MODELING EMISSION FOOTPRINTS OF SUSTAINABLE LAND USE POLICIES AT LOCAL JURISDICTIONAL LEVEL

by

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A Dissertation
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Doctor of Philosophy
Civil Environmental and Infrastructure Engineering

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DEDICATION

To my beloved Guru, H.H. Sri Sri Bharathi Teertha Mahaswamiji and my beloved family whose love, support and blessings have motivated me to take up ambitious ventures in life.

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DISCLAIMER

The land use scenarios analyzed, assumptions made, hypotheses tested and conclusions reached in this research are academic in nature. Agencies who provided data for this research, such as MWCOG and Loudoun County, neither endorse nor disapprove the methodologies, assumptions, results and recommendations of this research.

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ABSTRACT

MODELING EMISSION FOOTPRINTS OF SUSTAINABLE LAND USE POLICIES AT LOCAL JURISDICTIONAL LEVEL

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Sustainable land use practices are redefining the urban form, mobility and therefore the transportation planning processes. Regional travel demand models are not sensitive to variables associated with land use practices at neighborhood level, such as transit-oriented developments (TOD). The first objective of this research is to quantify and compare land-use specific emission footprints at the household level (grams/household) for TOD and Non-TOD areas. Household travel survey data is used to stratify households into various TOD and Non-TOD zones. A comparison of means for emission footprints between Non-TOD and TOD land uses indicated that Non-TOD emission footprints are generally higher than the TOD footprints and the differences are statistically significant. On the other hand, the differences amongst pairs of TODs and pairs of Non-TODs showed no statistical significance.

As its second major objective, the research proposes a disaggregate methodology (the Methodology) that is sensitive enough to sustainable land use policies and allows planners to quantify emission impacts of the policies at sub-regional level. At the center of the Methodology is a sub-regional travel demand model with finer TAZ resolution than what is represented in the

regional model for the same sub-region. Different land use scenarios, including TODs, and transit patronages are represented in the experimental implementation of the Methodology for Loudoun County, VA, which is a rapidly growing suburban county in the metropolitan Washington D.C. area. Loudoun County's brisk growth, its emphasis on sustainable land use and transportation planning, and recent expansion of Metro Rail mass transit service in to the County presented a unique opportunity to develop and experiment with TOD scenarios in the end-to-end (from planning to modeling) implementation of the Methodology. The effectiveness of the Methodology is demonstrated by the results, which show that significant emission reductions can be achieved by sustainable land use policy implementation at sub regional level. Furthermore, unlike the regional models, the Methodology is found to adequately model sensitivity of emissions to land use, area type and facility type as established by statistical validation using analysis of variance technique.

1. INTRODUCTION

1.1 Background

Increasing transportation system capacity is among the most commonly opted solutions for metropolitan regions facing problems of increasing congestion and its related environmental impacts. But the decisions on what to build, where to build or looking towards any other non-capital solution are far more challenging than simply opting for capacity expansion. Political factors are central to transportation planning and therefore add complexity to the decision-making processes. It is known that true impacts of urban form on travel activity and emissions are a result of complex interaction among travel measures. Therefore, examining mobility indicators alone may not readily explain those impacts. For planning and regulatory purposes, it is imperative that an emission capture methodology for local governments be deployed to fully address such questions

Smart growth strategy, an integral part of sustainable transportation, is an approach to development that encourages a mix of building types and land uses, diverse housing and transportation options, development within existing neighborhoods, and community engagement. Included among foundations of smart growth are such strategies as transit-oriented development (TOD), new urbanism, and new towns are mixed land use, taking advantage of compact design, lowering demand for driving, and encourage walk, bike, and ride transit more (SGA 2017). Because of the reduced demand for travel, the smart growth strategies have significant potential of reducing motor vehicle emissions.

Transportation policies are developed at three levels; namely, state/federal, regional (e.g., a metropolitan region) and Local (e.g., a county or town within the region). Examples of policies at these three levels are shown in Figure 1-1. The primary obligation of federally mandated metropolitan planning organizations (MPO) is to develop a region wide transportation policy in coordination with local governments. For example, the Metro Washington Council of Governments (MWCOG) is the designated MPO for the Washington DC metro area. MWCOG oversees region wide transportation policy and planning in cooperation with several local governmental transportation authorities, which include several counties (e.g. counties of Fairfax, Loudoun, Prince William, Montgomery etc.) and cities (e.g. city of Fairfax, Alexandria etc). Governments of these local jurisdictions provide policy inputs to the regional metropolitan planning organizations (MPOs) in order to develop a cohesive regional transportation plan. However, the tools and methods used in developing regional plans are not adequate to model many policies adopted at the local level shown in Figure 1-1.

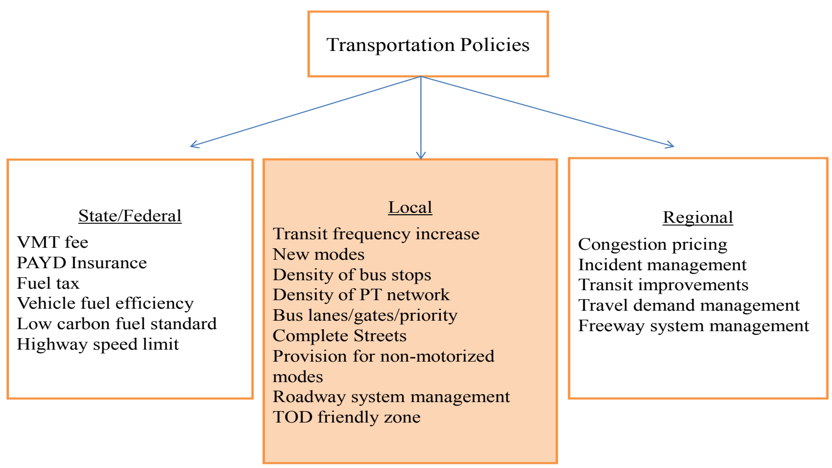


Figure 1-1: Transportation Policies Under Different Levels of Government

It is a challenge for the local governments to develop a valid attribution methodology, because disentangling the effects of regional policies from local policies is difficult. This study addresses this issue by isolating only the local level policies such as an alternative land use that can be implemented by the local government while listing the other state and regional policies incorporation for future work.

