the PM peak period.

Table 27 highlights the significant changes in VHT during the midday period. The only significant changes shown are within the five mile buffer during Scenario 5 and Scenario 6. Scenario 5, a three lane reduction in the eastbound direction has a 6.15 percent increase. Scenario 6, a three lane reduction in both the eastbound and the westbound direction has a 9.64 percent increase. Traffic during the midday period is not impacted as much as during other time periods in terms of VHT.

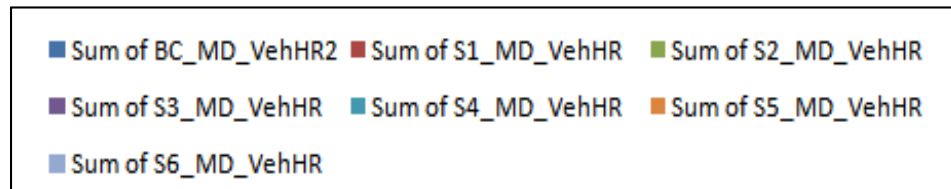


Figure 120: Legend for total VHT in MD period (10AM -3PM)

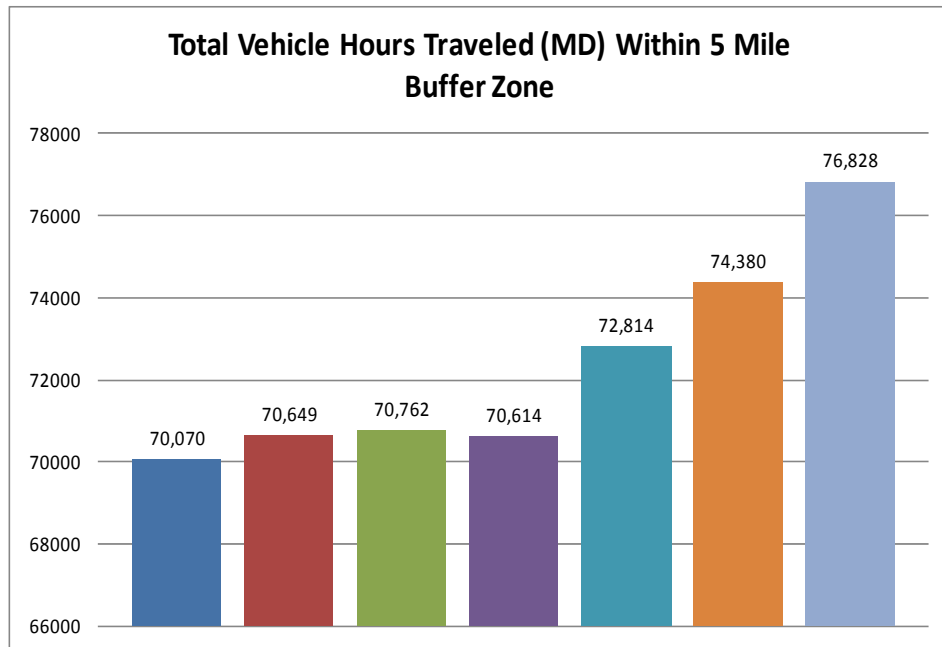


Figure 121: Total VHT in MD period (10AM -3PM) within 5 mile buffer zone

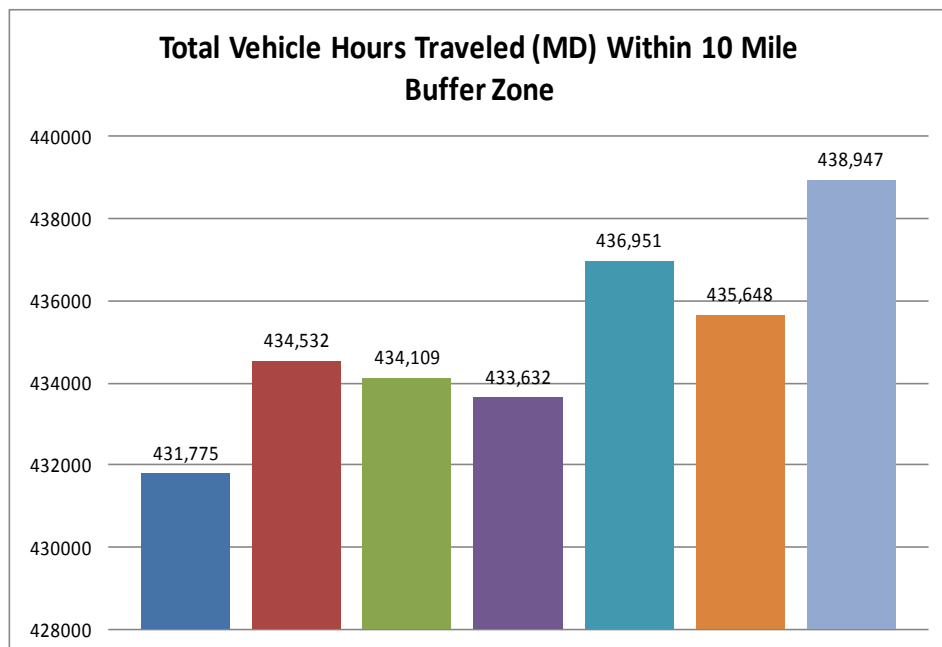


Figure 122: Total VHT in MD period (10AM -3PM) within 10 mile buffer zone

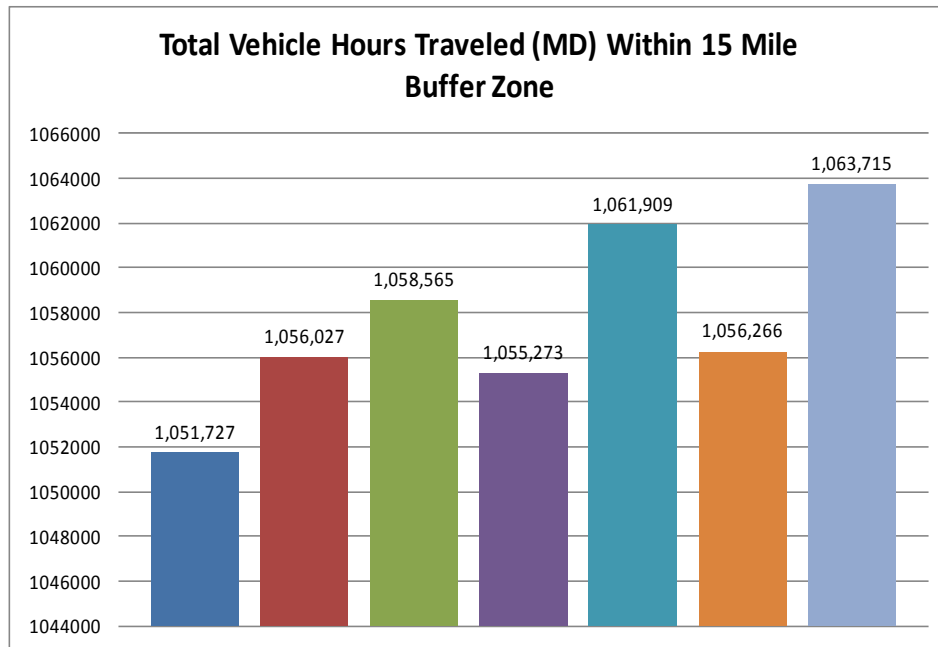


Figure 123: Total VHT in MD period (10AM -3PM) within 15 mile buffer zone

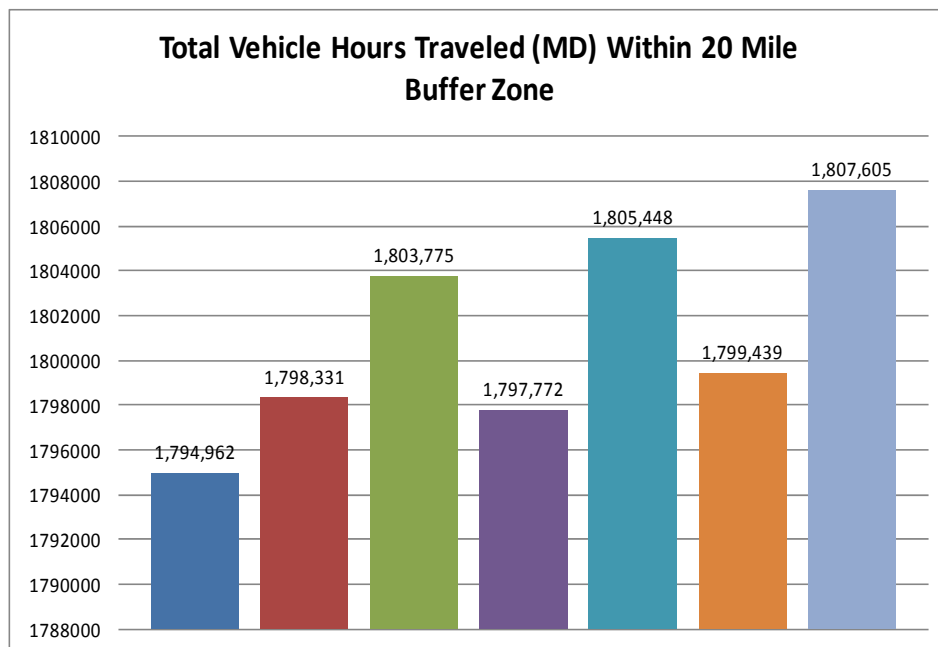


Figure 124: Total VHT in MD period (10AM -3PM) within 20 mile buffer zone

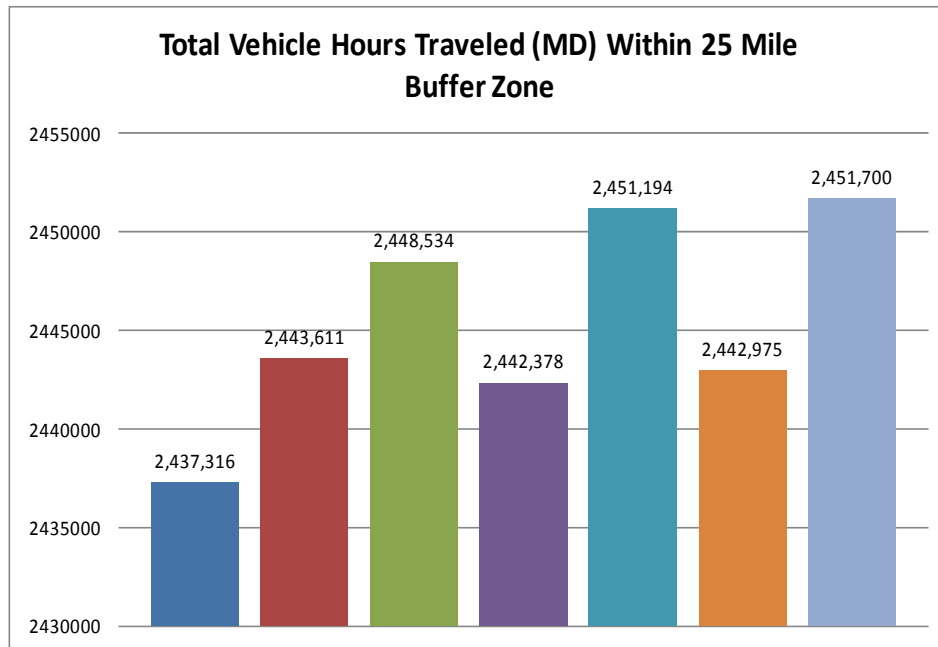


Figure 125: Total VHT in MD period (10AM -3PM) within 25 mile buffer zone

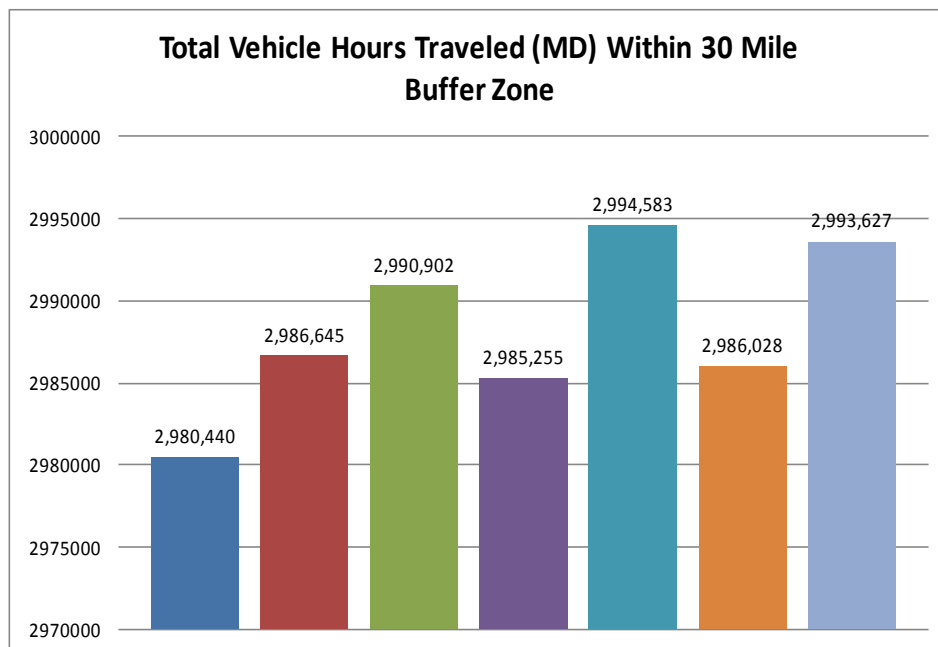


Figure 126: Total VHT in MD period (10AM -3PM) within 30 mile buffer zone

Table 27: Percent change in total VHT from BC (MD)

Distance	S1	S2	S3	S4	S5	S6
5	0.83	0.99	0.78	3.91	6.15	9.64
10	0.64	0.54	0.43	1.20	0.90	1.66
15	0.41	0.65	0.34	0.97	0.43	1.14
20	0.19	0.49	0.16	0.58	0.25	0.70
25	0.26	0.46	0.21	0.57	0.23	0.59
30	0.21	0.35	0.16	0.47	0.19	0.44

PM Period

During the PM peak period (3PM-7PM) the total hours traveled increased drastically during two of the scenarios, as shown in

Table 28. Scenario 4, a three lane westbound reduction on the bridge resulted in a 23.44 percent increase of VHT within a five mile radius of the bridge. Scenario 6, a three lane reduction in both the eastbound direction and the westbound direction caused similar increases in VHT. There is a 23.39 percent increase on links within five miles of the bridge.

Table 28 shows that the changes just discussed were the only significant increases in total vehicle hours traveled during the PM peak period. These changes all occurred on links within five miles of the bridge. The two scenarios both included a three lane reduction on the bridge in the westbound direction which is the peak travel direction over the Verrazano-Narrows Bridge during the PM period.

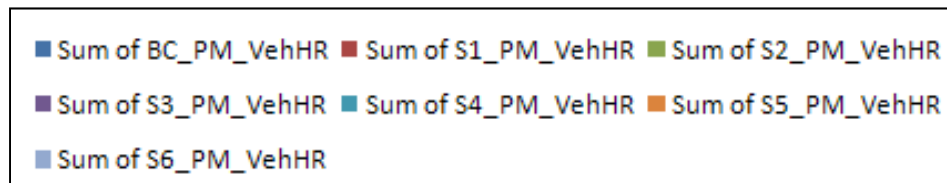


Figure 127: Legend for total VHT in PM period (3PM-7PM)