In addition to mobility and safety issues, emissions resulting from travel activity are associated with automobile dependency, trip distances and times, urban density, mode of transportation etc. Mobile source emissions are a leading cause of air pollution and are largely attributable to household vehicle travel (Frank, Stone, & Bachman, 2000). Emission of greenhouse gases such as CO_2, and criteria pollutants and their precursors (ground level ozone, oxides of nitrogen, carbon monoxide, etc.) can be a critical problem in areas with rapid growth and where future developments are expected (Bai et al., 2008). Urban sprawl leads to increased travel activity between major activity centers and the newly developed neighborhoods, thereby increasing transportation-related emissions. Due to significant growth of carbon emissions for multiple sectors, public policy issues are gaining attention thereby promoting transportation options such as reducing commuter trips through incentives for transit and carpooling options, sustainable land use practices and bicycle and pedestrian connectivity.

1.2 Modeling Smart Growth Strategies with Travel Demand Forecasting Methods

Travel demand forecasting at regional or metropolitan level is oriented almost exclusively toward analysis of long-term, capital-intensive expansion of the transportation system, primarily in the form of highways (Kitamura et al., 1996). Land use variables are embedded into the most popular four-step travel demand forecasting (TDF) process as socio-economic and demographic data at the zonal level. These variables are primarily used as inputs to the trip generation step. For computational ease, traffic analysis zones (TAZ) employed in regional modeling are large and often include several types of land uses. Therefore, by design, regional level TDF models represent several land uses at an aggregate level. On the other hand, land use planning geared towards smart growth tends to be smaller in size compared to a typical TAZ. This contrast presents a challenge to modeling impacts of smart growth strategies on regional or sub-regional mobility using TDF models at the regional scale.

Four-step TDF models at regional level were meant neither to estimate the travel impacts of neighborhood-level smart growth initiatives like transit villages, nor to estimate emission impacts of smart-growth strategies. Rather, regional TDF models were meant to guide regional highway and transit investments (Cervero, 2006). The rapid pace in adopting smart growth policies, the relative neglect of this land use phenomenon in the era of urban sprawl and limited availability of associated evaluation tools and methodologies has left policy makers and transportation planners in the United States with inadequate knowledge on the impacts of smart growth policies such as TODs on the transportation system and the environment. Travel demand parameters necessary to predict trip generation activity, develop trip distribution models, identify mode choice characteristics, and determine assignment of neighborhood-level trips such as TOD-based trips are yet to be fully explored. Of interest to planners are taking measurements on emission footprints of TOD when compared to Non-TOD land use alternatives. This research defines 'emission footprint' as quantity of a pollutant attributable to household travel activity. The units of emission footprints are grams per household when measured at the household level, or grams per thousand households when measured over a geographical area.

Impacts of different policy assumptions at state, regional and local level have been studied to the extent of quantifying impacts of land use scenarios on measures of effectiveness of the transportation system such as travel delay and v/c ratio. Land use scenarios that have been examined are existing conditions, trend estimates, compact development / TOD, mixed use, residential etc., along with policy scenarios such as mode shift and transit expansions on a statewide level (DuRoss, Taromi, Faghri, & Thompson-Graves, 2009). However, it would be beneficial to further study the impact of planned or future land use policy scenarios at a local scale on the intended benefits of those policies. Reduction in vehicular emissions is one such intended benefit of sustainable land use policies. However, by the very description of the Federal mandate, emission analysis is a focus at the MPO level and seldom a part of the land use and transportation planning process at the local jurisdictional level. When local governments can demonstrate that their policy options contribute to emission reductions, they can also claim incentives that are associated with such reductions through Federal grants such as CMAQ and TLC programs.

1.3 Impact of Transportation Policy Variables on the Environment

At the outset, land use policy and transportation policy are interrelated. However, modifying travel behavior or travel activity to address the energy or environmental requirement has not been the focus of land use and transportation planning (Saunders, Kuhnimhof, Chlond, & da Silva, 2008). This is because the environmental aspect is not within the realm of transportation planning itself but rather an extension of it. Environmental impacts are usually analyzed separately and the process involves cumbersome integration of different methodologies, software, platforms and data.

The four-step TDF method was developed well before the transportation emissions concerns came to the forefront of planning. However, the use of TDF method in policymaking at a regional level while considering environmental constraints presents significant challenges. In proposing an integration of the emission methodology into the planning process for evaluating land use policy options at a local jurisdictional level (such as county-level), it is imperative to check why stakeholders consider measuring emissions on that level (Deshazo & Matute, 2009)

a. Identify emission sources

b. Cross-sectional analysis between local governments

c. Longitudinal analysis for one local government

d. Understand local policy effects

e. Enforce multi-jurisdictional accountability schemes.

The air quality conformity is an extension of the planning process, which essentially conforms for any future and land use changes. The conformity process demonstrates if the total emissions projected for a Regional Transportation Plan (RTP) or a Transportation Improvement Program (TIP) is within the emission limits established by the State Implementation Plan (SIP) for future emission reductions. Emission reductions can be achieved by localized policy implementation through reduction in vehicle miles of travel and alternative land uses that promote transit use such as transit-oriented development (TOD). Quantifying these emissions is the first step in gaining insight into environmental benefits of a TOD versus a Non-TOD area.

The purpose of this research is to address policy concerns and problems related to sustainable land use scenarios by estimating the resulting impact on environment and attributing the impacts of those policies at a local jurisdictional level. Such information is valuable in contributing to decision-making. A local government's successful planning relies on the policies, which direct towards a sustainable result. In addition to the policies, the decision makers require an easy to understand assessment methodology for appropriate evaluating various alternatives under consideration. A mobility and emission assessment tool similar to prevailing state of the art tools (or methodologies) would increase the chances of adopting such tool by analysts and planners. Addition of such methodologies into the realm of transportation planning processes would add robustness to the decision-making process as well help integrate engineering requirements with policy. In this respect, an ideal methodology would be able to attribute specific level of emissions to specific land use policies adopted by a specific local government.

1.4 Research Outline

The overarching goal of this research is twofold:

1. To systematically study the effects of travel behavior on emissions associated with sustainable land use; and
2. To provide planners, at metropolitan and local levels, tools and methodologies to take measurements on the travel activity and associated emission impacts of smart growth land use policy options.

1.4.1 Research Questions

To accomplish its goals, the research addresses the following fundamental questions related to emission characteristics of TOD.

1) Do emission footprints (grams/household) of travel activity within TODs and Non-TODs differ significantly from each other?
2) Given the fact that TODs tend to be localized and relatively small in size within large metropolitan areas, how best we can model the impacts of TODs on travel and emissions using traditional travel demand modeling techniques?