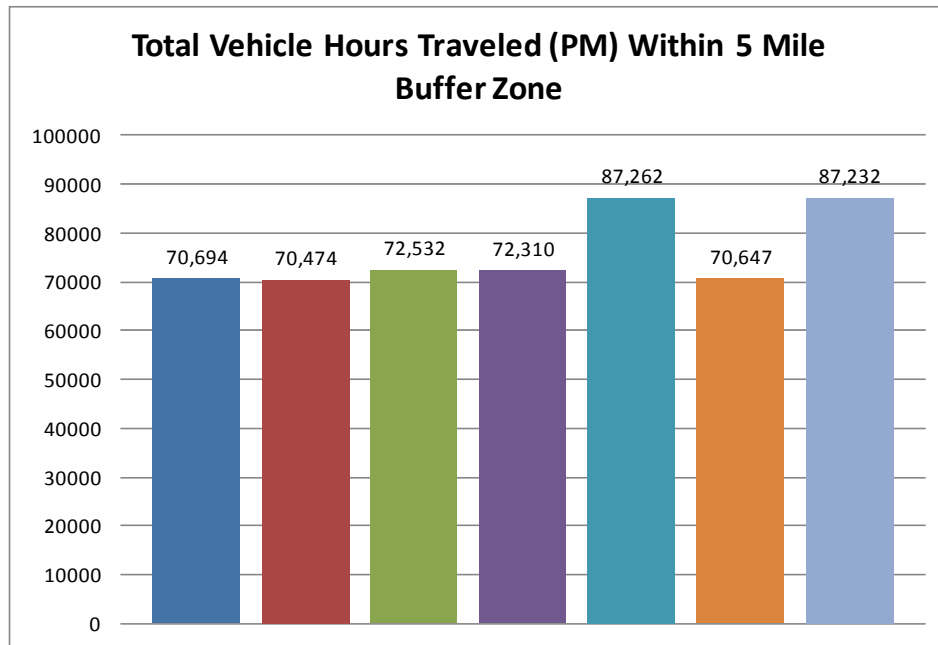


Figure 128: Total VHT in PM period (3PM-7PM) within 5 mile buffer zone

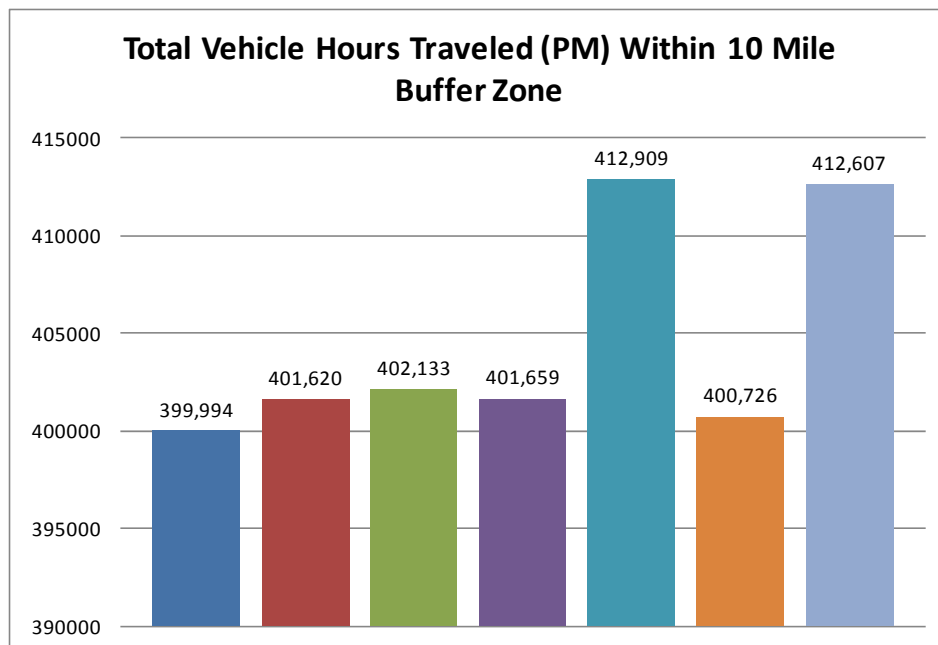


Figure 129: Total VHT in PM period (3PM-7PM) within 10 mile buffer zone

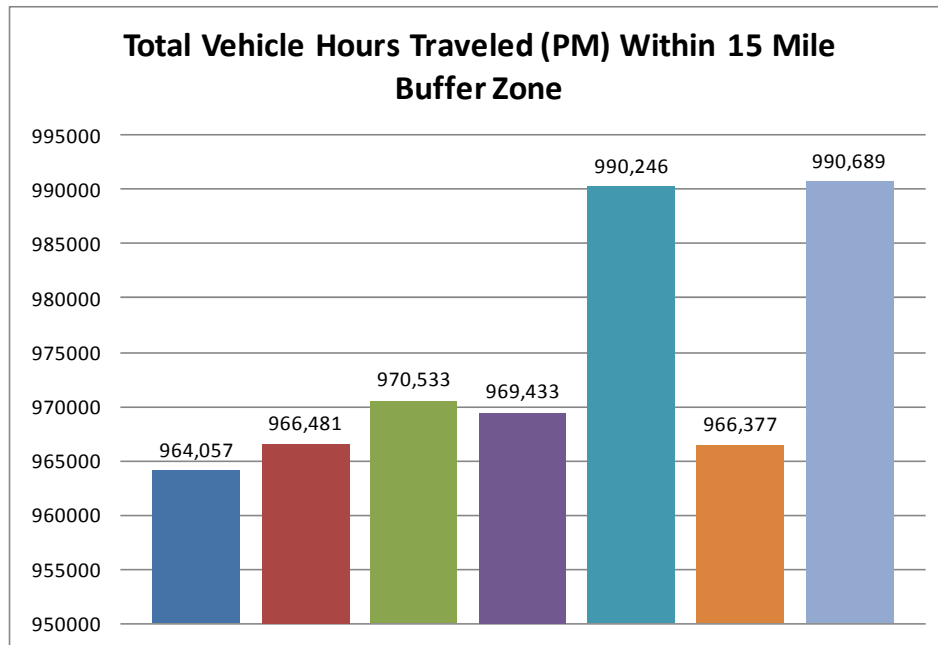


Figure 130: Total VHT in PM period (3PM-7PM) within 15 mile buffer zone

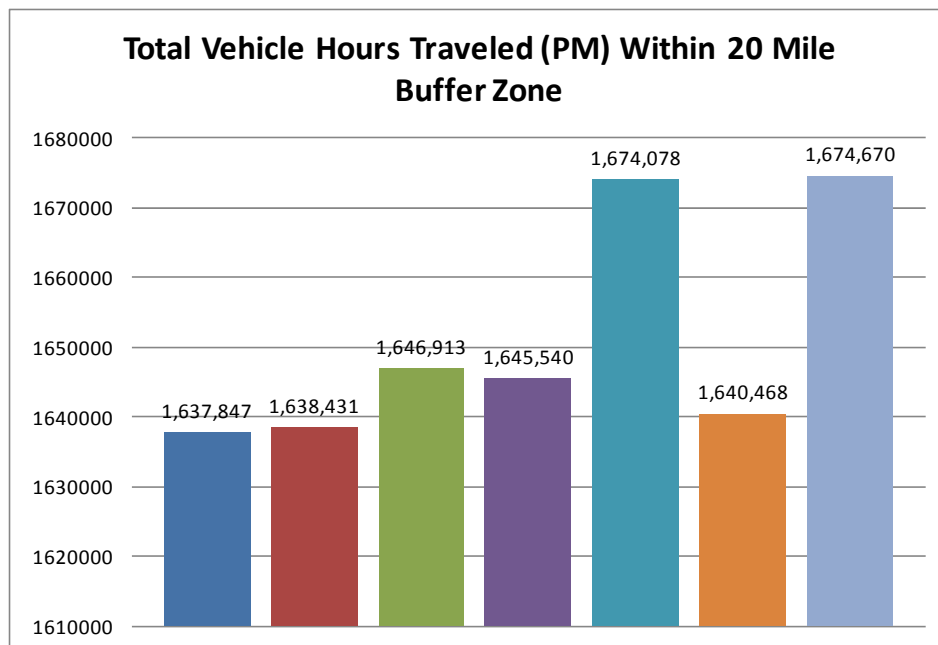


Figure 131: Total VHT in PM period (3PM-7PM) within 20 mile buffer zone

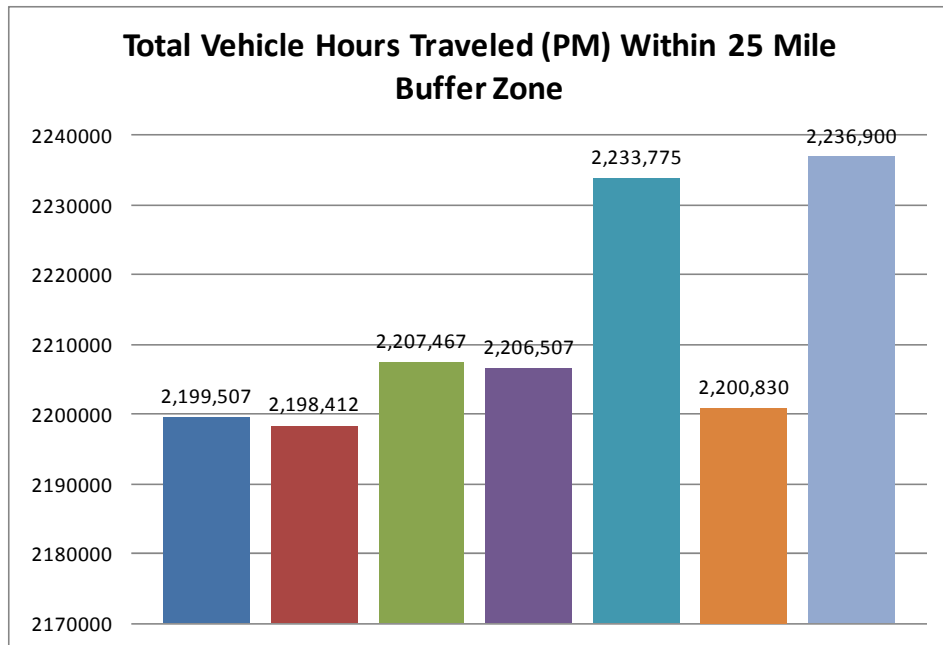


Figure 132: Total VHT in PM period (3PM-7PM) within 25 mile buffer zone

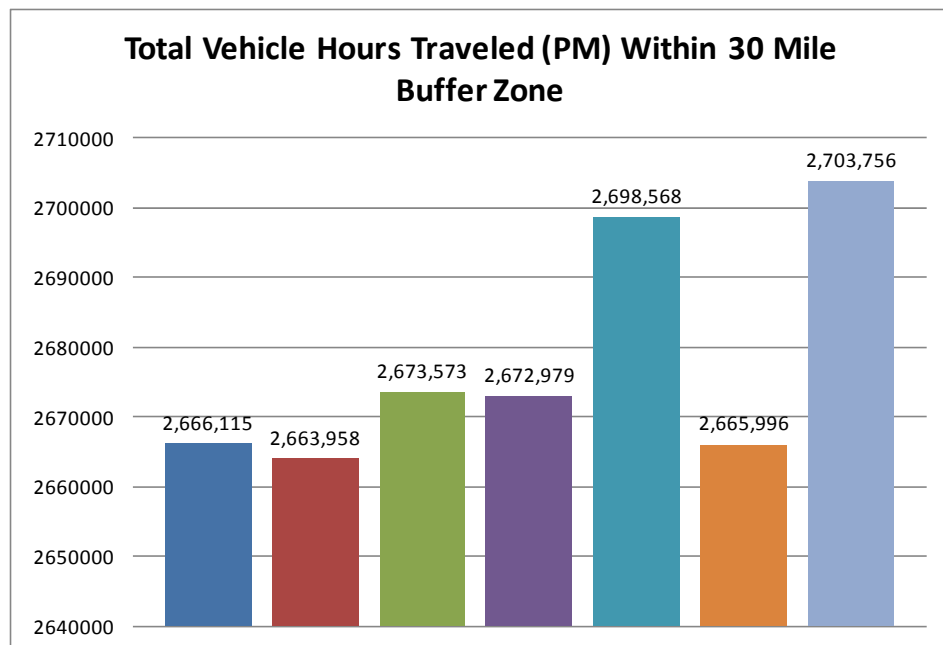


Figure 133: Total VHT in PM period (3PM-7PM) within 30 mile buffer zone

Table 28: Percent change in total VHT from BC (PM)

Distance	S1	S2	S3	S4	S5	S6
5	-0.31	2.60	2.29	23.44	-0.07	23.39
10	0.41	0.53	0.42	3.23	0.18	3.15
15	0.25	0.67	0.56	2.72	0.24	2.76
20	0.04	0.55	0.47	2.21	0.16	2.25
25	-0.05	0.36	0.32	1.56	0.06	1.70
30	-0.08	0.28	0.26	1.22	0.00	1.41

NT Period

There are no significant changes in vehicle hours traveled during this travel period. Table 29 shows that there are no highlighted cells that indicate a significant increase or decrease in VHT.

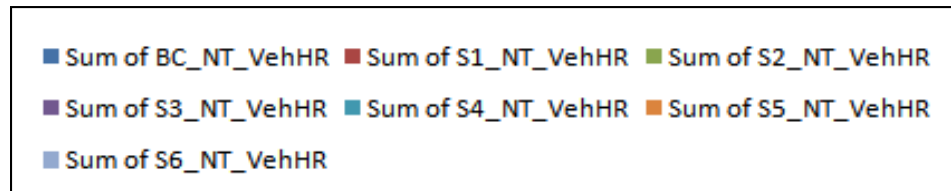


Figure 134: Legend for total VHT in NT period (7PM -6AM)

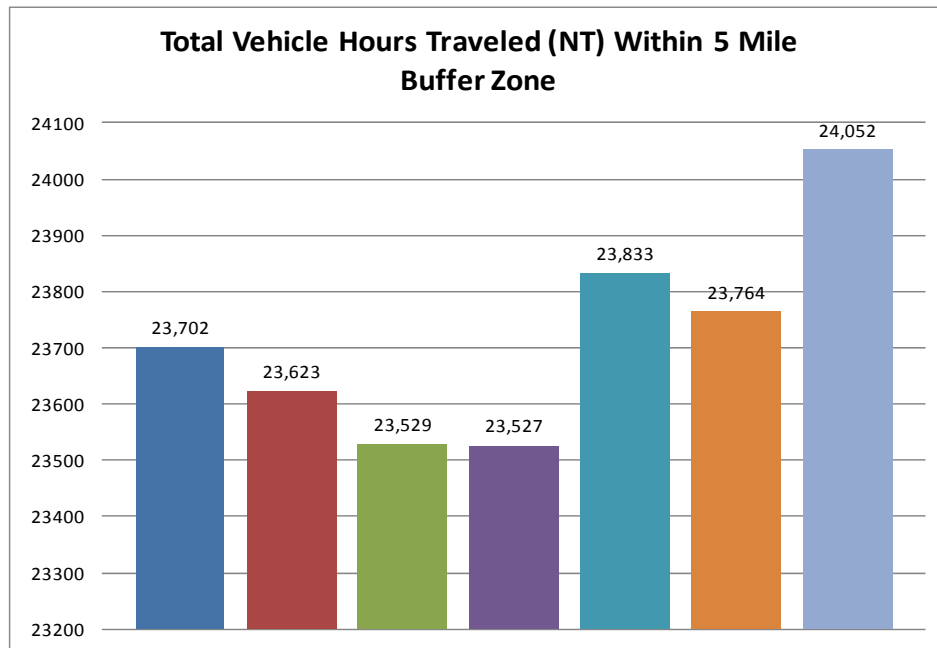


Figure 135: Total VHT in NT period (7PM -6AM) within 5 mile buffer zone

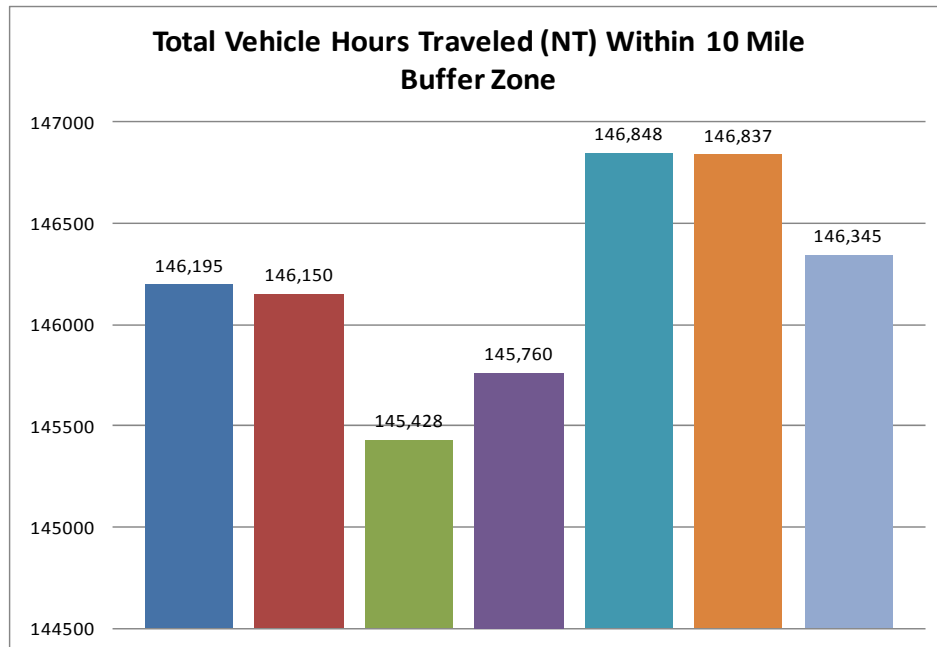


Figure 136: Total VHT in NT period (7PM -6AM) within 10 mile buffer zone

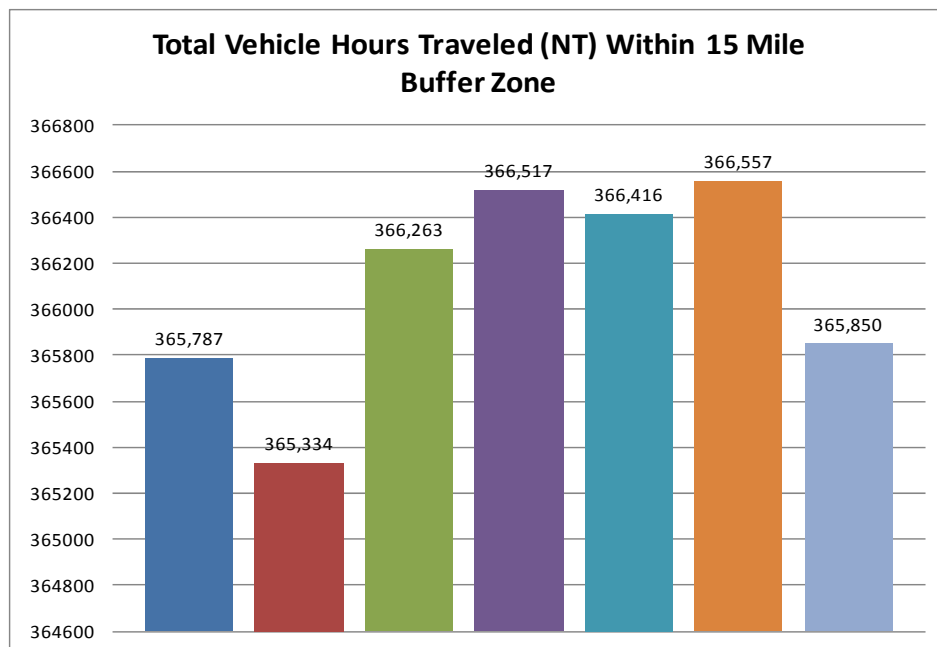


Figure 137: Total VHT in NT period (7PM -6AM) within 15 mile buffer zone

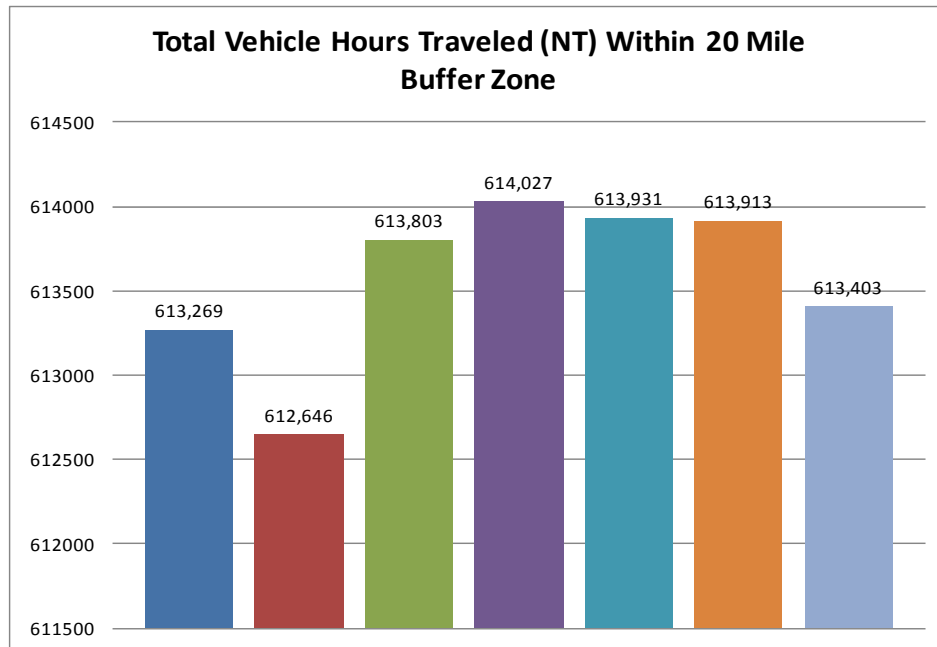


Figure 138: Total VHT in NT period (7PM -6AM) within 20 mile buffer zone

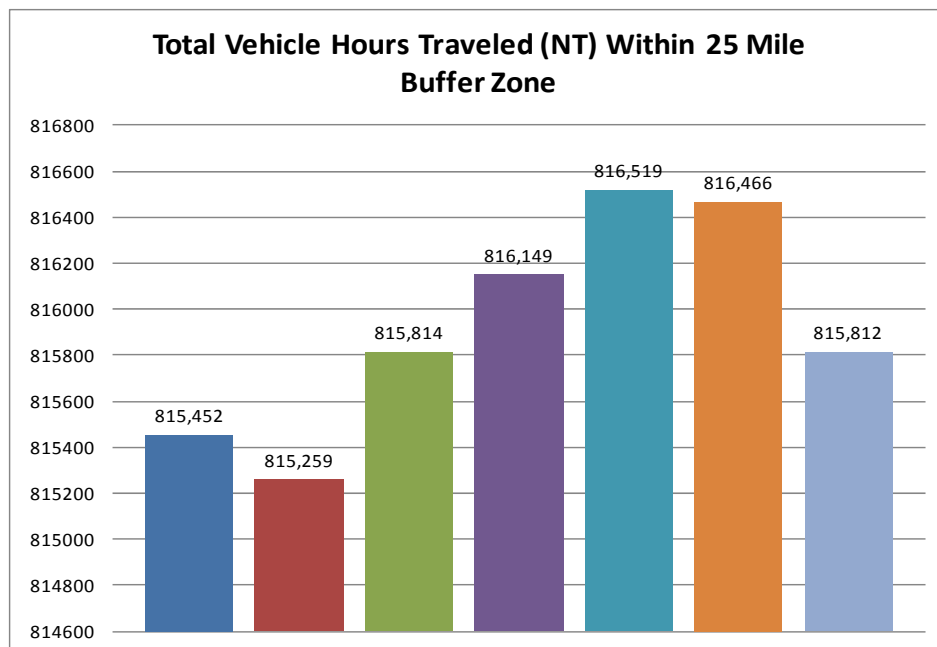


Figure 139: Total VHT in NT period (7PM -6AM) within 25 mile buffer zone

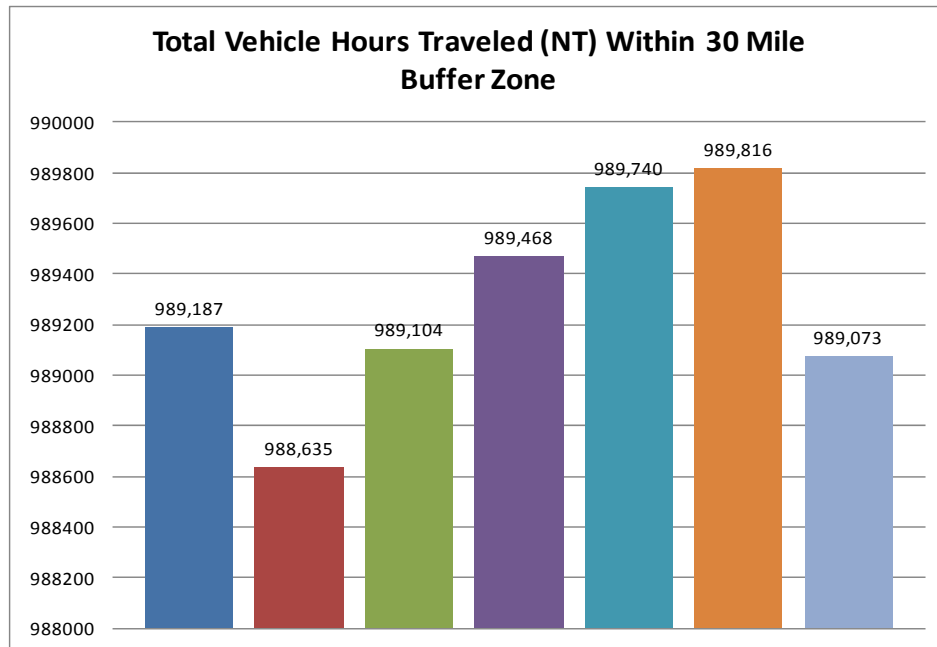


Figure 140: Total VHT in NT period (7PM -6AM) within 30 mile buffer zone

Table 29: Percent change in total VHT from BC (NT)

Distance	S1	S2	S3	S4	S5	S6
5	-0.33	-0.73	-0.74	0.55	0.26	1.48
10	-0.03	-0.52	-0.30	0.45	0.44	0.10
15	-0.12	0.13	0.20	0.17	0.21	0.02
20	-0.10	0.09	0.12	0.11	0.10	0.02
25	-0.02	0.04	0.09	0.13	0.12	0.04
30	-0.06	-0.01	0.03	0.06	0.06	-0.01

Total Delay per Band

Figure 141 through Figure 144 and

Table 30 through Table 33 show the total delay experienced within each five mile buffer around the Verrazano-Narrows Bridge. The delay represents a more direct impact faced by travelers from the capacity reductions on the Verrazano-Narrows Bridge. The figures

show the total delay in hours for each scenario and within each buffer zone around the bridge. The tables show the percent changes in delay from the base case scenario. The total delay was calculated by multiplying the average delay on each link by the total flow on that link.