1.4.2 Premises

The following research premises are based on the above questions.

1) Emission footprints (grams/hh) of TODs and Non-TODs significantly differ from each other.
2) The impacts of localized smart growth land use policy scenarios, such as TODs, on emissions can be measured using sub-regional four-step models. Should the

beneficial impacts be quantified, the benefits can be attributed to the local jurisdiction for seeking incentives such as regional, state and federal funding.

1.4.3 Approach

The two-step approach to this research is as follows:

1) Study travel and emission characteristics of existing TODs and Non-TODs in a metropolitan region and test premise #1
2) If premise #1 cannot be rejected, develop a methodology to test premise #2. If proven, recommend the methodology for planners. If not, conclude that the four-step model may not be used for modeling localized land use policy not only at regional scale, but also at local-level.

The study incorporates experimental setups that control for various independent variables such as proximity to heavy-rail station, area type, and facility type and transit patronage.

1.5 Organization of the Document

The remainder of this dissertation document is organized as the following sections.

- A comprehensive review of literature on the topics related to this study elements is presented in Chapter 2;
- Chapter 3 provides details of the study process via description of data, proposed disaggregate Methodology, and experimental analysis;
- In Chapter 4, emission footprints (in grams per household) specific to TOD and Non-TOD are derived and the variation of footprints between TODs and Non-TODs is studied;
- Chapter 5 provides the data and model description; experimental setup and implementation of the disaggregate Methodology for sub-regional analysis.

- Analysis results of the modeling exercises in implementing the Methodology are presented in Chapter 6
- Conclusions, recommendations and limitations of the study are discussed in Chapter 7.
- Data, SAS code and output pertaining to analyses described in Chapter 4 are presented in Appendix A
- Tabular and graphical results of the analysis using the proposed Methodology (Chapter 6) are presented in Appendix B
- SAS code and output pertaining to statistical analyses performed in Chapter 6 are presented in Appendix C

2. LITERATURE REVIEW

This chapter presents an extensive review of literature on characteristics of smart growth land use alternatives, the applicability of the travel demand forecasting process to measure mobility and emission impacts from these alternative and the methods associated with taking such measurements.

2.1 Characteristics of 'Smart-Growth' Land Use Alternatives

Creating 'livable' and 'walkable' communities concentrated along major transit corridors is the focus of recent land development trend in the United States. The concept of 'smart growth' has been recognized as a robust urban planning alternative to the status quo of urban sprawl. The basic tenet of smart growth is to slow the decentralization of urban development from urban centers to suburban areas (Faghri & Venigalla, 2016; and Brennan & Venigalla, 2016). Smart growth policies require reinvestments in urban areas through reconstruction of existing communities and brown fields to promote higher density mixed use developments combined with open spaces and reliable public transit system. The US Green Building Council specifies compact development (CD) as a form of land use that conserves land; promotes livability, walkability, and transportation efficiency, including reduced vehicle distance traveled; leverages and supports transit investments; reduces public health risks by encouraging daily physical activity associated with walking and bicycling.

2.1.1 Transit Oriented Developments (TOD)

Transit Oriented Developments (TOD) have been discussed for decades and the implementation of this land use phenomenon is still growing along with relevance and popularity.

TOD is essentially a combination of a type of development style that combines high-density, mix-use and pedestrian friendly development. This combination promotes a unique lifestyle for residents by not only serving as a hub for connectivity to other destination but also encourage people to walk and use transit more often to a host of nearby activity centers.

In this research 'smart-growth' land use primarily refers TOD and compact development. Several institutions and agencies such as Transit Oriented Development Institute, National League of Cities' (NLC) Sustainable Cities Institute, and Center for Transit Oriented Development (CTOD) have defined TOD. NLC has defined TOD as an approach to development that focuses land uses around a transit station or within a transit corridor. Transit Oriented Development Institute defines TOD as creation of compact, walkable, pedestrian-oriented, mixed-use communities centered on high quality train systems. CTOD has defined TOD as compact development (CD) within easy walking distance of transit stations (typically a half mile) that contains a mix of uses such as housing, jobs, shops, restaurants and entertainment. Therefore, this research treats CD and TOD as one and the same.

Included among other definitions for transit-oriented developments are the following:

- TOD is a development that aims to increase transit ridership and use, while granting access to more job centers, educational opportunities and cultural facilities while providing a pedestrian friendly environment (Cervero, Ferrell, & Murphy, 2002)
- TOD is a component of smart growth that positively influences transit ridership (Cervero, 2006).
- TOD is an urban planning strategy when paired with regional policies enable reductions in energy use and environmental impacts of urban living and transportation (Nahlik & Chester, 2014).

- TOD is a design strategy to encourage use of public transit and create a pedestrian friendly environment and thus cope with congestion and environmental issues. The authors also characterize TOD as a type of development where residents live within walking distance of a major transit station and aims to encourage the use of transit thereby reducing auto trips (Nasri & Zhang, 2014)

Alternative land use projects such as Infill and Mixed-use that are located near transit or land use such as TOD, are successful in reducing single occupancy vehicles or auto drivers and encourage the use transit (Danieau, 2009). TODs have gained a relevance as an “urban planning strategy” to encourage smart growth, economic revitalization. Also said to facilitate reduction in environmental impacts of urban living and transportation when paired with regional policies (Nahlik & Chester, 2014) Thus, TOD as a smart growth land use alternative attempts to reduce auto trips by promoting use of public transit and developing high density mixed land-uses (Crowley, Shalaby, & Zarei, 2009; Still, Seskin, & Parker, 2000). However, these strategies lack evaluation tools that can assess the TDM and mode shift strategies at a “smaller scale” (Rosenbaum & Koenig, 1997)

Faghri & Venigalla (2013) addressed the gap in methodologies for developing and validating disaggregate mode choice models for work trips associated with TOD. The study used the travel activity data from the 2007/2008 household travel survey within the Washington DC metro area for model development and validation. Faghri & Venigalla (2013) also studied the trip-making behavior of the TODs and developed a method for determining vehicular trip generation rates in TODs. A comparative assessment of TODs vis-à-vis Non-TODs in relation to trip rates, transit usage, and primary travel mode was performed for the Metro Washing DC area. (Cervero et al., 2002) ascertained that neither trip generation nor mode choice models included density or any other land-use variables. Time constraints and data limitations precluded the recalibration of models to directly account for built-environment influences. Disaggregate models have potential for use in various sketch planning tools, which are commonly employed during the preliminary planning stages of TODs.

There are limited data and analyses to ascertain the net shift in travel modes of TOD residents before and after relocating to a TOD environment (Hendricks, Fleury, Flynn, & Goodwill, 2005). The 2003 California TOD travel characteristics study as well as the 2005 surveys of Portland area TODs and transit-adjacent developments for the TransNow Center attempted to determine the net mode shift in TOD residents before and after relocating to a TOD environment. Results of these studies ranged from 2 to 16 percent gain in transit mode share after relocation (Evans, Pratt, Stryker, Kuzmyak, & others, 2007). The gain in transit mode share included a significant change to the workplace by the TOD residents The correlation between transit mode share and the proximity of workplace to a transit station is equally important to mode shift in a TOD environment than the place of residence alone (Cervero, 1993).

2.1.2 Mass Transit Stations and TOD

A number of studies have identified 400 meters (0.25 miles) radius around a mass transit station as the ideal walking distance for a successful patronage of transit among TODs. Alshalalfah & Shalaby (2007) and O'Sullivan & Morrall, (1996) indicated that the average walking distance to suburban stations in the city of Calgary was 650 meters (0.40 miles) with a 75^{th} percentile of 840 meters (0.52 miles). However, the average and the 75^{th} percentile walking distance at CBD stations were 325 meters (0.20 miles) and 420 meters (0.26 miles), respectively (O'Sullivan & Morrall, 1996). On the same note, Cervero (1993) determined that the number of residents in the San Francisco Bay Area who moved to 0.5-mile radius of a transit station and switched their mode of travel from personal passenger car to transit exceeded 50 percent.

Literature suggests that availability of transit options tends to reduce vehicle trips and vehicle miles of travel. Faghri & Venigalla (2013) investigated this argument by extracting the mode and travel data for TOD and Non-TOD environments data from MWCOG's household travel survey. The employments and number of household compared followed by a contrast of vehicle ownership data are examined are similar for both transit and non-transit environments. TOD selected for this analysis is the Rosslyn Ballston corridor with a mass transit option which exemplifies a transit oriented corridor and the Non-TOD selected for the analysis is Loudoun County in Northern Virginia, an existing suburban type environment. The selection of TAZ's is based on 0.25-mile radius of all Washington Metro Transit Stations. The 0.25-mile radius is selected deliberately as this is the ideal walking distance to a transit station. Finally, all trips to and from TOD zones is examined and is compared with rates of a Non-TOD zone.

2.1.3 Travel Characteristics of TODs

Nasri & Zhang (2014) studied how travel behavior is different for TOD residents in the Washington DC and Baltimore region by examining changes in VMT. They studied whether a proposed or an implemented TOD can reduce vehicle miles of travel in the urban area. The study establishes a quantitative methodology to identify a TOD based on three factors:

1.Walkability and high density

2. Walking distance to a transit station

3. Collaboration of mixed uses and transit

Both studies by Faghri & Venigalla (2013) and Nasri & Zhang (2014) used 2007-08 household travel survey data for the analysis and identifies traffic analysis zones based on land use variables such as residential density, employment density, land use mix, average block size also referred to as street connectivity measure and distance from CBD. The TAZs were identified as TOD of the above indicated densities were greater than the average density values of the entire metropolitan area. However, this is questionable because the densities across any metropolitan area and the densities across TOD can vary. The dependent variable- household VMT is calculated as per-person VMT and only trips shorter than 50 miles were considered while anything greater were considered as long distance trips.

The Nasri & Zhang (2014) study built on the conclusions by a preceding study by Zhang, Hong, Nasri, & Shen (2012), which observed that a higher density resulted in a lower VMT and a bigger block size resulted in higher VMT. The study concluded that TOD areas tend to drive less thereby reducing their VMT by 38% in the Washington D.C. area and 21% in Baltimore compared to residents of Non-TOD areas with similar land use patterns. The study also observed that in the metropolitan areas of Washington D.C. and Baltimore, the average household size, auto ownership, annual income of a TOD is lower than that of Non-TOD. Percentage of zero vehicle households is greater about 23% in TODs compared to 9% in Non-TOD areas. Percentage of work and non-work trips by transit or non-motorized mode is half of all work trips in TOD than Non-TOD areas. The study revealed transit accessibility (measured by density of bus stops) has a negative impact on household VMT meaning, greater the accessibility lesser the VMT. The study used a multi-level mixed effect modeling to show a strong association among VMT, but environment and living in TOD while controlling for potential effects socioeconomic status using household size, income, vehicle ownership and workers.

L. Zhang et al., (2012) also confirmed that living within a walking distance to transit and TOD will alter travel behavior toward a sustainable manner with less driving and more transit use which thereby decreasing congestion and pollution. An extension of the study would be to perform a mode choice analysis to see how transit share is different in TOD and Non-TOD areas as opposed to other modes considering all effective factors. However, M. Zhang, (2010) indicates that having higher population and employment densities in TOD areas typically generate more traffic thus worsening congestion rather than improving traffic conditions in TOD and surrounding areas which contradicts the general belief about TOD which aims to reduce traffic congestion by promoting other modes of transportation. Not only it would be beneficial to develop a continuous score rather than binary variable used in the study to better address characteristics of TOD areas and their potential impact but also examine the TOD impacts of TOD on a local or TAZ level.

A few mode choice studies of TOD residents and office workers typically show that transit travel times and their comparison to private car travel times is the strongest predictor of transit ridership. In other words, travel time differentials are a critical factor, and these differentials can vary greatly depending on local circumstances (Arrington & Cervero, 2008). In a study on transit usage by residents of TODs by various trip purposes, Chatman (2006) randomly selected households and workers within 0.4-mile radius of transit stations in San Diego and San Francisco, California, and collected 24-hour activity and trip diary via phone survey. The study concluded that people living or working near Metrorail stations have a higher non-auto share of commuting and non-work travel. The study further determined that the non-auto share dissipates as the proximity to transit stations increases.

Mudigonda, Ozbay, Ozturk, Iyer, & Noland (2014) compared costs associated with driving and transit for TOD land uses in New Jersey to assess and derive the net benefit for transportation system users as a result of the TOD. Driving costs included such vehicle operating costs as fuel, wear and tear, and depreciation; value of time based on highway travel time, parking cost and cost of externalities such as air and noise pollution. Transit costs were composed of fares, parking costs, and values of travel time, waiting time, and transfer time. The study found that, in general, TOD results in financial benefits to the user and the transportation system.