AM Period

During the AM period (6AM-10AM) there are major increases in delay for a number of capacity reducing scenarios. Within the five mile radius S1, S2, S5 and S6 all have drastic and immediate impacts to travelers as shown in

Table 30. The total delay when there is a one lane reduction in the eastbound direction (S1) increases 12.81 percent. Similarly S2, a one lane reduction in both directions causes a 12.88 percent increase in total delay on links within five miles of the bridge. Increases in total delay are only noticeable within the five mile band during the AM period when there is a one lane reduction in the eastbound direction.

However, Scenario 5 and Scenario 6 have the most impact on the total delay and the impact of these scenarios can be felt within the thirty-mile radius. S5 is a three lane reduction in the eastbound direction and S6 is a three lane reduction in both the eastbound and the westbound directions. Immediately around the Verrazano-Narrows Bridge, major increases in delay are felt. In S5 there is a 67.35 percent increase in the delay and in S6 there is a 66.41 percent increase in the delay on the links closest to the bridge.

Table 30 shows each highlighted cell for these two scenarios. It can be concluded that a three lane reduction in the eastbound direction, which is the peak travel direction in the AM period, significantly increases the total delay on the network within the entire thirty-mile radius.

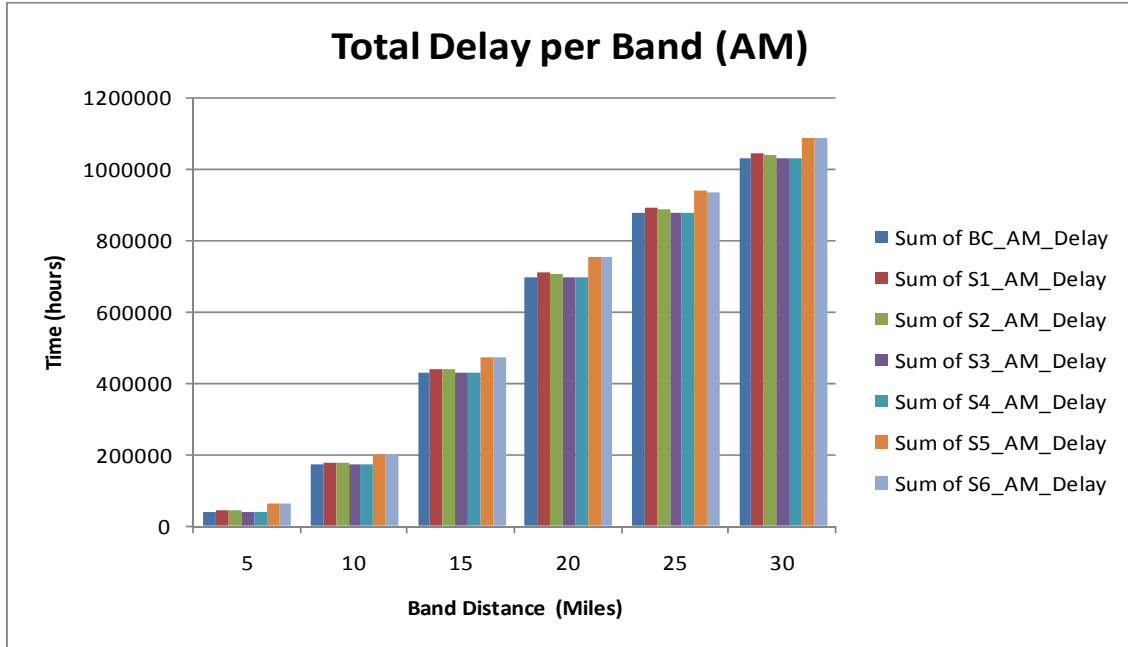


Figure 141: Total delay in AM period (6AM -10AM)

Table 30: Percent change in total delay from BC (AM)

Distance	S1	S2	S3	S4	S5	S6
5	12.81	12.88	0.50	0.59	67.35	66.41
10	3.04	3.44	0.57	0.48	17.24	16.92
15	2.56	2.21	0.18	0.34	10.78	10.82
20	2.13	1.59	0.16	0.33	8.62	8.50
25	1.76	1.17	0.16	0.29	6.98	6.76
30	1.49	0.95	0.08	0.24	5.88	5.76

MD Period

The impact on delay is not as significant during the midday period (10AM-3PM). As with the total VMT and the total VHT, the total midday delay is higher than the AM peak period and the PM peak period however as stated before this is due to the fact that the duration of the MD period is one hour longer.

Table 31 shows that the increases in delay are mainly limited to within the five mile radius around the bridge when there is a three lane reduction in either direction. Significant changes result from S4, S5, and S6 which all include a three lane reduction. S4 is a three lane reduction in the westbound direction, causing a 10.08 percent increase in total delay. S5 is a three lane reduction in the eastbound direction, causing a 16.38 percent increase in total delay and S6 is a three lane reduction in both directions causing a 25.28 percent increase in total delay. An increase in delay is not present during the midday period when only one lane is shut down in either direction.

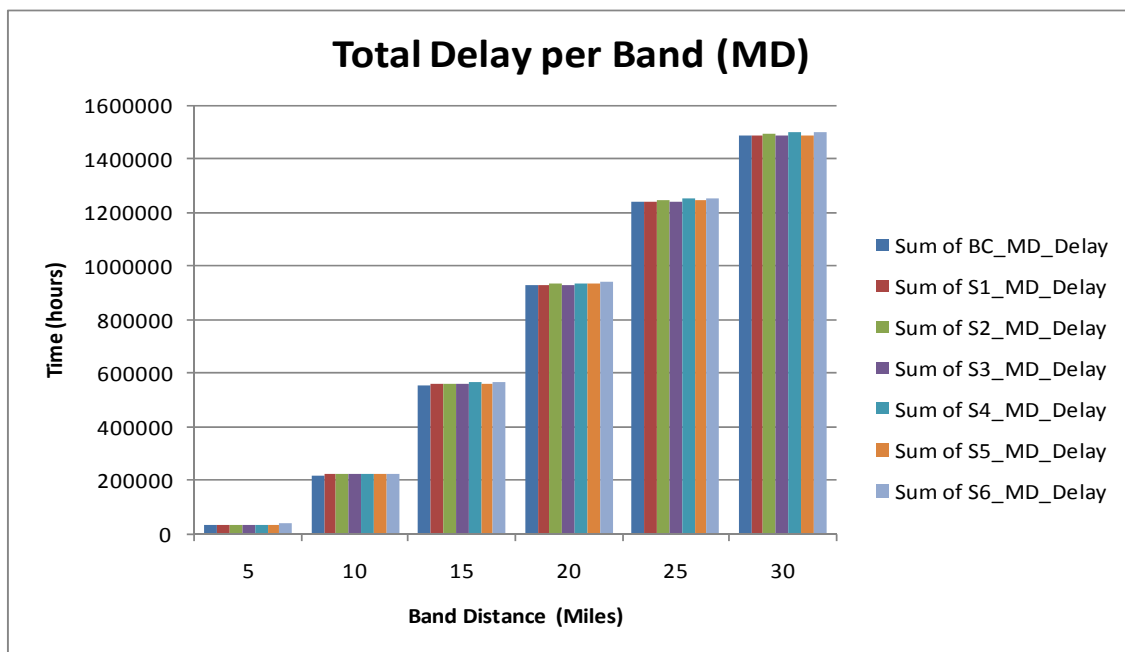


Figure 142: Total delay in MD period (10AM -3PM)

Table 31: Percent change in total delay from BC (MD)

Distance	S1	S2	S3	S4	S5	S6
5	2.30	2.66	2.03	10.08	16.38	25.28
10	1.24	0.98	0.82	2.38	2.08	3.62
15	0.68	1.13	0.58	1.75	0.88	2.19
20	0.26	0.83	0.24	1.00	0.44	1.28
25	0.37	0.77	0.33	0.95	0.39	1.05
30	0.29	0.59	0.26	0.79	0.30	0.79

PM Period

During the PM peak period (3PM-7PM) major impacts on delay are now seen in Scenario 4 and Scenario 6. Scenario 4 is a three lane reduction on the bridge in the westbound direction and Scenario 6 is a three lane reduction on the bridge in both the eastbound direction and the westbound direction. The peak travel direction on the bridge during the PM period is westbound. Within the five mile radius S2, S3, S4 and S6 all have drastic and immediate impacts to travelers as shown in

Table 32. The total delay when there is a one lane reduction in the westbound direction (S2) increases 5.70 percent. Similarly S2, a one lane reduction in both directions causes a 5.04 percent increase in total delay on links within five miles of the bridge. Increases in total delay are only noticeable within the five mile band during the PM period when there is a one lane reduction in the westbound direction.

However, Scenario 4 and Scenario 6 have the most impact on the total delay and the impact of these scenarios can be felt within the fifteen-mile radius. S4 is a three lane reduction in the westbound direction and S6 is a three lane reduction in both the eastbound and the westbound directions. Immediately around the Verrazano-Narrows Bridge, major increases in delay are felt. In S4 and S6 there is a 50.02 percent increase in total delay on the links closest to the bridge. It can be concluded that a three lane reduction in the westbound direction, which is the peak travel direction in the PM period, significantly increases the total delay on the network within a fifteen-mile radius.

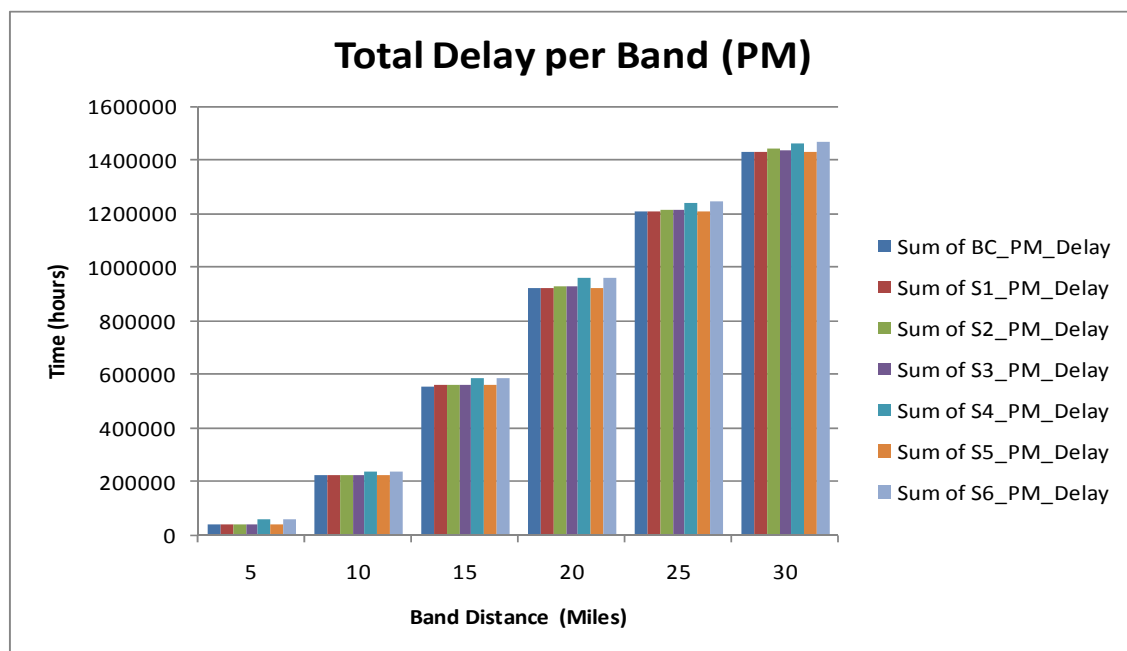


Figure 143: Total delay in PM period (3PM -7PM)

Table 32: Percent change in total delay from BC (PM)

Distance	S1	S2	S3	S4	S5	S6
5	-0.58	5.70	5.04	50.02	0.08	50.02
10	0.69	1.06	0.85	6.85	0.38	6.71
15	0.45	1.19	0.99	4.97	0.46	5.06
20	0.07	0.98	0.82	3.94	0.31	4.02
25	-0.09	0.65	0.57	2.83	0.13	3.09
30	-0.15	0.49	0.45	2.24	0.00	2.61

NT Period

As with VMT and VHT, the total delay was least affected during the night time travel period (7P – 6A). Some small changes in delay are seen in Scenario 4 and Scenario 6. The highlighted cells in Table 33 represent these percent changes in delay.

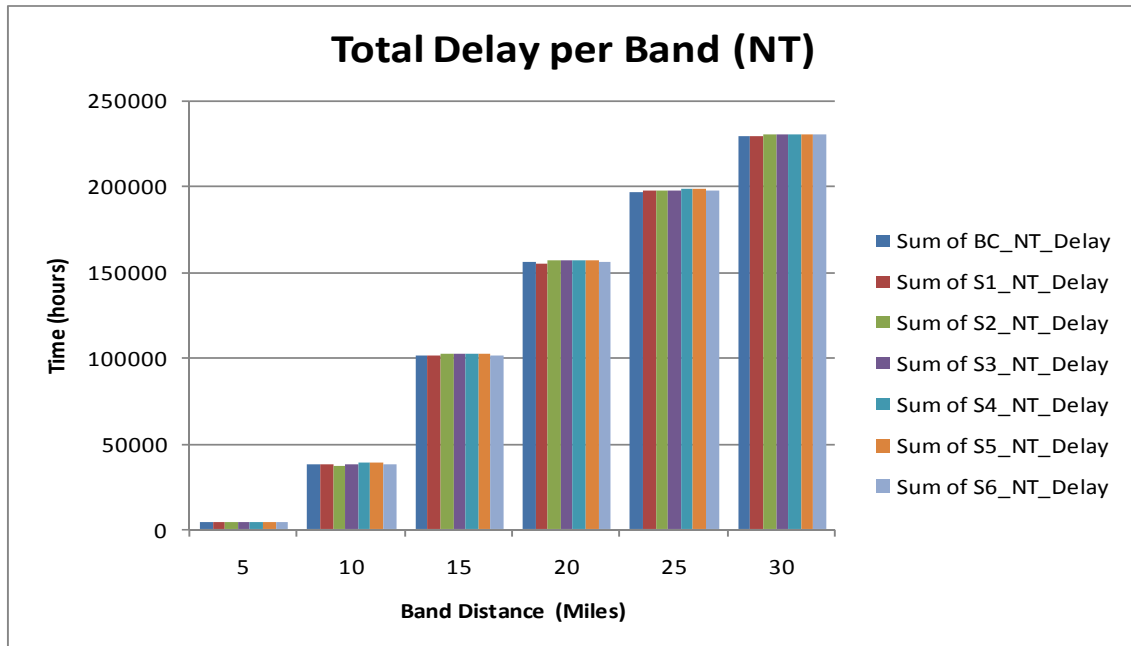


Figure 144: Total delay in NT period (7PM -6AM)

Table 33: Percent change in total delay from BC (NT)

Distance	S1	S2	S3	S4	S5	S6
5	-0.38	-2.45	-2.47	5.56	3.73	11.24
10	0.10	-1.82	-0.95	2.17	2.06	0.63
15	0.03	0.84	1.08	0.95	1.17	0.45
20	-0.14	0.57	0.71	0.69	0.66	0.32
25	0.03	0.38	0.51	0.67	0.67	0.33
30	-0.14	0.10	0.22	0.35	0.40	0.07

3.3.2 Link-Level Analysis

This section of the report gives an analysis of the results produced by the Best Practices Model on a link level. Rather than looking at the effects each scenario has on the network within a thirty-mile radius around the Verrazano-Narrows Bridge as in the previous section, this section of the report will focus on the major impacts each scenario has on specific links due to delays and alternate paths chosen by travelers. This section first looks at changes on the bridge itself. The impacts each scenario has on flows and travel times on the bridge are shown in the following graphs and tables presented in this section. This section also provides an analysis on the delay each scenario causes on links throughout the network. Color-themed maps of the network are summarized to show how each different scenario each affect vital links in the region.

Flow on Verrazano-Narrows Bridge

This set of figures and tables shows the change in flow on the Verrazano-Narrows Bridge in both directions (eastbound and westbound) for the base case and the six scenarios (S1 – S6). The figures show the total flow per period for each scenario while the corresponding tables show the percent changes from the base case scenario for each capacity reducing scenario. Scenarios that have a noticeable impact on the flow over the Verrazano-Narrows Bridge are highlighted in the tables shown at the end of this section.

AM Period

During the AM peak period the flow on the Verrazano-Narrows Bridge was impacted the most by Scenario Five and Scenario Six. S5 was a three lane reduction in the eastbound direction and S6 was a three lane reduction in both the eastbound and westbound directions. Figure 145 shows that the total flow in the eastbound direction during the base case is approximately 40,000 vehicles throughout the AM period and the flow drops to nearly 30,000 vehicles (approximately -24 percent) when the capacity is reduced by three lanes in the eastbound direction. Table 34 shows that Scenario One and Scenario Two show only small changes in flow compared to the base case (approximately -4.3 percent). These two scenarios have a one lane reduction in the eastbound direction. Figure 145 and Table 34 show that there are no major changes in flow in the westbound direction on the bridge. The total flow during the base case in the westbound direction is approximately 12,000 vehicles throughout the period. S5 and S6 have a slight decrease in flow, -7.63 and -8.22 percent respectively. As expected, during the AM peak period the most impacted scenarios are those with capacity reduction in the eastbound direction. This is the peak direction for commuters during the AM period.