Messenger & Ewing (1996) observed that bus mode share by place of residence proved primarily dependent on automobile ownership and secondarily on jobs-housing balance and bus service frequency. Automobile ownership, in turn, proved dependent on household income, overall density, and transit access to downtown. Thus, three types of variables – socio-demographic, land use, and transit service – were found to affect bus use through a web of interrelationships.

Gebeyehu & Takano (2007); and Ma, Liu, & Chai, (2015) observed that bus fare, convenience, and frequency have significant effect on user satisfaction with bus services. Using a binary logit mode, Lin & Jen (2009) found that household income, household size, and floor space needs are negatively associated with TODs and presence of children or elder family members and preference for mixed land use are positively associated with TODs. The degree of association is related to the preference of living in a TOD environment. Higher income people tend to prefer to live in suburbs where land is more generous and privacy is abundant. The results of the study Lin & Jen (2009) indicated general consistency with the hypotheses. However, household size is found to have a negative impact on the decision to live in a TOD community, in contrast to the hypothesis, having children or elder family members were positively associated with the preference to live in a TOD area.

Cervero et al., (2002) argued for the explicit inclusion of land-use variables in the utility expressions of mode choice models in urbanized settings. Recalibrating mode choice models to incorporate characteristics of built environments is no easy task, in part because in many metropolitan areas variables related to land-use diversity and urban design are not readily available. Furthermore, TODs are usually much smaller in size than the smallest geographic aggregation units, also known as the traffic analysis zones (TAZ), in the traditional travel demand modeling methods such as the four-step planning process. For this reason, TOD data are aggregated to the level of its TAZ, thereby losing the fidelity of the TOD influence on trip making and travel behavior.

Guthrie & Fan (2016) conducted a series of interviews with 24 residential and commercial developers in the Twin Cities region. The analysis indicated that developers see transit as making compact, walkable development more profitable. Developers also see potential for synergy between TOD and affordable housing.

Bartholomew & Ewing (2008) conducted a meta analysis of a wide range of scenario planning studies to determine how far compact growth scenarios (such as TODs) are predicted to reduce vehicular travel below existing trends. Using hierarchical modeling the authors developed a regional VMT model based on 85 scenarios in 23 planning studies from 18 metropolitan areas. Using coefficients from this model, the authors conservatively estimated that compact growth scenarios reduce VMT in 2050 by 17% below scenarios assuming a continuation of existing trends. Other sources suggest that other driving elements for a true TOD are mixed use design is high capacity transit, jobs-housing balance and balanced parking policy

Studies show that a true TOD will include the following (Danieau, 2009):

- Destination within 1/4th mile of transit stop or or a 5-10-minute walk
- Land use mix that can generate 24-hour ridership
- Minimum parking requirements are abolished. Maximum parking spaces are less than 500
- Efficient transit with a headway of 5mins of less
- Reduced speed limits and roadway space allocated for convenience of bikers and pedestrians
- Auto levels of service are met

Planners believe that integration of land use and transportation considerably improves travel results. Auto oriented areas such as Perth in Australia and Southern California transformed into TODs with introduction of active transportation systems because of transit and land use integration. The characteristics that define a true TOD can be classified as three D's – Density, Diversity and Design TOD varies from a Non-TOD in characteristics and involves integration of land use and transportation into planning techniques (Flores, 2013). While keeping Flores's 3D framework for TOD, some key features that differentiate a true TOD to a Non-TOD can be listed as follows. Table 2-1 shows features of existing regional TOD and Non-TOD areas namely Rosslyn-Ballston TOD corridor in the D.C metropolitan region in comparison to a currently Non-TOD Loudoun County.

Table 2-1: TOD Characteristics

Characteristic	Features	TOD Range in DC Region/ RB Corridor	Non-TOD Range around DC Region
Density	Population Density	35 persons/acre*	1.69 persons/acre
	Employment Density	41 persons/acre*	1.69 persons/acre
	Residential Density	16 households/acre*	0.6 households/acre
Design	Pedestrian Connectivity	Considerable to significant accessible walkway connections to the adjacent parks, services, and public sidewalk system	Sparse connectivity
	Walkability Index/Walk Score	68/100	33/100
	Four way Intersections for walkability	Pedestrian crossings at every intersection / block	Mostly arterials and collectors with few or no pedestrian access or crossings
	Smaller Block Size	Yes	No
	Parking Supply	Parking supply for high rise commercial and some street parking	Open parking lots
	Bicycle Facilities	More bike infrastructure and connectivity	Very less connectivity
Diversity	Land Use Mix		Mix of Land Uses
	Non-Residential Intensity	3-6 FAR envisioned for compact scenario	
	Employment		
	Public and Civic Spaces	Medium to High in walkable distance	Low to Medium in drivable distance.

2.2 Modeling Smart Growth Land Use Policy Impacts on Transportation System

Smart growth policies are localized land use plans and are akin to project-level improvements in the traffic operations (e.g. specific to a single intersection or an arterial segment) in the sense that regional TDF models do a poor job of predicting the impacts of these two elements on the transportation system. In the conventional four-step trip-based TDF, the unit of analysis is individual trips. Travel forecasting using the TDF models is usually carried out in the following sequence, as briefly presented here.

i. The first step involves the geographic aggregation of land uses into homogeneous traffic analysis zones.

ii. Trip generation models, which may be linear regression models or cross-classification models, are used to predict the number of trips into and out of each zone. The trip generation models depend on socioeconomic parameters as predictor variables. These parameters include residential density, employment, household size, household incomes, household vehicle characteristics, and trip making habits.

iii. Trip distribution models are then employed to link the trip ends predicted by the trip generation models. This results in the prediction of origin-destination flows.

iv. Modal split models are then used to predict the percentages of flow carried by the various modes available for travel between each origin and destination pair.

v. The final step (traffic assignment) involves the use of models to assign origin-destination flows for each mode on specific route of travel through the network being modeled based on various types of algorithms. The methodology for the traffic assignment step varies with respect to the highway/transit travel model (Kumapley & Fricker, 1996; Meyer & Miller, 1984).

In a widely cited study, Cervero, (2006) observed that regional TDF models were never meant to estimate the travel impacts of neighborhood-level smart growth initiatives like transit villages. The TDF models were originally meant to guide regional highway and transit investments. The study cited efforts to enhancing large-scale models and post-processing methods and direct models to reduce modeling time and cost, and to better capture the travel impacts of neighborhood-scale land use strategies such as TODs.

In a tour based TDM, however, the tour is the basis of analysis. A tour is defined as "a closed chain of trips that begin and end at the same location. Trips are intermediary stops along the tour" (CTR 0-6210-2, University of Texas, Austin, 2009).

As tour-based travel demand models emerge as a new state-of-the practice to analyze travel characteristics of a region, many planning organizations determine the need to for 24-hour activity-based household travel survey. However, due to the limited adaptation of ABM, this study methodology focuses solely on the adapting TDF for modeling smart growth land use. Further, travel forecasting using TDF has evolved over the last 55-years and extensive knowledge base and literature are available on this subject. Therefore, limited coverage of literature is presented on this topic as it relates to this study.

2.3 VMT Estimation

VMT estimation using Gridding method- Estimating block group residential VMT and assigning it to the census tracts split by income, area type employment rate and number of vehicles. This is a new method introduced by the Department of Agriculture (USDA) which estimates the VMT rates for census tracts and disaggregates it to the block group level. The methodology allocates commercial VMT to the near interstate block groups by time of day to a 1 Km^2 grid (Stone, Obermann, & Snyder, 2005)

Polygon method VMT measures- The polygon method is the sum of all VMT that occurs within the city boundaries. This method considers the pass-through trips but truncates the longer trips at the city boundaries. Thus not reflecting the demand for VMT exerted by the cities because a "commuter shed" in the metropolitan areas extends well beyond the city limits to bigger political jurisdictions like counties (Hillman, Janson, & Ramaswami, 2009)

Highway/Transit Network Model VMT Estimation or “Demand VMT” - VMT estimates obtained by this method is generally accurate for models that are well calibrated with actual traffic data (18). These models are known to be good tools, capable of forecasting the effects of future policy actions (Kumapley & Fricker, 1996).

The VMT from demand models are often used for air quality modeling and impact assessments of new developments or changes in the transportation systems (Hillman et al., 2009) . The study showed a comparison of polygon to demand based VMT with an error or difference in VMT by 1.7% The study also proves that the demand based methodology is fully sensitive to percentage mode shift, highly correlated to employment intensity with an R2 of 0.97 but not so much to employment density with R2=0.59 which was better than 0.32 for employment density. As this is the most used and considering the relevancy to the research of using travel demand modeling as a policy tool we use this type of VMT estimation technique (Hillman et al., 2009).

HPMS Estimation method: The HPMS method of VMT estimation involves the use of adjusted 24-hr traffic counts, referred to as annual average daily traffic (AADT), and obtained on sample sections identified through a systematic stratified random sampling process. The sample section VMT is estimated as the product of the section AADT and road segment mileage. The sample section VMT is tended using expansion factors to obtain the area wide and universal VMT estimates. The information on centerline mileage for all roads in the state is available; however, information on traffic counts is unavailable for some functional classes, such as local roads in the state network. The accuracy of VMT estimates produced by the HPMS method is therefore dependent on, but not limited to, the representative nature of the samples from the state network. A second shortcoming is that HPMS is designed to concentrate on federal-aid roads only, with virtually no provision for local roads (EPA 1992; Kumapley 1996; FHWA 1995).

Elastic demand traffic assignments concepts: Arampatzis extended the traditional travel demand model and achieves consistent estimates for predicting equilibrium between supply and demand. However, this method is not valid, as it does not relate to the use of traditional travel demand modeling that is being used in this study. For this study as this method is developed requiring the GIS platform and is out of scope of this study.

- VMT estimation based on fuel sales
- VMT estimation from odometer readings
- VMT estimation from household and driver surveys
- VMT based on spreadsheet analysis using varied parameters like socio economic data, fuel sales etc.

2.4 Currently Used Alternative Approaches to Regional Model

Large-scale models have been enhanced and studies have turned toward post processing model outputs from the four-step model using elasticities to account for impacts of density land use and elasticities on trip generation. This expedites the process by saves considerable time and cost of recalibrating large-scale models (Cervero, 2006). Often, post-processing is used as evaluation model to reflect impacts of transportation demand management than to explore influences of smart growth. One such study was to examine the travel impacts of a Steel site redevelopment in Atlanta. The redevelopment of which was frozen because of the region's non-conformity to federal air quality standards. The study also involved examining impacts of mixed use infill development near rail transit that could yield air quality benefits. However, the Atlanta

Regional Commission's four step regional model was not sensitive to such local land use changes and a post processed its outputs by justifying their adjusted modeled trips and mode choice from other similar studies in San Francisco, Portland and other areas (Walters, Ewing, & Schroeer, 2000). The Atlanta study also concluded that the Atlantic Steel project would produce 52% fewer trips than the same developmental in a greenfield location by post processing their regional model output. These post processed results were of central importance in EPA's decision to permit redevelopment of the Steel plant with mixed use development near transit (Cervero, 2006).

Post Processing of outputs from the regional MWCOG model has also been used widely used to predict daily traffic for various land use scenarios such as for the New Carrolton Metro Station TOD Development (MNCPPC, 2010) and for planned Legacy Parkway west of Salt Lake City. However, for Salt Lake, the final Environmental Impact Statement was delayed on grounds that mass transit potential of handling projected traffic increase along this busy corridor was not fully explored. Elasticities were adjusted to result in less than 1% increase in 2020 transit ridership forecasts along the planned corridor in Salt Lake Wasatch Front Regional Council's four-step model's outputs were post-processed to incorporate travel impacts of TOD and transit service enhancements (Cervero, 2006). Studies such as Cervero & Kockelman (1997), Ewing & Cervero (2001) have found density, land use development patterns and pedestrian access reduced trip rates and VMT.

Finally, an alternative growth scenario was assessed in the Baltimore, MD region using post-processing. The growth scenario included shuffling households into an employment rich corridor and analyzed a mixed-use developmental pattern within the area of study. The household vehicle ownership and VMT models were developed from a recent household travel survey data similar to the effort in studies by Faghri & Venigalla (2013, 2016).

Having initially estimated the impact of household shift and transit service using the Baltimore Metropolitan Council's conventional travel model for growth impact assessment, elasticities were then applied to post process the results. While the regional model showed acceptable sensitivity to transit shift, it however was insensitive to the household relocation. Therefore forecasts were obtained by applying vehicle ownership and VMT models to the County and Study area TAZ level (Cervero, 2006)..