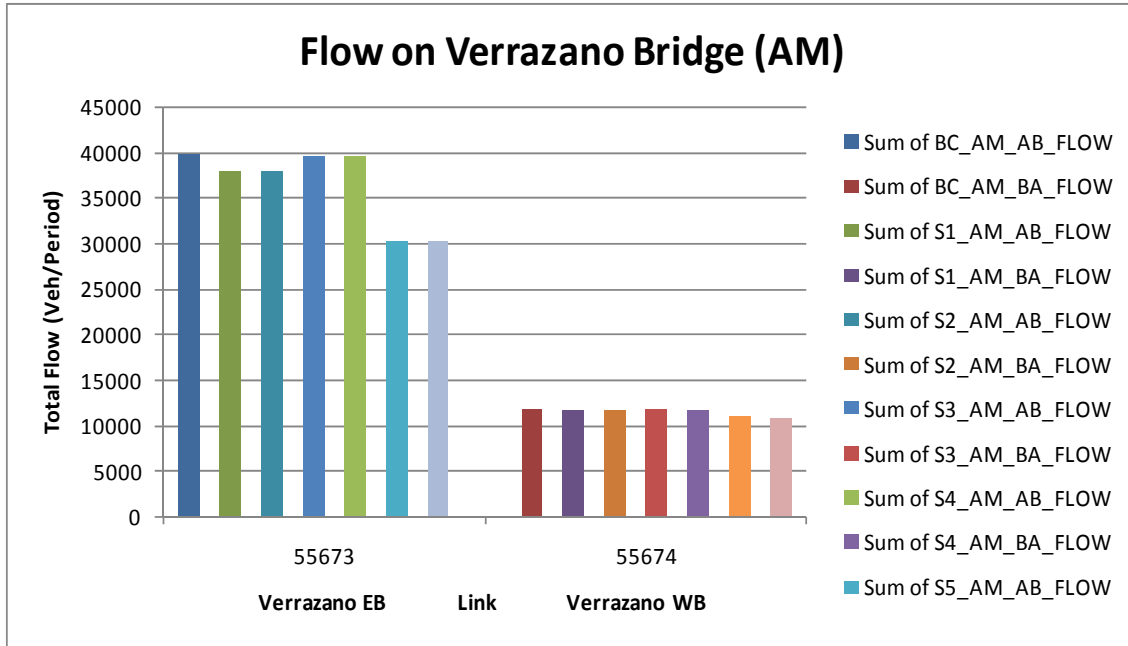


Figure 145: Flow on Verrazano in AM period (6AM-10AM)

Table 34: Percent change in flow from BC (AM)

S1_AB	S2_AB	S3_AB	S4_AB	S5_AB	S6_AB
-4.34	-4.37	-0.44	-0.37	-23.88	-23.98
S1_BA	S2_BA	S3_BA	S4_BA	S5_BA	S6_BA
-1.81	-1.90	-0.85	-1.18	-7.63	-8.22

MD Period

During the midday period, none of the capacity reducing scenarios had a major impact on the change in flow throughout the travel period. The flow in the eastbound direction during the base case was around 30,000 vehicles. Figure 146 shows that in the eastbound direction the change in flow remained below a 1 percent drop for all scenarios with the exception of S5 and S6. Table 35 shows that the flow dropped approximately 8 percent for these two scenarios during the midday period. The flow in the westbound direction during the base case was slightly under 30,000 vehicles and only S4 and S6 had somewhat of an impact on the flow. S4 is a three lane reduction in the westbound direction and S6 is a three lane reduction in both directions. During the midday period only those scenarios with three lane capacity reduction in either direction had a noticeable impact on the flow over the Verrazano.

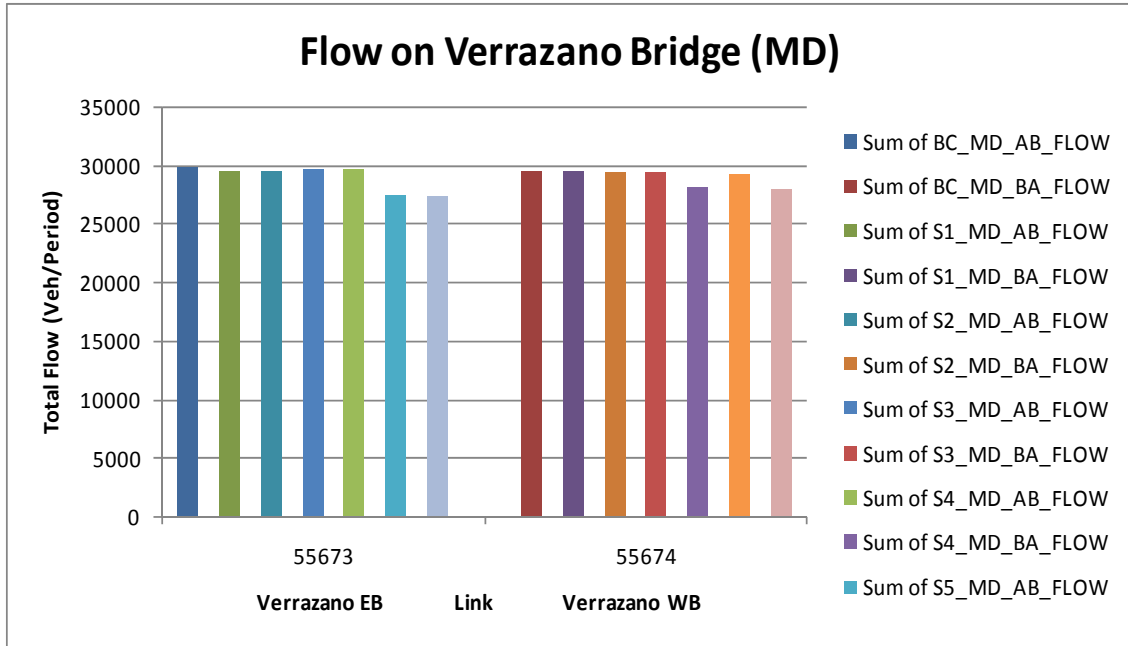


Figure 146: Flow on Verrazano in MD period (10AM-3PM)

Table 35: Percent change in flow from BC (MD)

S1_AB	S2_AB	S3_AB	S4_AB	S5_AB	S6_AB
-0.91	-0.98	-0.30	-0.60	-7.99	-8.25
S1_BA	S2_BA	S3_BA	S4_BA	S5_BA	S6_BA
-0.42	-0.82	-0.74	-4.84	-1.17	-5.51

PM Period

During the PM peak period the flow on the Verrazano-Narrows Bridge was impacted the most by Scenario Four and Scenario Six in the westbound direction. S4 was a three lane reduction in the westbound direction and S6 was a three lane reduction in both the eastbound and westbound directions. Figure 147 shows that the total flow in the eastbound direction during the base case is approximately 15,000 vehicles throughout the PM period and the flow remains quite constant for all six of the scenarios. In the westbound direction the flow is slightly above 40,000 vehicles in the PM peak period. During S4 and S6, when there is a three lane reduction in the peak direction (westbound) the flow drops around 17.6 percent to nearly 34,000 vehicles.

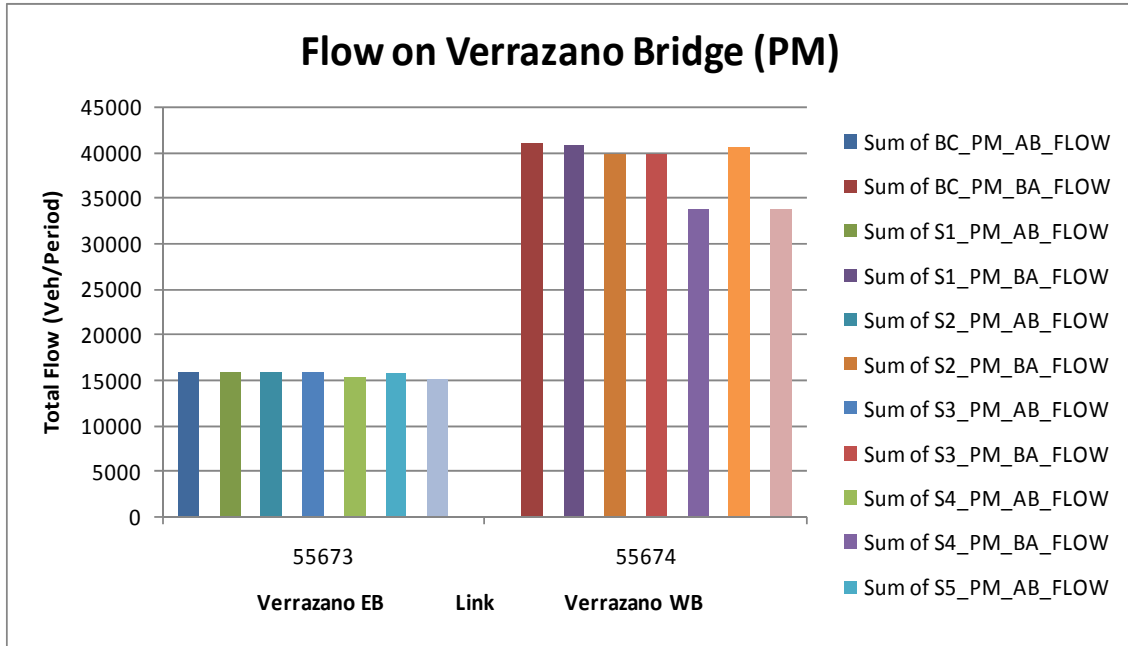


Figure 147: Flow on Verrazano in PM period (3PM-7PM)

Table 36: Percent change in flow from BC (PM)

S1_AB	S2_AB	S3_AB	S4_AB	S5_AB	S6_AB
-0.42	-0.77	-0.75	-3.90	-1.61	-5.06
S1_BA	S2_BA	S3_BA	S4_BA	S5_BA	S6_BA
-0.39	-2.63	-2.60	-17.58	-0.58	-17.57

NT Period

Figure 148 and Table 37 show that none of the scenarios noticeably impact the flow during the night time period between 7 PM and 6 AM. The flow remains around 15,000 vehicles throughout the period in the eastbound direction and near 20,000 vehicles throughout the period in the westbound direction.

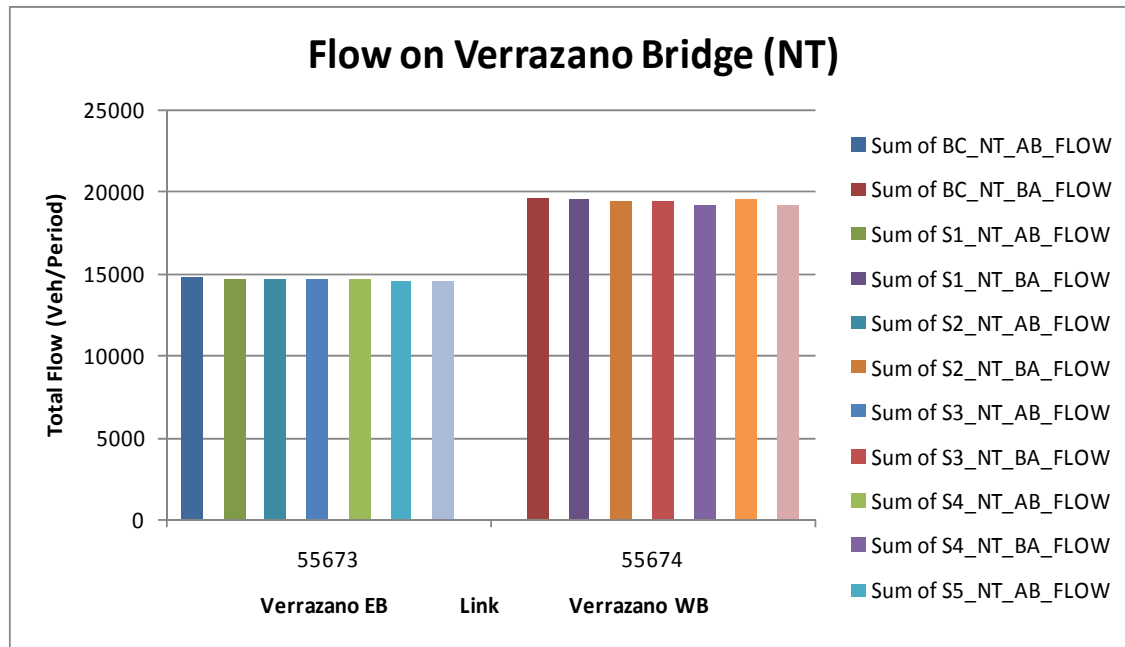


Figure 148: Flow on Verrazano in NT period (7PM-6AM)

Table 37: Percent change in flow from BC (NT)

S1_AB	S2_AB	S3_AB	S4_AB	S5_AB	S6_AB
-0.54	-0.75	-0.69	-0.86	-1.31	-1.44
S1_BA	S2_BA	S3_BA	S4_BA	S5_BA	S6_BA
-0.70	-1.36	-1.34	-2.42	-0.81	-2.15

Travel Time on Verrazano-Narrows Bridge

Figure 149 through Figure 152 show the change in travel time on the Verrazano-Narrows Bridge in both directions (eastbound and westbound) for the base case and the six scenarios (S1 – S6). The figures show the average travel time in minutes over the Verrazano during the specified travel period. Major impacts to travel time are seen when there is a capacity reduction in the direction of peak travel. The following figures show how each scenario will change the average travel time to traverse the bridge.

AM Period

During the AM period, the peak travel direction over the bridge is eastbound. The majority of AM travelers are heading over the Verrazano in the eastbound direction on the commute to work. The figure shows that the average travel time during the base case in the eastbound direction is around 12 minutes, while the average travel time in the opposing direction (westbound) is around 2 minutes. Figure 149 shows that in westbound direction the travel times do not noticeably vary, averaging around 2 minutes for each scenario. In the peak direction the different scenarios significantly effect travel time over the bridge. S3 and S4 are one lane reduction and three lane reduction in the westbound direction, respectively and as expected when there is no capacity reduction in

the peak direction the average travel time remains around 12 minutes as shown in Figure 149. S1, S2, S5 and S6 all contain capacity reductions in the eastbound direction. When there is a one lane reduction, as in Scenario One and Scenario Two, the travel time doubles to approximately 24 minutes. When there is a three lane reduction in the eastbound direction, a major increase in travel time is seen averaging above 80 minutes for both S5 and S6. In the AM period, it can be concluded that the capacity reducing scenarios only affect travel times in the peak, or eastbound direction.

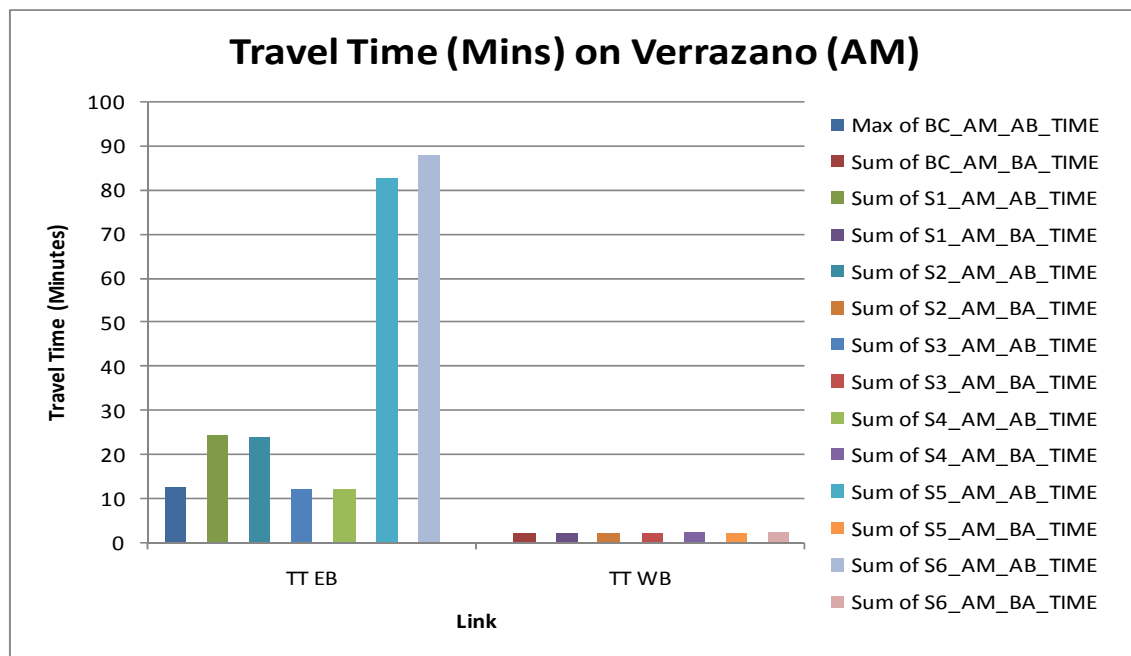


Figure 149: Travel Time on Verrazano in AM period (6AM-10AM)

MD Period

The midday period (10A-3P) does not have a peak travel direction. Average travel times on the bridge are much lower in the eastbound direction during this period than they were in the AM period previously discussed. The average travel time in the eastbound direction for the base case (BC) scenario during the midday period is around 2.6 minutes.. The only major changes seen during the midday period are when a scenario contains a three lane reduction in either direction. Figure 150 shows that the travel time in the eastbound direction jumps to around 15 minutes during S5 and S6 and the travel time in the westbound direction jumps to around 8 minutes during S4 and S6. The changes are not as significant since the midday is not a peak travel period, however some delays are likely to be seen when crossing the bridge during the specified scenarios.

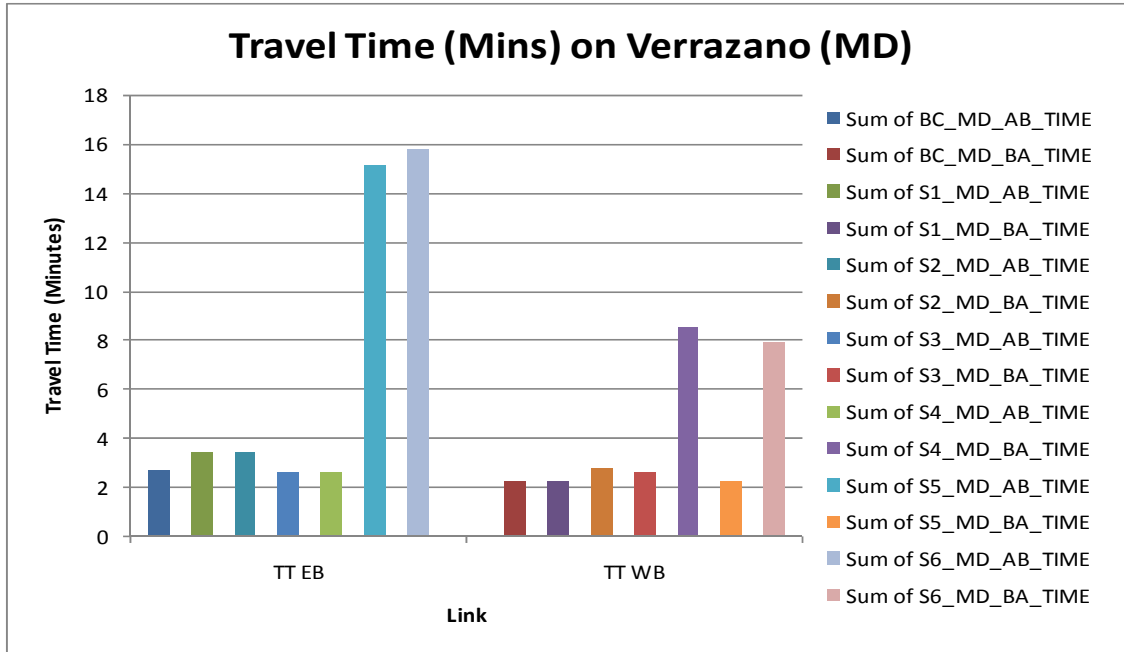


Figure 150: Travel Time on Verrazano in MD period (10AM-3PM)

PM Period

During the PM period, the peak travel direction over the bridge is westbound. The majority of PM travelers are heading over the Verrazano in the westbound direction on the commute back from work. Figure 151 shows that the average travel time during the base case in the eastbound direction is around 2 minutes and the average travel time in the westbound is around 5.5 minutes. Figure 151 shows that in the non-peak direction the travel times do not noticeably vary, averaging around 2 minutes for each scenario and jumping to around 4 minutes during S5 and S6, the two scenarios that contain a three lane reduction in the eastbound direction. In the peak direction the different scenarios significantly affect travel time over the bridge. S1 and S5 are one lane reduction and three lane reduction in the eastbound direction, respectively and as expected when there is no capacity reduction in the peak direction the average travel time remains around 5.5 minutes as shown in Figure 151. S2, S3, S4 and S6 all contain capacity reductions in the westbound direction. When there is a one lane reduction, as in Scenario Two and Scenario Three, the travel time doubles to approximately 10 minutes. When there is a three lane reduction in the westbound direction, a major increase in travel time is seen averaging above 45 minutes for both S4 and S6. In the PM period, it can be concluded that the capacity reducing scenarios only affect travel times in the peak, or westbound direction.