Direct or offline models that use elasticities and incorporate self-selection effects are far too specific and intuitively lose credibility while extrapolating on to a sub-regional scale. Regional model as are way to vast to capture land use impacts locally and direct models require way too much detail starting from densities.

However, these issues are addressed when taking a unique approach to capture travel activity and emission impacts using a sub-regional conventional four-step travel demand model. The impacts due to land use policy changes such as TOD that encompasses medium to high-density employment and other land use scenarios such as suburban or residential development scenarios.

Another approach taken is using travel survey data for estimating total emissions is by exploring significance of land use factors such as work trip distance, households, connectivity density etc on vehicle emissions that show significance of these factors through statistical data analysis and equations. The study by Frank et al., (2000) shows that air quality benefits could be achieved through land use approaches that reduce vehicle travel distance and time. Having said that, using travel survey data cannot allocate these impacts on the local transportation network. Such an approach is a single path approach that may not lead to multiple benefits. Moreover, it is not a user-friendly model or methodology to deploy across local governments for policy decision making that shows tangible results. Using models from a travel survey can't be seamlessly applied to any region due to the variation of the travel survey data that is captured across regions. For, example the methodology designed by Frank et al., (2000) can only be used with other travel survey data only when information about mode of travel, time of day at which trips began and ended, travel distance is captured. It could estimate emissions only for the region without allocating any emission to a specific jurisdiction. This shortcoming that local land use density changes and their impacts are not allocated to the sub-region, prevents the jurisdictions from receiving any incentives, grants or emission reduction incentives that may be extended by Federal agencies.

When increase in densities is proposed within existing local jurisdictions, it results in a need for infill development and adoption of growth management programs to occur that needs intergovernmental coordination at the regional level. For example, Loudoun county, where activity centers are planned or TODs are envisioned, would require it to coordinate with MWCOG for growth management programs and to "commit" to its initiatives guide book for emission control, reduction and progress towards clean air.

This research examines the potential for sub-regional models to model and capture the travel activity changes due to land use; allocate these impacts locally, within districts and on local transportation infrastructure.

2.5 Emission Analysis and Transportation Planning

Since early 1970s the four-step TDF models have been tweaked and their outputs are post-processed to meet the regulatory need for transportation air quality analysis (Venigalla, Chatterjee, & Bronzini, 1999). The Clean Air Act mandates that transportation investment projects must conform to the emission reduction plans (known as State Implementation Plans or SIP; Transportation Improvement Program or TIP; Fiscally Constrained Long Range

Transportation Plan or CLRP) for criteria pollutants and their precursors (viz. ground-level ozone, airborne lead, particulate matter, oxides of nitrogen, and sulfur dioxide) submitted to the Environmental Protection Agency (EPA). This regulatory review process is called Conformity determination.

Travel measures such as vehicle miles of travel (VMT) and estimated speeds obtained from the TDF models are used in combination with emission factors derived from emission factor models such as EPA's MOVES model to develop emission inventories for compliance with the Clean Air Act. Literature review indicates that the use of TDF to measure emissions impacts of local-scale land use policy decisions is limited. For example, MWCOG acknowledges that local governments for several decades have adopted strategies and implemented programs that help to improve air quality for the entire region. However, MWCOG also contends the following (MWCOG, 2014):

> "*COG began tracking the Air Quality Index (AQI) and issuing daily air quality readings in 1970. This led to work with local governments to reduce air pollution in the region, and to build public awareness of air quality issues. Though important, most local measures are not easily quantifiable and/or are not being credited in the SIP. Additional initiatives continue to be explored and are of significant interest, but have not been fully implemented by state and local governments because of a shortage of time or resources.*"

Previous emission modeling research has been further refined to create a new framework/tool to quantify measurable emission footprint into transportation planning and policy on a local level. The local level as best spatial scale is defined as counties as they are recognized as a political unit with authority to formulate local policies (Parshall et al., 2010). Current methods to inventory GHG emissions from within the geopolitical boundaries of a jurisdiction do not meet current needs for local GHG measurement (Deshazo & Matute, 2009). Currently there is a need for local measurement approaches to address and overcome existing accuracy and attribution issues. Land Use planning strategies and transportation demand management strategies have a common goal of reducing/managing traffic volume and to an extent contribute towards GHG reduction.

Emission reductions attributable to land use vary based type and level of policy or strategy and magnitude of implementation (Wilson et al., 2009). The study indicates that facilitating reduction of future GHG emissions needs travel behavior changes such as increased mode share and trip reduction. Mitigation is also possible with effective land use changes such as TOD. Wilson's study estimates that smart growth initiatives and TODs have a 12% reduction potential for transportation emissions through smart growth initiatives. Kay (2014) studied lifecycle emission reductions using a combination of vehicle-fuel technology and behavioral policies such as mode shift and land use. The study analyzed such combination scenarios including one such land use + transit scenario simulating growth in household and employment growth in TOD core and in zones 3-12 miles from transit station. Aggressive transit use was assumed which resulted in 2.8% of reduction in emissions from 2040 baseline and 18% reductions in lifecycle GHG emissions from 2000 levels.

Frank et al. (2000) developed a methodology to quantify and understand cause-effect relationships, between land use, travel patterns and vehicle emissions using travel survey data at regional scale for Pudget Sound. The study explored interaction between measures of land use such as household density, employment density, block density and vehicle emissions estimates to see if vehicle emissions are sensitive to land use. It also tested the relationship between travel variables such as VMT, VHT, trip generation and cold start production with land use measures and their effect on emission production process.

Bai et al. (2008) developed an emission-modeling framework for San Joaquin Valley in Central California at a regional scale. The study examined land use, travel patterns and emission inventories based on policy scenarios such as growth strategies, variable residential densities and transportation system expansion thereby assessing sensitivity of mobile emission inventories to different policy scenarios for the study region which included eight counties. It also examined impacts of policy scenarios on local level travel pattern and system effectiveness such as v/c ratio and travel delays but did not identify effectiveness of those policy scenarios on emissions at a local or sub-regional level. Bai's study also did not study the primary factors that could lead to improved air quality and emissions benefits. The study concluded that applying controlled growth strategies such as smart growth and constraints on roadway system expansion may contribute to 15% reduction in vehicular traffic and associated mobile source emissions at a regional scale.