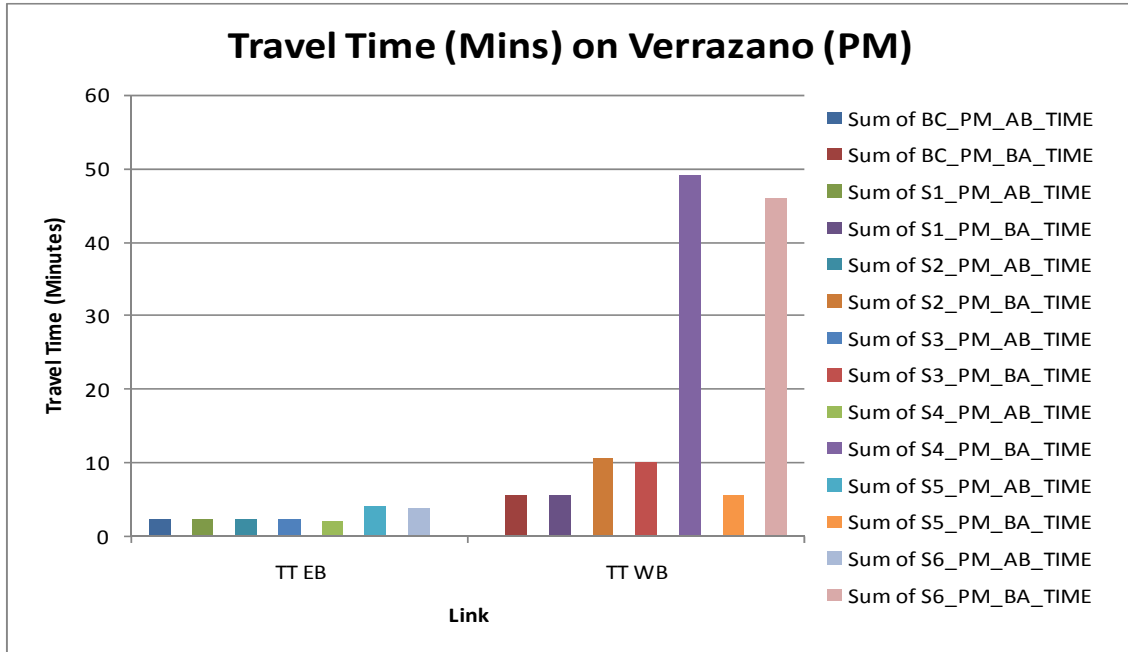


Figure 151: Travel Time on Verrazano in PM period (3PM-7PM)

NT Period

Figure 152 shows that none of the scenarios dramatically impact the travel time during the night time period between 7 PM and 6 AM. The largest increase in travel time is only approximately 1 minute. It can be concluded that is only a very minor change in travel time when there is a three lane reduction in capacity during the night time period.

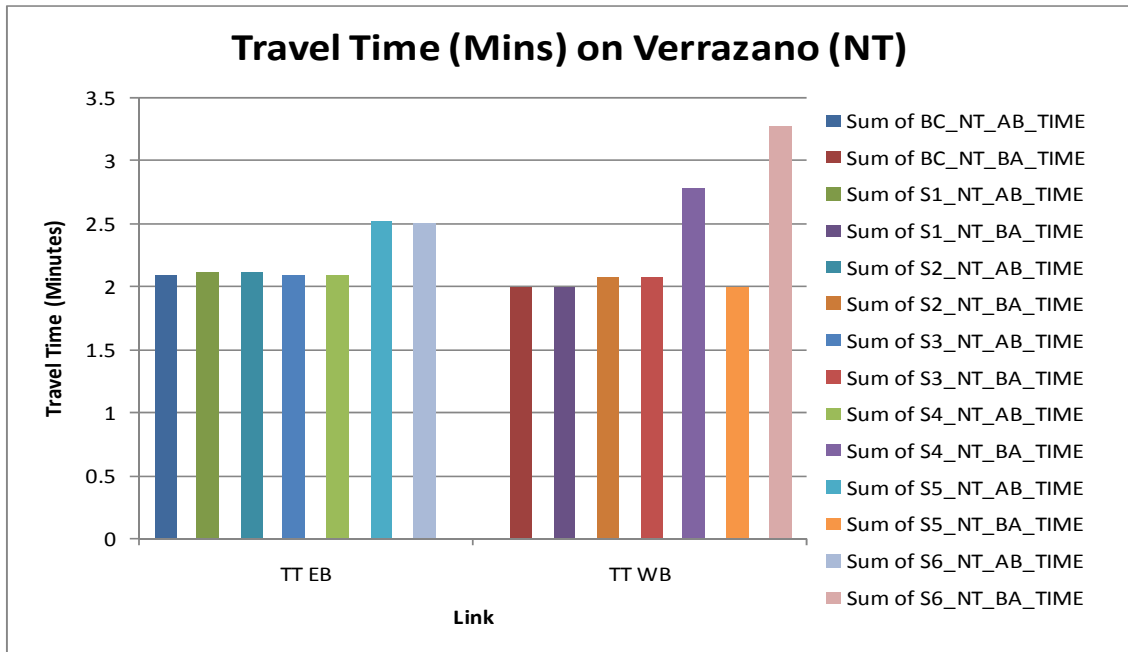


Figure 152: Travel Time on Verrazano in AM period (7PM-6AM)

Link-Level Delay

This section of the report shows how each scenario impacted travel times on vital links during the AM and PM peak travel periods. Seven color-themed maps were produced for each scenario including the base case for the AM and PM periods. These images can be found in the appendix of this report.

To understand the images and the analysis provided in this section, the construction of these images will be briefly discussed. Fourteen images were produced for this scenario (*B3*) *Impact of disruption of infrastructure* in order to provide an understanding how each capacity reducing scenario impacted vital links in the network. Seven images were produced for the AM peak travel period; one for the base case and six for each of the scenarios outlined in the scenario description (S1-S6). The same was done for the PM peak travel period. A short description of each scenario is presented below.

- Base Case (BC) – no change
- Scenario One (S1) – one lane eastbound reduction
- Scenario Two (S2) – one lane eastbound and westbound reduction
- Scenario Three (S3) – one lane westbound reduction
- Scenario Four (S4) – three lane westbound reduction
- Scenario Five (S5) – three lane eastbound reduction
- Scenario Six (S6) – three lane eastbound and westbound reduction

First the delay on each link was calculated by taking the difference of the average travel time output by the NYBPM for each link and the free flow travel time of that link. This data was taken from the output that the NYBPM model produced. A color-themed map was then created to give a visual of delay on the network. On each map a red, circled star represents the location of the Verrazano-Narrows Bridge. The color-theme that was used to represent the delay ranges from green, representing the lowest delay to red, representing the highest delay. Each map has its own corresponding legend with the exact magnitude of delay represented by each color. These legends can also be found in the appendix attached to the corresponding map.

AM Period

First the Base Case scenario map was examined to get an idea of where significant delay existed on the network before any changes were made to the Verrazano-Narrows Bridge during the AM peak travel period. As the Base Case map shows, the link with the highest delay is the Holland Tunnel, colored orange to represent 20 to 24 minute delays in Figure 171. Other major delays in the region are on the Lincoln Tunnel, showing 8 to 12 minutes delays and several links along the New Jersey Turnpike. The NJ Turnpike from Exit 14-15E shows delays in the 12 to 16 minute range. The Verrazano-Narrows shows only up to 8 minute average delays during before any capacity reduction occurs.

During S1 no major changes were observed on the map. Some slight increases along the NJ Turnpike corridor are noticed. As shown in the map, the one-lane reduction on the

Verrazano has immediate impacts on the bridge. The delays on the bridge increase from an approximate 8 minute average to nearly a 20 to 24 minute average. No major increases in delay over the Holland Tunnel, Lincoln Tunnel or George Washington Bridge are seen from a one lane reduction in capacity on the Verrazano.

Scenario 2 produces nearly the same results as S1. S2 is a one lane reduction in both the eastbound and westbound directions. The one lane closure in the westbound direction has a minimal impact on the network and the one lane reduction in the eastbound direction results in the same delays just discussed for Scenario 1. This is due to the fact that the eastbound direction is the peak direction of travel during the AM period.

Again for Scenario 3, a one lane reduction in the westbound direction during the AM period there are no major changes from the results produced during the base case. Only very minor increases on the westbound side of the Verrazano can be observed.

Scenario 4 also has no capacity reduction in the eastbound direction. Like Scenario 3, no major increases in delay are seen on the map.

Scenario 5 shows major changes in delay throughout the network. S5 is a three lane reduction in the eastbound direction of the bridge. The delay on the bridge jumps to nearly 70 minutes on eastbound link of the bridge. The Holland and Lincoln Tunnels, as well as the New Jersey Turnpike see some major jumps in delay. Most likely, this is due to commuters who would normally cross over the Verrazano, deciding to head further north on the turnpike and enter Manhattan through one of the tunnels or the George Washington Bridge. The map for S5_AM_Delay in the appendix shows sharp increases in the links just mentioned. A number of links within proximity of the Verrazano also appear to have slightly increased delay due to major backups over the bridge.

Scenario 6, a three lane reduction on the Verrazano in both directions produces very similar results as S5. Although the three lane reduction in the westbound direction produces some delay near the immediate area of the bridge, it does not have a major affect throughout the network during the AM period.

PM Period

The PM peak period maps show similar trends as those maps produced for the AM peak period. The majority of increased delay is caused by capacity reduction in the peak travel direction, in this case westbound over the Verrazano. Capacity reductions in the eastbound direction have minimal impact during the PM peak period.

The PM Base Case delay map in the appendix shows delay on the same major links as in the AM period. The Holland Tunnel, Lincoln Tunnel and the New Jersey Turnpike are the links that immediately stick out on the map. However, during the PM period the magnitude of the delay on all links is slightly lower than in the AM period. This could be due to the dispersion of commuters after work for recreation, shopping, etc.

Scenario 1 produces nearly the same map as the Base Case. S1 is a one lane reduction in the eastbound direction, which is not the peak direction during the PM period.

In Scenario 2, a one lane reduction in the eastbound direction during the PM period, there are no major changes shown from the results produced during the base case. Only very minor increases on the eastbound side of the Verrazano can be observed.

During Scenario 3, a one lane reduction in the westbound direction of the bridge, no major changes were shown on the map. Delays on the bridge increase from an approximate 4 minute average to around an 8 to 12 minute average. No major increases in delay over the Holland Tunnel, Lincoln Tunnel or George Washington Bridge are seen from a one lane reduction in capacity on the Verrazano.

Scenario 4 shows the most significant changes shown from any scenario during the PM period. S4 is a three lane reduction in the westbound direction of the bridge. The delay on the bridge jumps to nearly 35 minutes on westbound link of the bridge. The Holland and Lincoln Tunnels, as well as the New Jersey Turnpike see some major jumps in delay. These jumps in delay are not as large as those seen during S5 in the AM peak period.

Scenario 5 also has no capacity reduction in the westbound direction. Like Scenario 1, no major increases in delay are seen on the map.

Scenario 6, a three lane reduction on the Verrazano in both directions produces very similar results as S4. Although the three lane reduction in the eastbound direction produces some delay near the immediate area of the bridge, it does not have a major effect throughout the network during the PM period.

4. SUMMARY

As mentioned in the introduction, the purpose of the work presented in this report is to test and demonstrate the capabilities of NYMTC's Best Practices Model for policy analysis in the New York Metropolitan Region, through peer reviewed sensitivity analysis. The scenarios that were selected for this set of sensitivity tests examine and demonstrate the utility of the NYBPM as a tool for policy analysis by looking at a detailed level at how the model responds to network or policy changes.

The first scenario that was tested (*B1*) showed the impact of truck demand changes on the network. The purpose of testing this scenario was to show the zonal and link-level effects on passenger travel on the major corridors into Manhattan as the level of traffic rises on the network. Freight demands for a number of origin and destination pairs (defined in Section 2.1) going from New Jersey into Manhattan were gradually increased at a rate of 5 percent per year to observe the changes in the model output. The number of trucks for the rest of the O-D pairs and passenger demand were also increased at a rate of

2 percent per year. The analysis of this scenario showed the impact this increase in freight and passenger demand had on total network delay, total network vehicle miles traveled and total vehicle hours traveled. The analysis also showed how flow on major links into Manhattan was impacted. As expected, delay, total VMT, and total VHT increased for each future year scenario. For the 20 year future scenario (2022) total network delay increased nearly 200 percent, total VMT increased approximately 40 percent, and total VHT increased nearly 50 percent. Since demand is growing at a steady rate on the network each year, the corresponding increase in VMT to 40 percent is expected. The steady growth in demand causes delays, which result in the 50 percent increase in total VHT on the network. Flow on certain key links in the network is rising above the optimal flow increasing travel times on these links, leading to the increase in VHT and also leading to the large increase in delay on the network. The link-level analysis of flow on major links between New Jersey and New York City helps explain these network increases of delay, VHT and VMT. The following links were included in this analysis: George Washington Bridge, Goethals Bridge, Holland Tunnel, Lincoln Tunnel, Outer Bridge Crossing and the Verrazano-Narrows Bridge.

The second scenario that was tested (*B2*) showed the impact of tolling policy changes on a major link of the network. For this scenario several changes in tolling policies on the Verrazano-Narrows Bridge were tested and the impacts these changes had on other NYC crossings were analyzed. Four scenarios were run including: a base case (BC) with tolling in the current westbound direction, S1 with tolling in the eastbound direction, S2 where the tolling is bi-directional with half of the current toll being collected in the westbound direction and half of the toll being collected in the eastbound direction, and S3 where the toll collection remains in the westbound direction however the current toll price will be doubled. Five mile buffer zones around the Verrazano-Narrows Bridge were created in order to observe aggregate results within a thirty mile radius around the bridge. The buffer distances included five miles, ten miles, fifteen miles, twenty miles, twenty five miles and thirty miles. The AM peak travel period is in the eastbound direction on the Verrazano-Narrows Bridge and the PM peak travel period is in the westbound direction on the bridge.

The analysis first looked at total vehicle miles, total vehicle hours and delay within the five mile bands. No scenario made a significant impact on the total vehicle miles travelled within any of the five mile bands. The analysis of vehicle hours traveled showed there was some significant impact on the network which occurred within the five mile radius of the bridge during peak travel periods (AM and PM). During the AM travel period there was a nearly 7 percent increase in VHT for S1 and S2 within the five mile buffer zone. This increase in the immediate vicinity of the bridge is expected since toll collection is shifted to the peak travel direction (eastbound) on the bridge in both scenarios S1 and S2. During the PM travel period there was an increase of close to 2 percent in VHT for S2 and S3 within the five mile buffer zone. Although this is a fairly small increase, it shows that the change in tolling policy to a bi-directional tolling regime or doubling the toll in the current direction is impacting travel decisions and slightly increasing VHT near the bridge.

Unlike VMT and VHT which only showed small changes within the five mile buffer zone, the analysis for delay showed more significant impact during the AM and PM peak travel periods. In the AM travel period delay increased approximately 12 percent within the five mile zone, 3 percent within the ten mile zone and close to 2 percent for each band up to the thirty mile radius for both scenarios S1 and S2. Scenario One was a change of toll in the peak travel direction, therefore the jump in delays for this scenario is expected. Likewise, Scenario Two is a change to a bi-directional toll collection and similar results are seen. During the MD travel period a 2 percent increase in delay is seen for all three scenarios and during the PM travel period an approximately 5 percent increase occurs within the five mile buffer zone for S2 and S3. Smaller changes in delay are seen here because the toll collection is already in the westbound direction and travelers are not responding to the change in tolling policy as drastically as they were when the toll collection switched direction.

Overall, it is known that the model has limited ability to produce sound estimates of user responses to pricing changes and does not represent complex or variable pricing structures. These issues are known and have been considered to be addressed in future versions of the model.

The third scenario that was tested (*B3*) showed the impacts of a disruption of infrastructure on the network. This scenario tests how travel choices change at the facility level if the capacity of a bridge is reduced due to construction, maintenance, or unplanned events. Because of NYBPM's known difficulties forecasting traffic levels on Manhattan's East River Crossings, this scenario focuses on a facility that does not enter Manhattan. The Verrazano-Narrows Bridge, which is undergoing repairs that require lane closures is used for this scenario. Seven sub-scenarios were run to test the capacity changes on the Verrazano-Narrows Bridge. The base case will include no changes in capacity on the Verrazano-Narrows Bridge. The results from this case will be used as a basis to compare the results from the other scenarios. In Scenario One, one of the six lanes in the eastbound direction on the bridge is closed. In Scenario Two, one lane in both the eastbound and westbound direction on the bridge is closed. One of the six lanes in the westbound direction is closed for Scenario Three. In Scenario Four three of the six westbound lanes on the Verrazano are shut down. Three of the six eastbound lanes are shut down in Scenario Five and in Scenario Six three lanes will be shut down in both directions. Similar to *B2* (Impact of Changes in Tolls) five mile buffer zones around the Verrazano-Narrows Bridge were created in order to observe aggregate results within a thirty mile radius around the bridge. The buffer distances included five miles, ten miles, fifteen miles, twenty miles, twenty five miles and thirty miles. As in Scenario *B2*, it is important to note that the AM peak travel period is in the eastbound direction on the Verrazano-Narrows Bridge and the PM peak travel period is in the westbound direction on the bridge.

The analysis first looked at total vehicle miles, total vehicle hours and delay within the five mile bands. The most significant change in vehicle miles traveled occurs in the AM peak travel period for Scenario Five and Scenario Six within the five mile buffer zone. VMT decreased approximately 9 percent in both cases. Both Scenario Five and Scenario

Six have a three lane capacity reduction (50%) in the eastbound direction of the bridge. The reduction in vehicle miles traveled within five miles of the bridge shows that travelers are selecting different routes into New York City when the capacity is reduced by 50 percent in the peak travel direction. Similarly Scenario Four and Scenario Six show an approximate 5 percent reduction in VMT within five miles of the bridge during the PM travel period. This is also expected since S4 and S6 include a 50 percent reduction on in the westbound direction on the Verrazano-Narrows Bridge.

One would expect high delays and travel times on links within close proximity of the Verrazano-Narrows Bridge when the capacity of this key link between New York and New Jersey is reduced. The analysis of vehicle hours traveled and delay shows just this. In the AM travel period major increases in vehicle hours traveled are seen for all scenarios that involve any lane closures in the eastbound direction. Scenario One and Scenario Two, which have a one lane reduction in the eastbound direction of the bridge, show a 7 percent increase in VHT within the five mile band. When there is a three lane reduction in capacity in the eastbound direction as in Scenario Five and Scenario Six an approximate 36 percent increase is seen within five miles of the bridge. For the one lane reduction scenarios the significant increases are limited to the five mile buffer zone, however for the three lane reduction scenarios the increases in VHT are seen at the 30 mile buffer zone where there is an approximate 3 percent increase in VHT. Similarly the PM travel period has large increases in VHT for Scenario Four and Scenario Six, which have three lane reductions in the westbound direction (peak PM travel direction). The analysis of the delay was very similar to the VHT analysis. The highest delay increases were seen within five miles of the bridge when there was a capacity reduction in the direction of the peak travel. When there were three lane closures on the Verrazano, significant delay increases extend to the thirty mile radius around the bridge. The results for this scenario certainly help validate the BPM program. The regional and link level analyses performed in this report show expected results for the described lane closures.

5. APPENDIX

B1: Impact of truck demand changes

Delay on Links during AM period for all Scenarios (B1)



Figure 153: B1_BC_AM_Delay

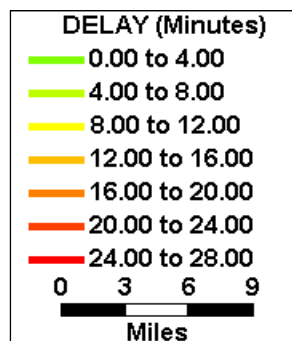
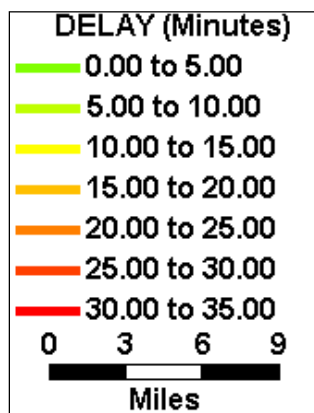




Figure 154: B1_2007_AM_Delay



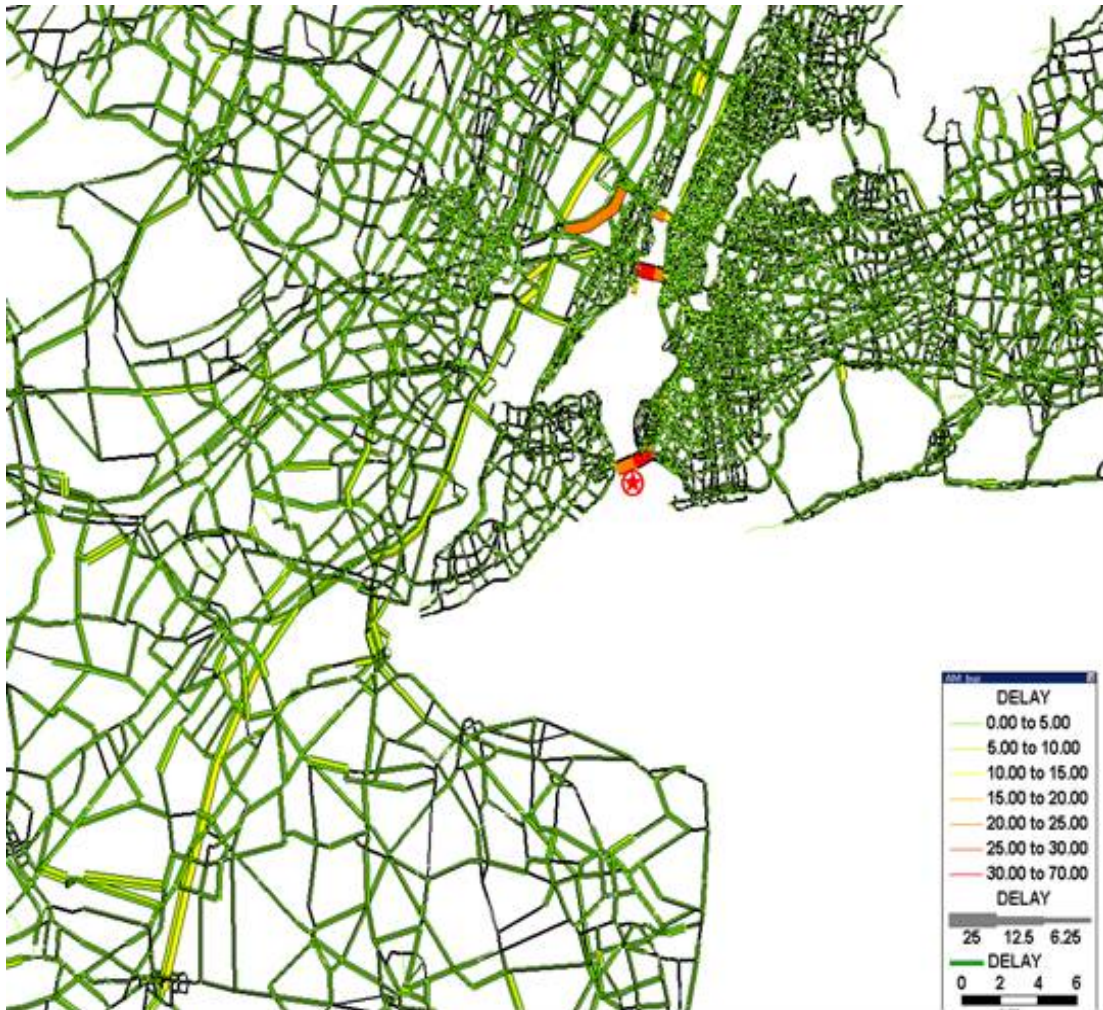


Figure 155: B1_2012_AM_Delay

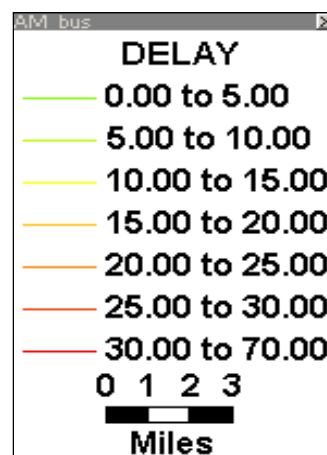




Figure 156: B1_2017_AM_Delay

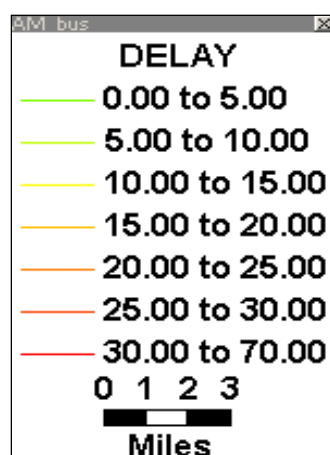
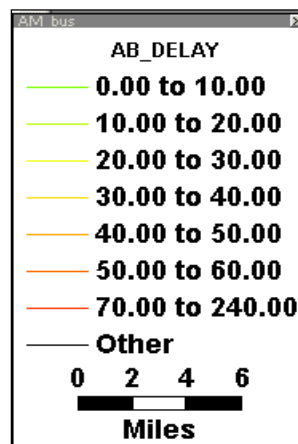




Figure 157: B1_2022_AM_Delay



Delay on Links during PM period for all Scenarios (B1)

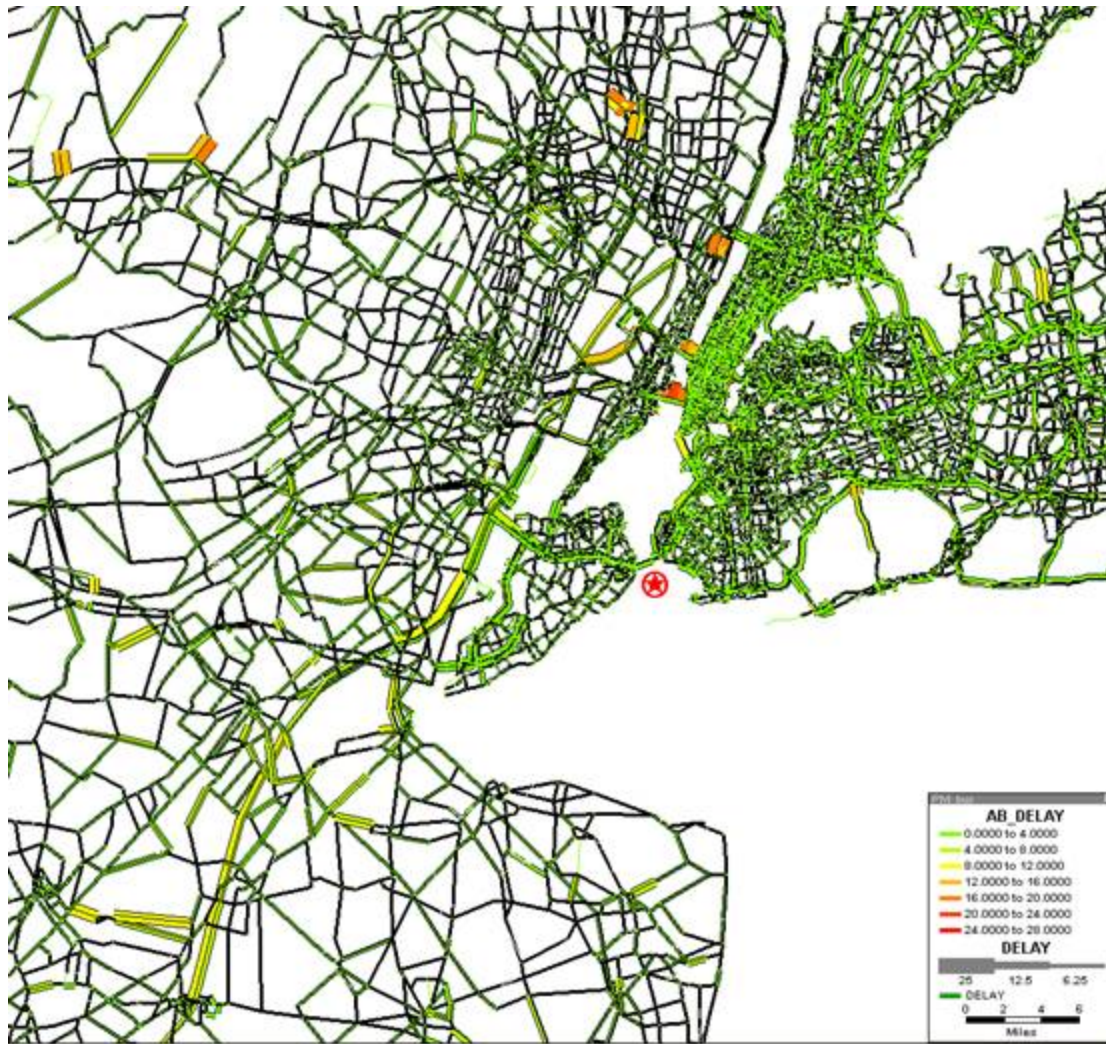


Figure 158: B1_BC_PM_Delay

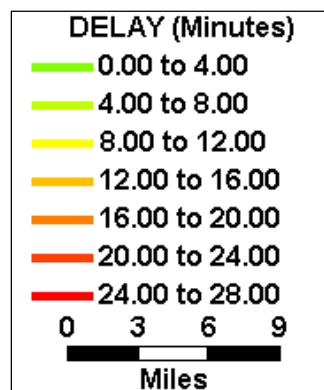




Figure 159: B1_2007_PM_Delay

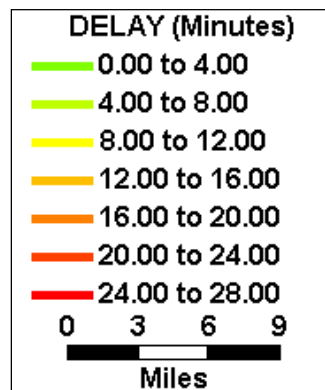




Figure 160: B1_2012_PM_Delay

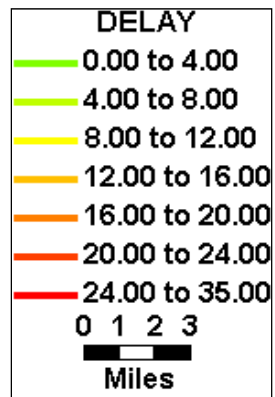




Figure 161: B1_2017_PM_Delay

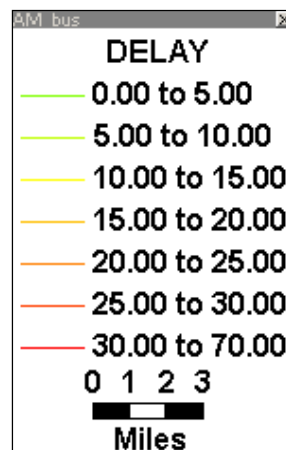
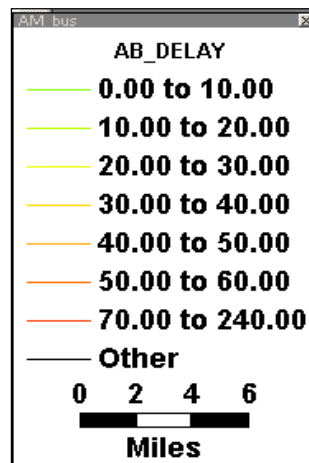




Figure 162: B1_2022_PM_Delay

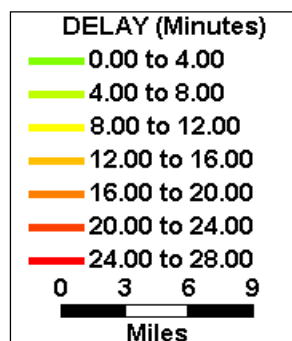


B2: Impacts of changes in tolls

Delay on Links during AM period for all Scenarios (B2)



Figure 163: B2_BC_AM_Delay



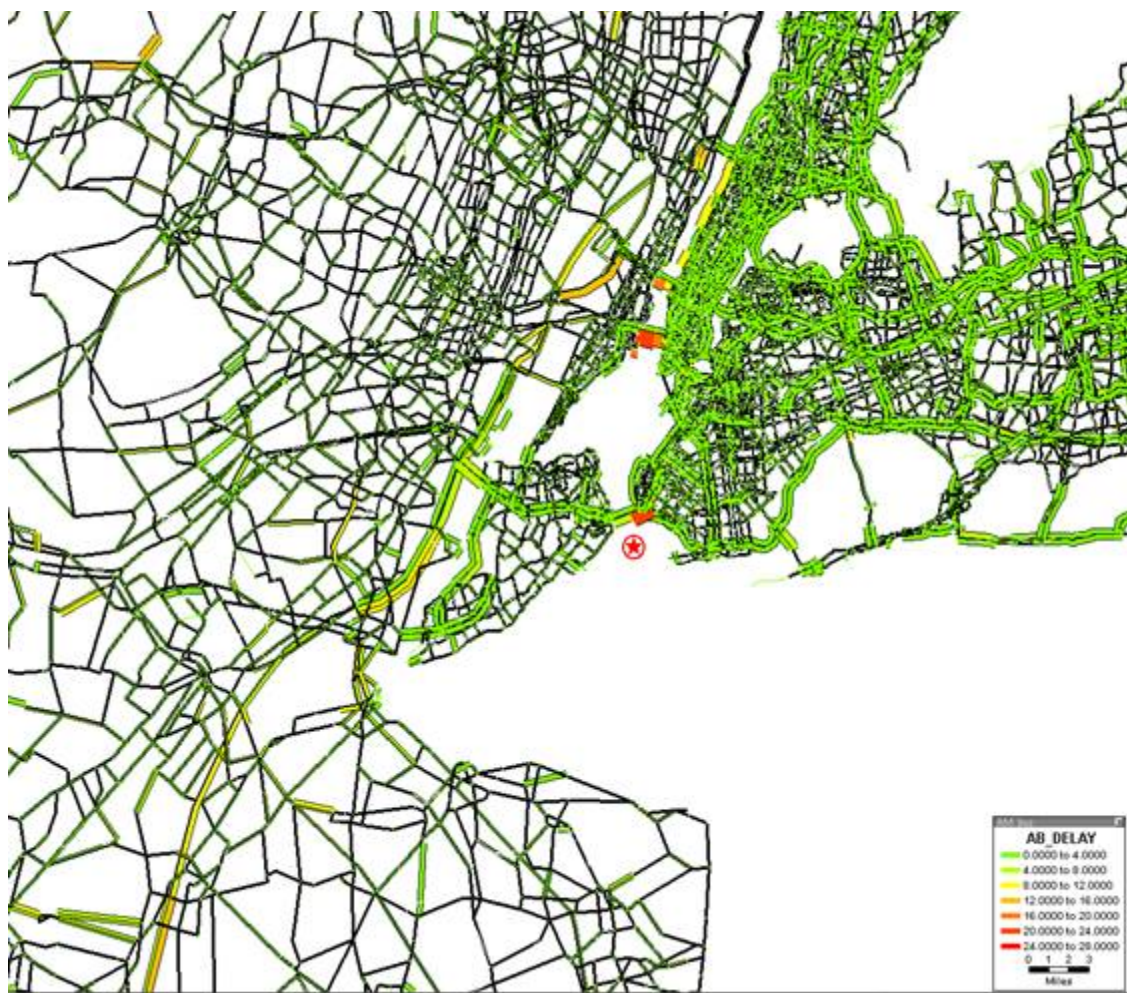
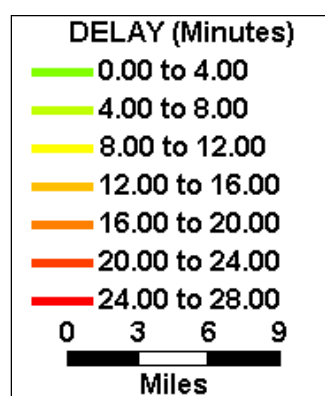


Figure 164: B2_S1_AM_Delay



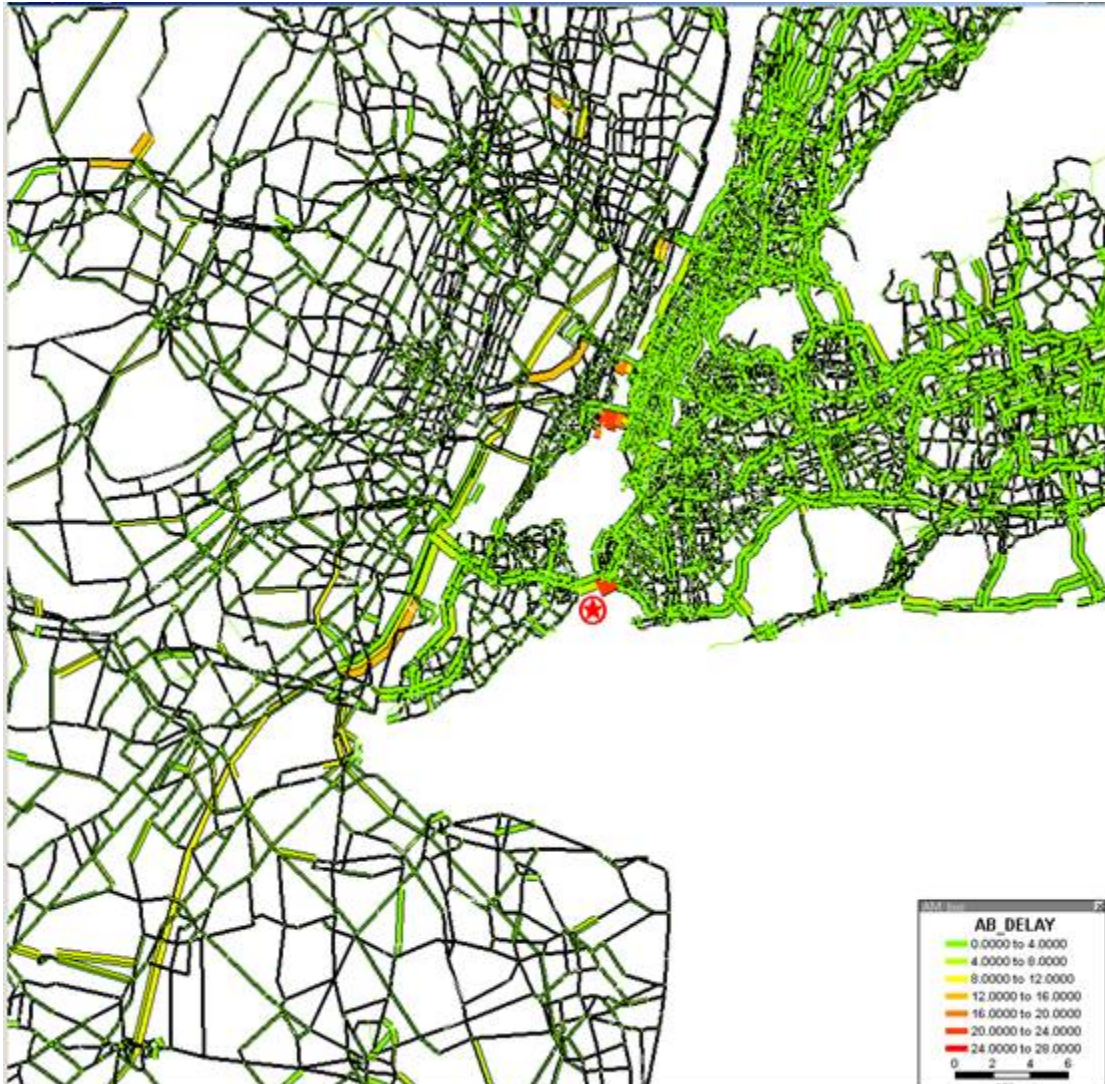


Figure 165: B2_S2_AM_Delay

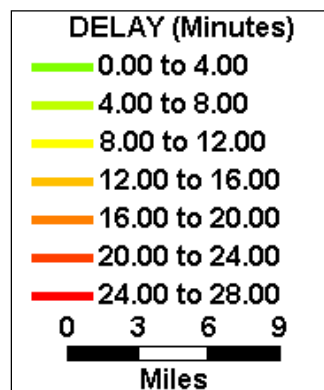
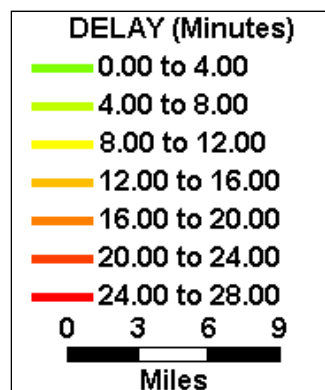




Figure 166: B2_S3_AM_Delay



Delay on Links during PM period for all Scenarios (B2)

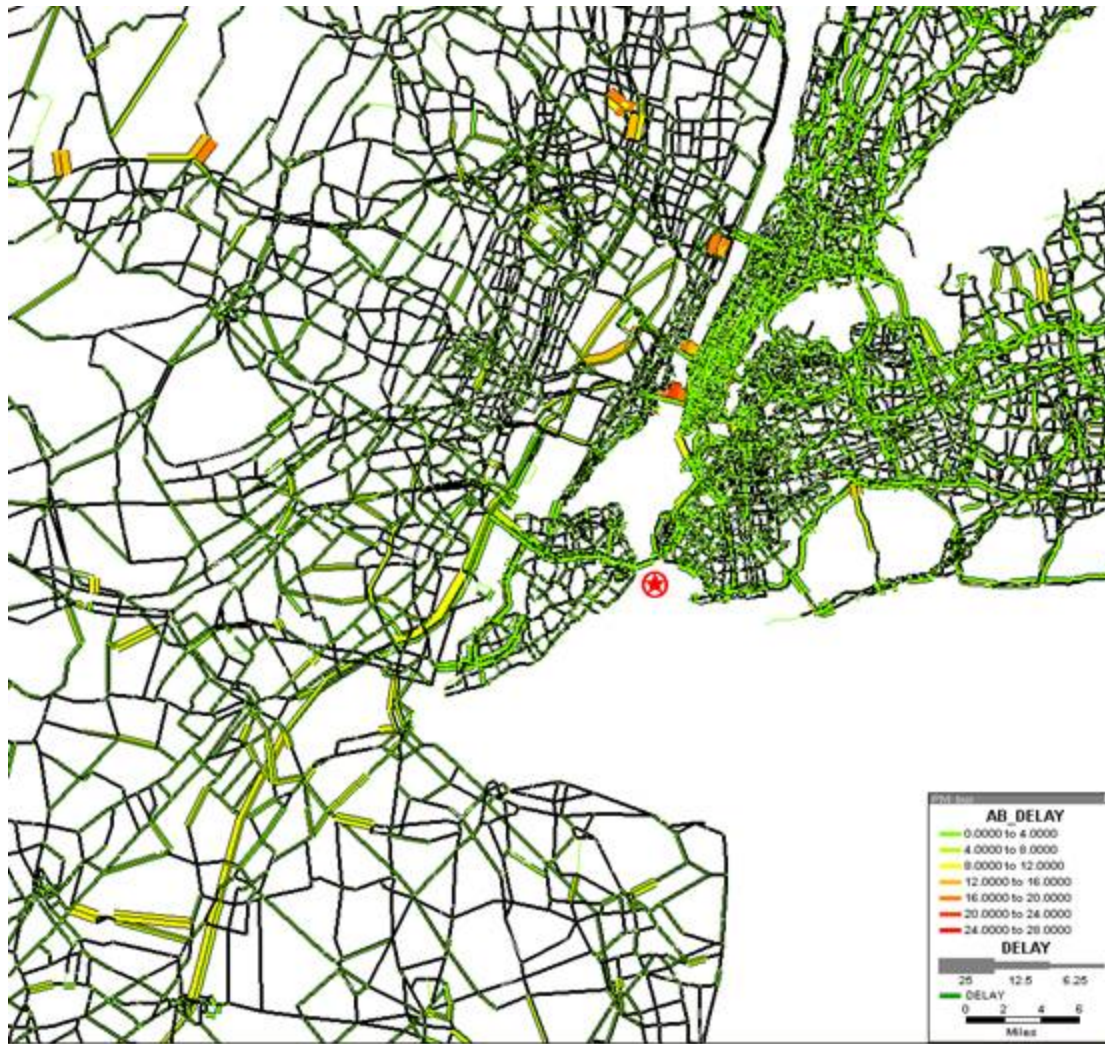


Figure 167: B2_BC_PM_Delay

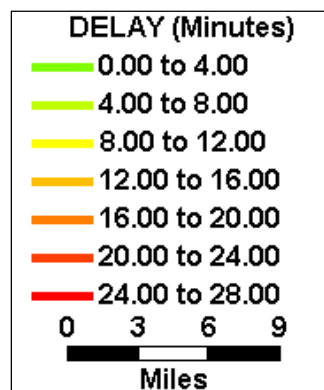
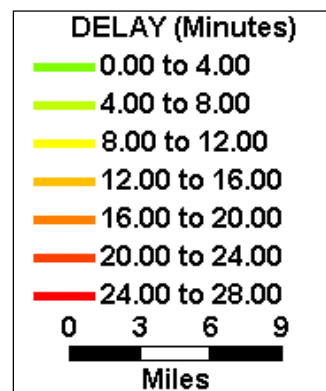




Figure 168: B2_S1_PM_Delay



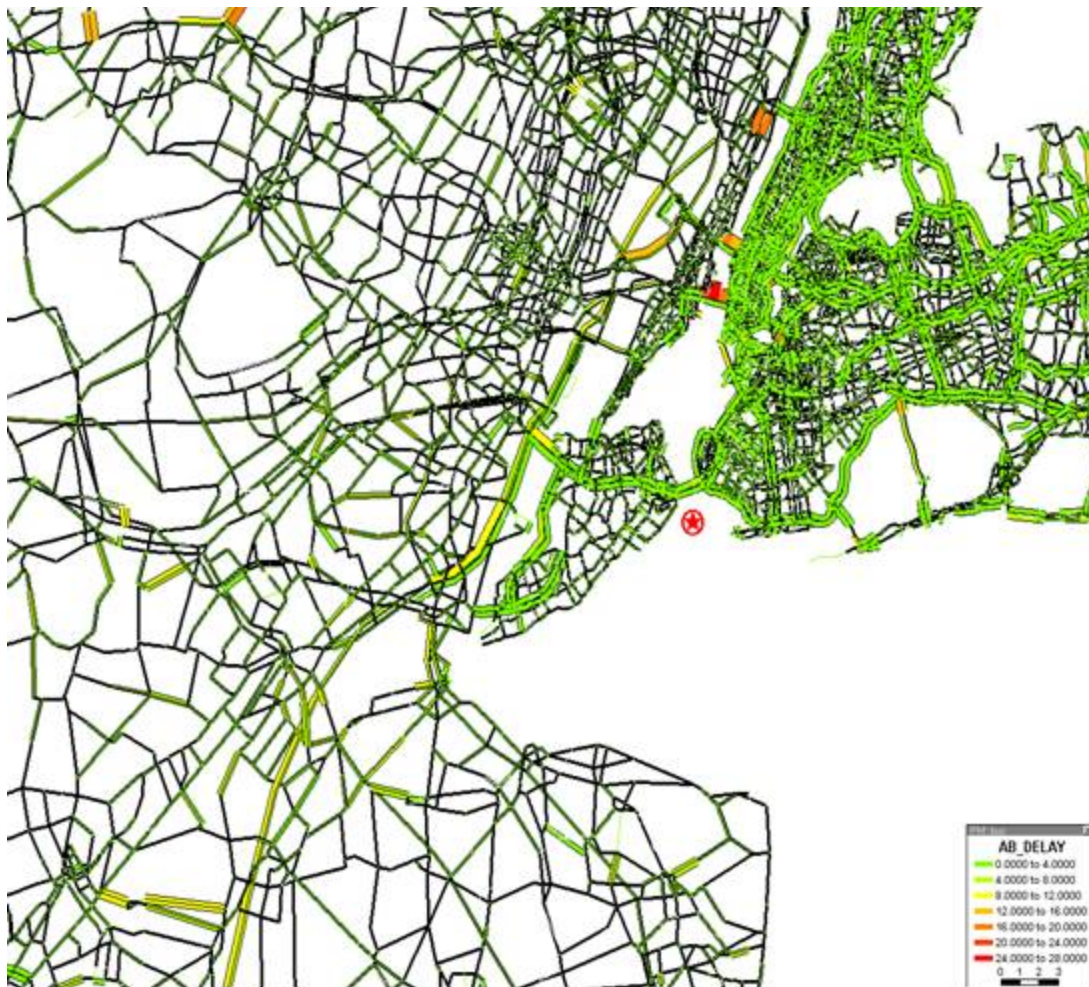
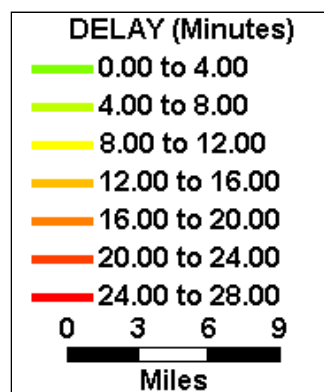


Figure 169: B2_S2_PM_Delay



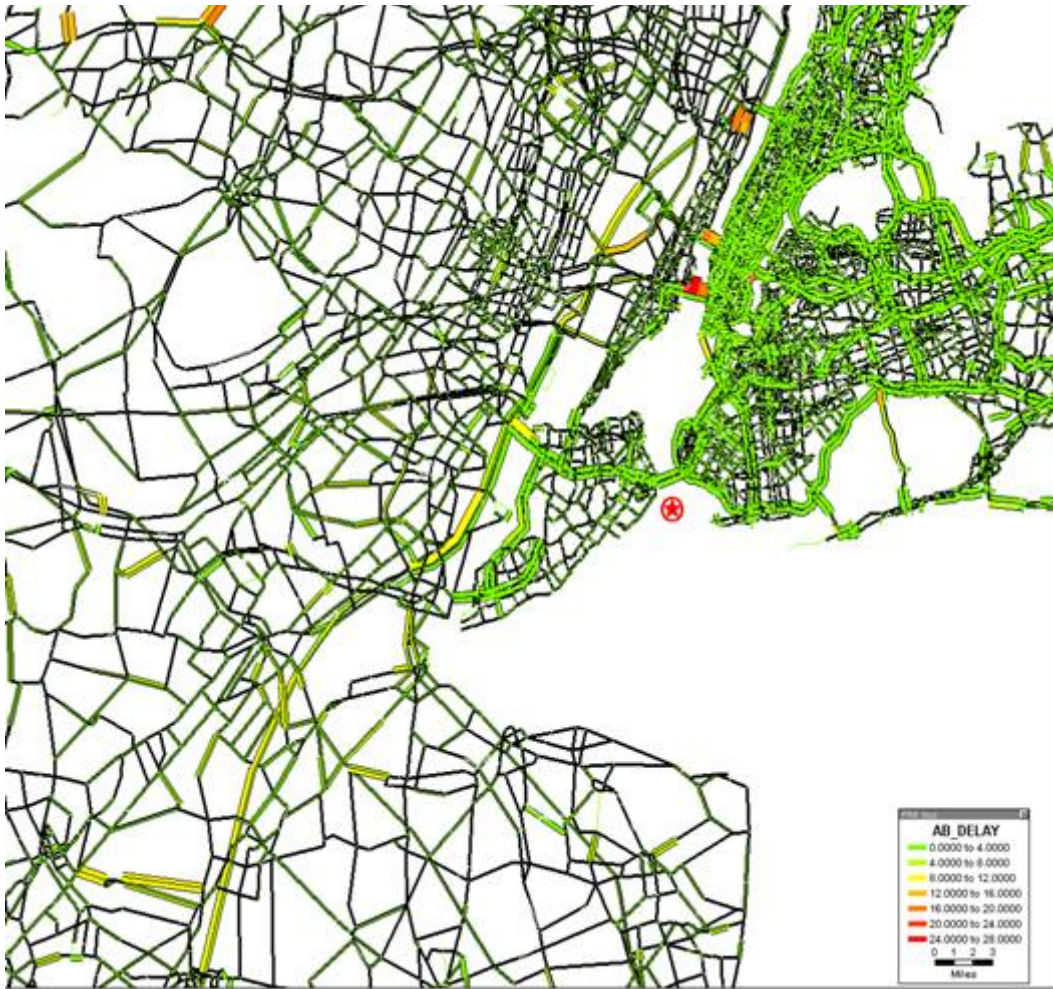
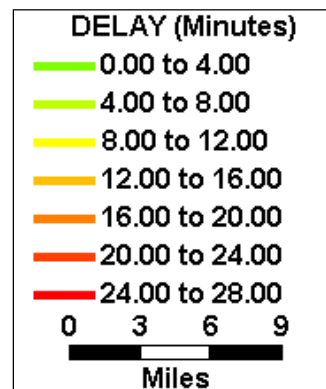


Figure 170: B2_S3_PM_Delay

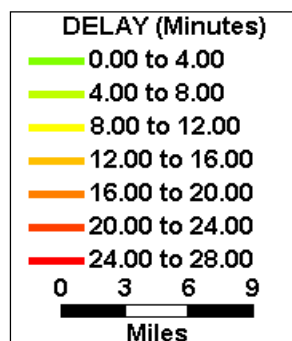


B3: Impact of disruption of infrastructure

Delay on Links during AM period for all Scenarios (B3)



Figure 171: B3_BC_AM_Delay



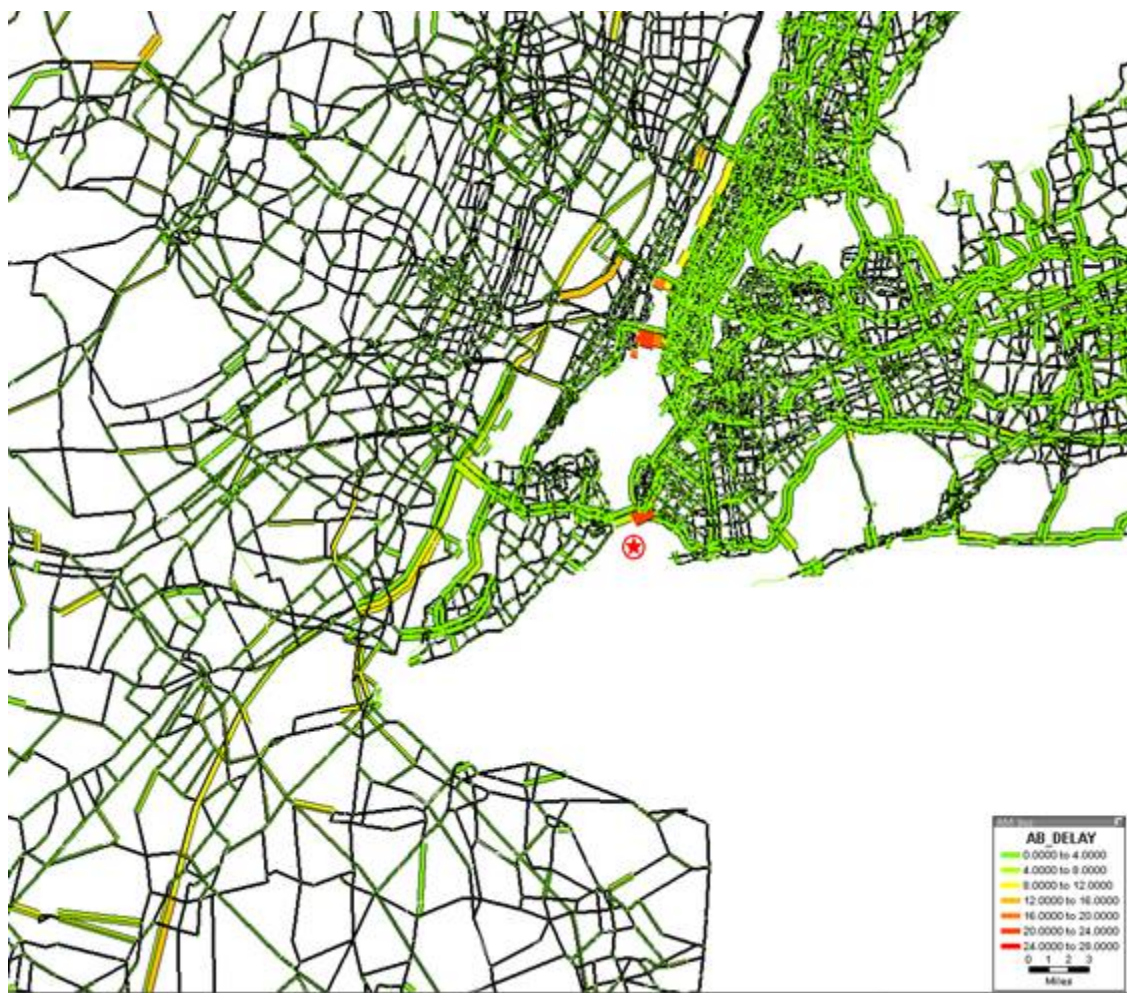
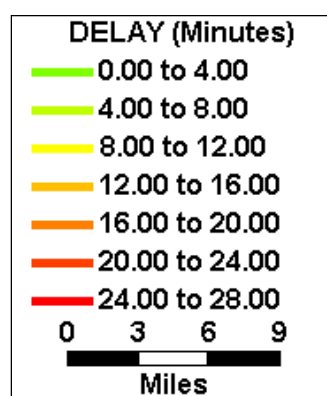


Figure 172: B3_S1_AM_Delay



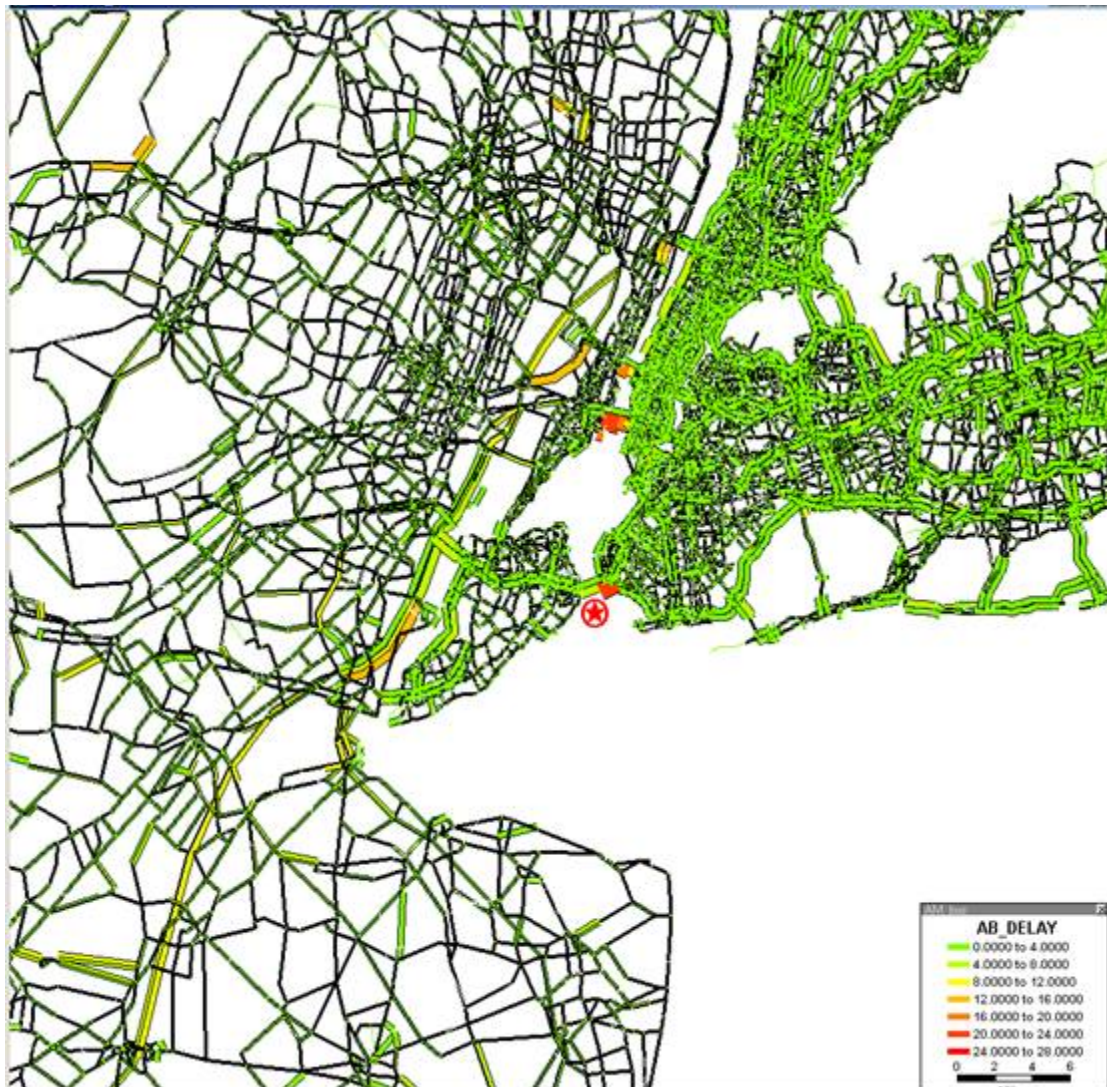
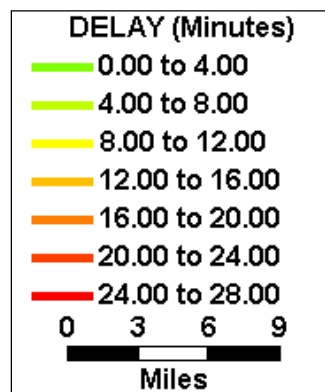


Figure 173: B3_S2_AM_Delay



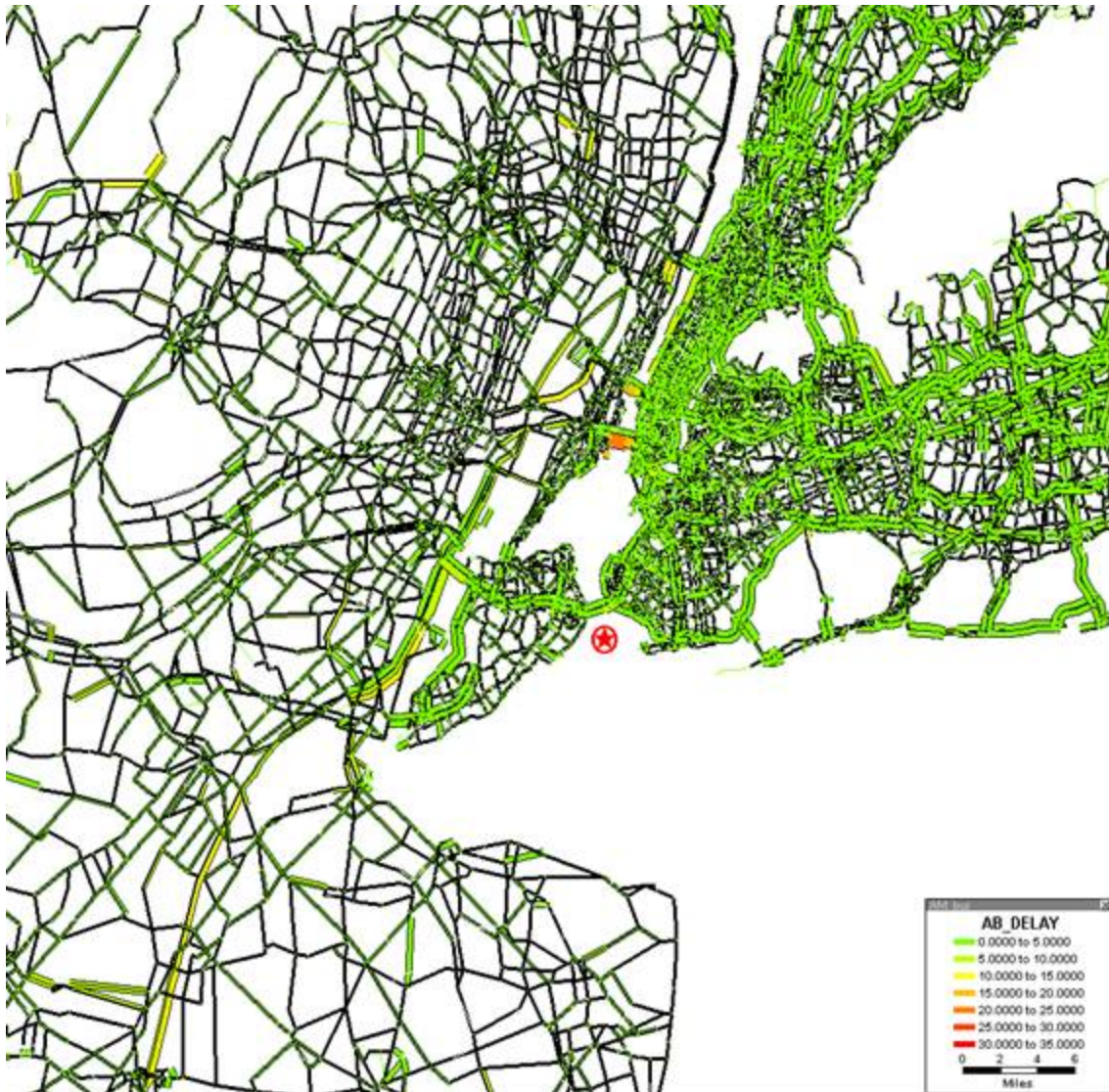


Figure 174: B3_S3_AM_Delay

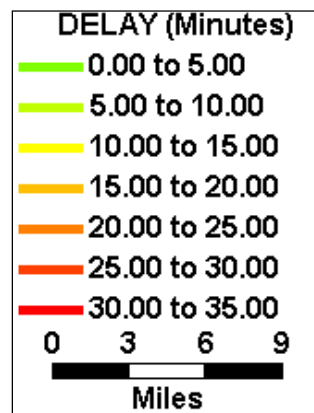




Figure 175: B3_S4_AM_Delay

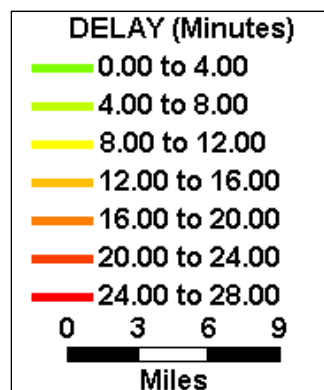




Figure 176: B3_S5_AM_Delay

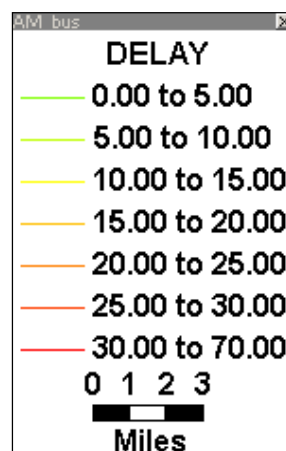
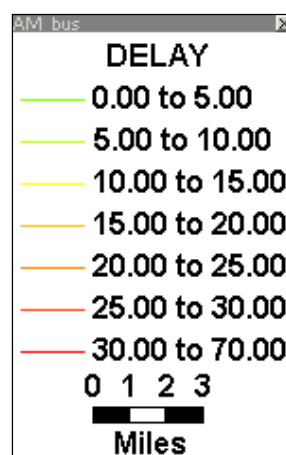




Figure 177: B3_S6_AM_Delay



Delay on Links during PM period for all Scenarios



Figure 178: B3_BC_PM_Delay

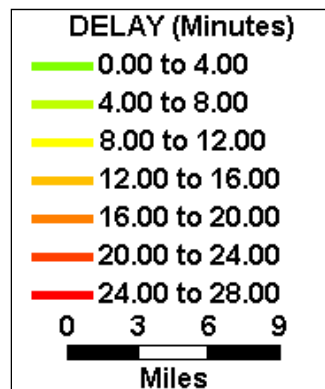
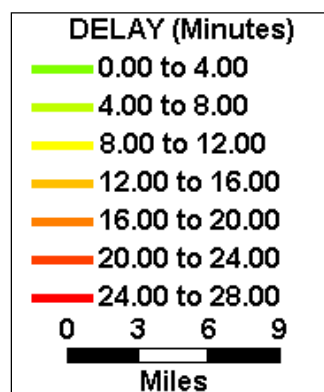




Figure 179: B3_S1_PM_Delay



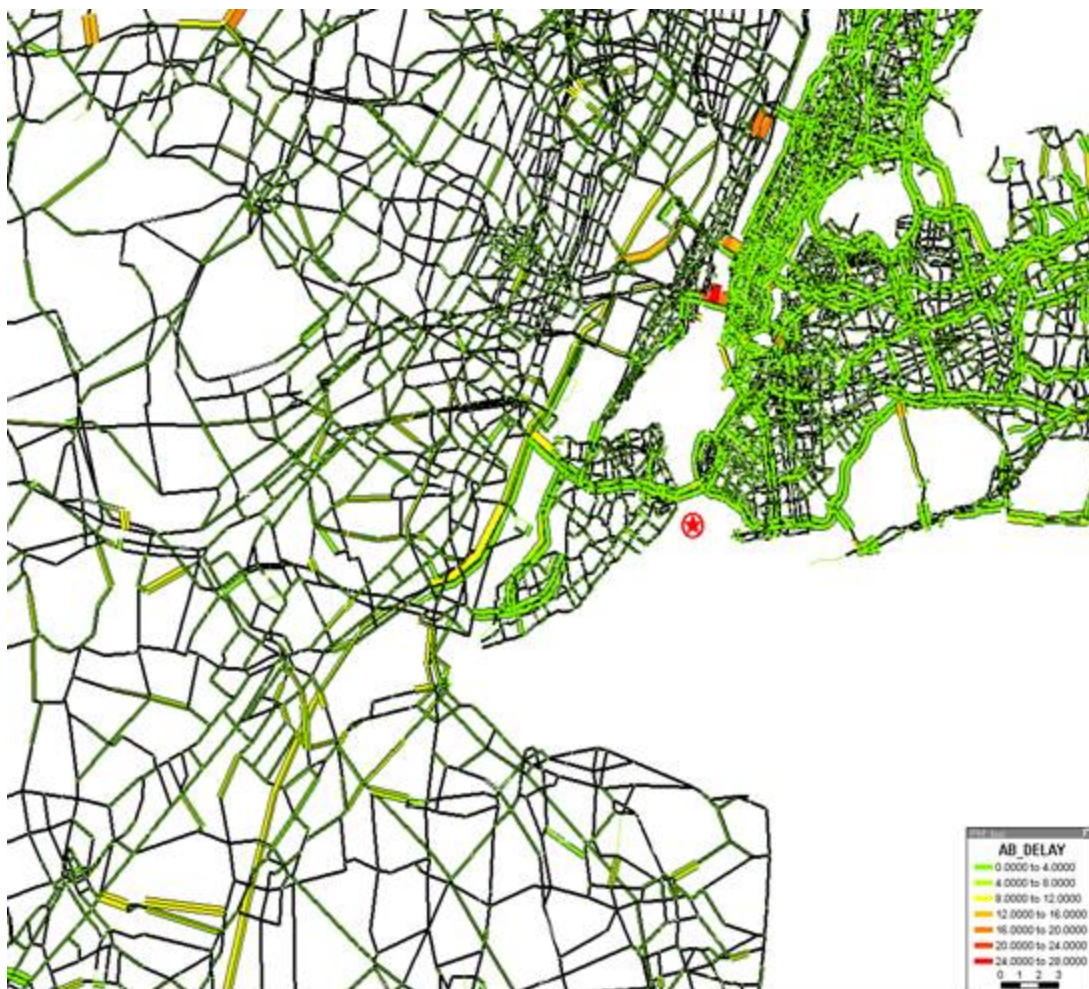
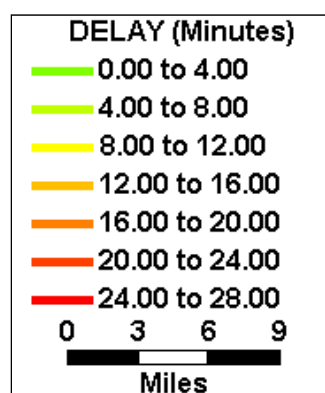


Figure 180: B3_S2_PM_Delay



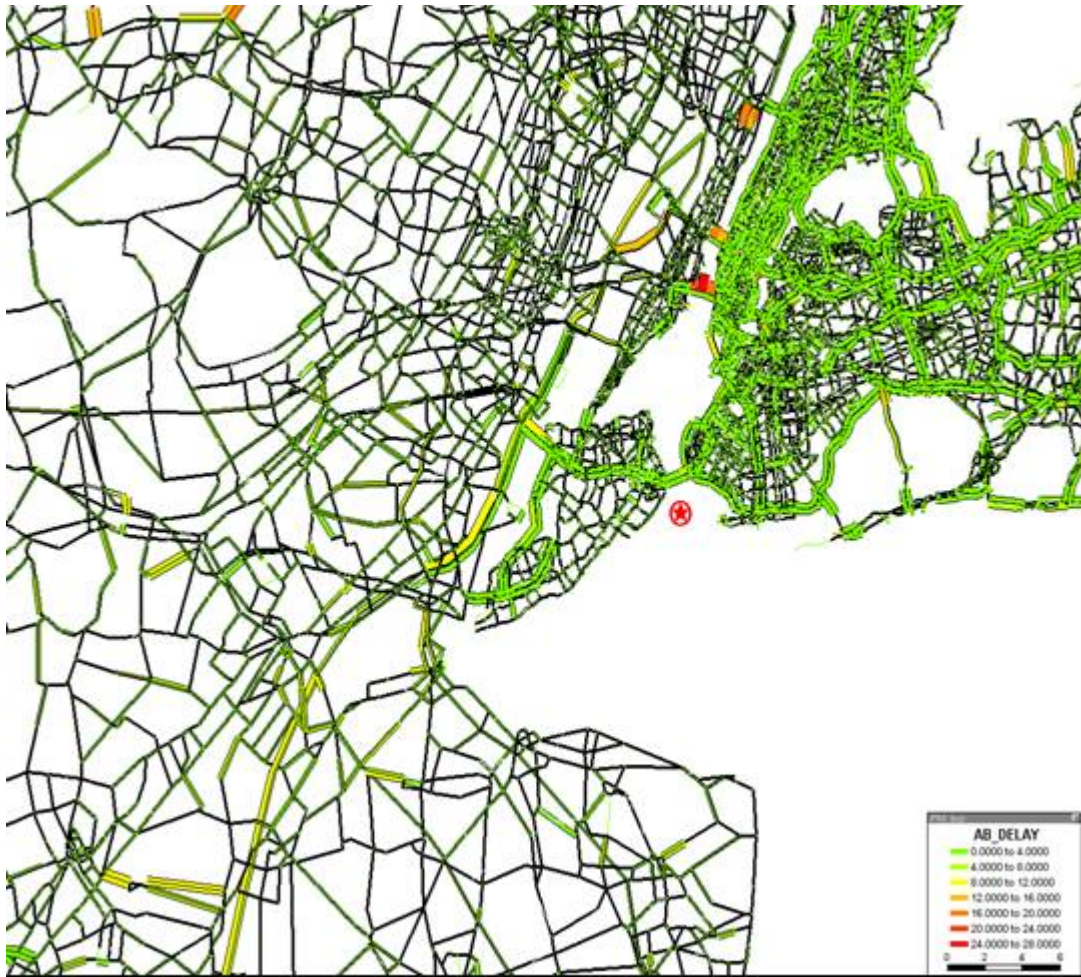


Figure 181: B3_S3_PM_Delay

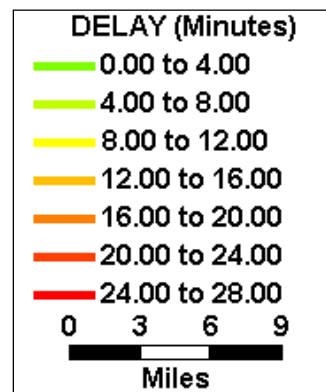
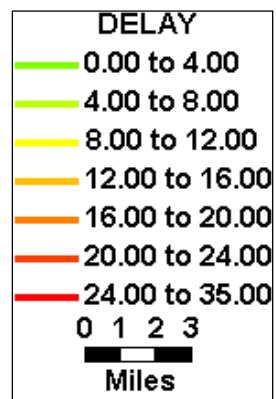




Figure 182: B3_S4_PM_Delay



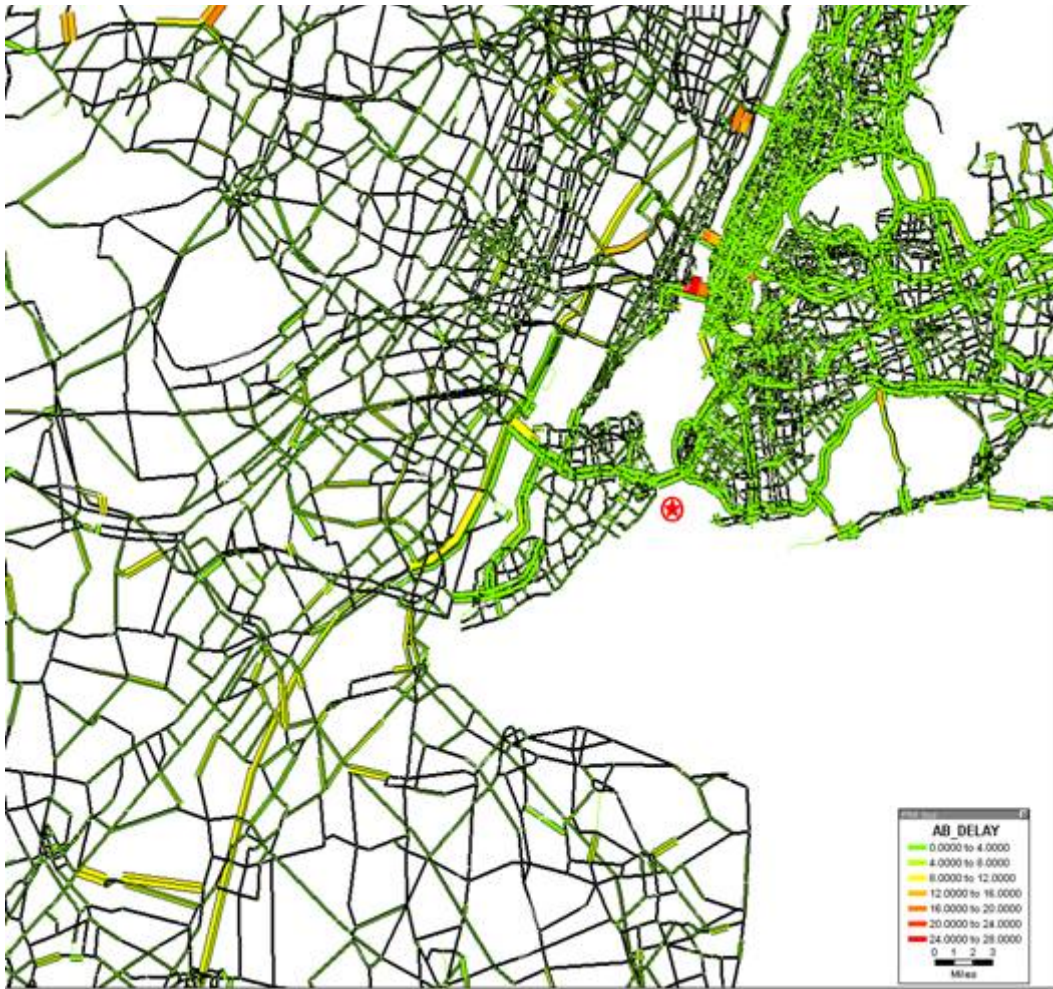


Figure 183: B3_S5_PM_Delay

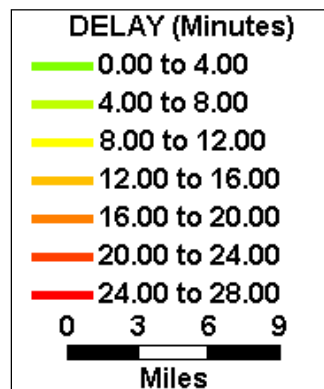




Figure 184: B3_S6_PM_Delay