A similar effort by DuRoss et al. (2009) analyzed the impact of discrete land use scenarios in terms of variable residential relocation and transit expansion scenarios on vehicle miles and vehicle hours of travel, oxides of Nitrogen (NOx) and volatile organic compounds (VOCs) on a regional scale in Delaware. The study concluded that reduction in VMT resulting through mode shift and transit expansion produced a comparable reduction in VOC and NOx emissions.

Tirumalachetty, Kockelman, & Nichols, (2013) also analyzed household energy demand along with GHG emissions estimates under various land use and roadway system capacity expansion scenarios for forecast year 2030 for the Austin Metropolitan region with 1074 traffic analysis zones. Danieau (2009) researched emission benefits from alternative land use development strategies in the Dallas-Fort Worth region. The strategies included infill development, mixed-use, neo-traditional design and TOD. The study narrowed to investigate developments located near transit and a methodology to quantify air quality benefits at TOD locations.

Nasri, Zhu, Zamir, Xiong, & Zhang (2014) evaluated impact of behavioral changes induced by TODs on congestion, emissions and other performance indicators such as delay. The study was done for TOD and Non-TOD zones in Montgomery County, Maryland where traffic conditions on both corridor level and network level were analyzed. The study developed a TOD module for TOD identification, and travel estimation, which was linked to the micro simulation module to estimate network performance. This was connected to the post process module that modeled emissions and conducted environmental impact analysis. This analysis uses a microscopic traffic simulation model developed by the author in his preceding research and EPA's MOVES model (EPA, 2014) to investigate quantitatively the impact of induced travel patterns due to TOD and their effect on total VMT, delay, number of trips, level of service for the corridors around TOD TAZs, queue lengths and emission and fuel consumption of whole network. The data used for this research was developed by National TOD Database developed by the Center for Transit Oriented Developments (CTOD) with geocoded social demographic information made available at the TAZ level by Census TIGER website. The 2007/2008 Household Travel Survey Data for Washington D.C. with a randomly selected data set of 8000 households was also used for simulation and environmental analysis area. A large scale macroscopic travel simulation model with 7121 links and 3521 nodes was developed and calibrated at a regional scale which included the North Washington D.C metropolitan area, central and eastern Montgomery County and the northwestern Prince George's County of the State of Maryland. The model however did not incorporate multimodal travel demand and transit being an indispensable component of TOD, an enhanced multimodal simulation could further strengthen the analysis. This shows the need for high resolution TAZ travel demand models at the county scale that aid in forecasting efforts for traffic and environmental impacts at the local level.

The study by Nasri et al., (2014) also used the MOVES model for a county level environmental impact analysis using inputs such as VMT, travel speed and road distribution that result from the calibrated travel simulation model and other additional data from various sources. The study examines quantitative impacts such as network wide traffic statistic and intersection level performance measures simulated for a for PM peak hour of before and after TOD scenarios. However, there is an opportunity to expand the temporal scale to a 24-hour period. The performance measures included trips, vehicle miles of travel, vehicle hours of travel, levels of service, queue lengths, average speed and travel time savings. This case shows that there is a need and a keen interest in gaining insight into how TODs impact travel patterns and environment. The study concluded that TODs contribute to reduced emissions due to decreased queue lengths, lower level of Household VMT and less travel delays which are more significant in the local surrounding links than in the whole study area. The study claims that the microscopic model and simulation would improve understanding and relative effectiveness of existing and proposed TOD scenarios on transit ridership, congestion and emissions. The study concluded that for the whole Washington D.C. slightly reduces auto usage and VMT by 0.41%, delay by 4% for the PM peak period and reduced emission by 0.5 % in the TOD areas. The study indicates that with about 1.2 percent of vehicles removed off the network, TOD helps to reduce peak hour travel delay by 2.83 percent.

Per Nelson and Shakow methods and analytical tools that are able to make improvements possible with assessing feasible alternatives for proposed developments and their resulting environmental impact forecasts are useful for decision making (Table 2-2).

Table 2-2: Studies, Tools and Methods Related to Modeling Transportation Related Emissions

Shiftan & Suhrbier (2002)	Used Activity based models developed for Portland to investigate impacts of transportation demand management measures on tours, trips, VMT and emissions
Kitamura, Pas, Lula, Lawton, & Benson,(1996)	Activity based micro simulation models (PCATS-Prism Constrained Activity Travel Simulator) has been coupled with Dynamic Network Simulator (DEBNetS) to forecast CO2 emissions.
Kitamura, Fujii, Kikuchi, & Yamamoto (1998)	AMOS has been embedded in Sequenced Activity Mobility Simulator (SAMS) framework for generating air quality emissions
Kanaroglou, Benoit, & Potoglou, (2006)	Mapping of CO concentrations by linking IMULATE with emission dispersion models.
Lautso et al., (2004)	MEPLAN- a land use transport model was combined with sustainability indicators which included transport emissions and air quality.
Beckx et al., (2009)	Study in Netherlands, linked activity based model to with emission modeling and used the results as input to air quality model to predict hourly concentrations of different pollutants
OSCAR (European research)*	Developed models in an air quality assessment system for studying street level air quality on an annual and hourly basis.
TEMMS (Traffic Emissions Modeling and Mapping Suite) – UK based research*	Modeling system that integrates traffic emissions and air dispersion
SATURN (Simulation and Assignment of Traffic to Urban Road Network)*	Vehicle Emissions Model
ROADFAC*	Air Pollution Dispersion Model
AIRVIRO*	Recognizing exposure as a better indicator of health effects of air pollution
DAPPLE* (Dispersion of Air Pollution and Penetration into the Local Environment)	Assessing sustainability in terms of exposure to traffic related air pollution.
URBANSim	Models policy effect based on urban development models
VULCAN	Emission inventory from different forms (point, area) and scales(county, facility) at contiguous spatial 10x10 km^2 grids and at temporal scales with an assumption that more emissions occur near to sources.
TAPES (Venigalla et al., 1999)	TAPES (for Traffic Assignment Program for Emission Studies) isa specilized equlibrium assignment model to measure cold- and hot-starts and stabilized operating models on a link-by-link basis.

High-resolution emission inventory involves deriving link-specific emission rates and inventories and later aggregating them at desired categories such as area-type, land use, and facility type. Extensive research has been conducted related to high-resolution emission analysis and inventory using the erstwhile EPA's emission factor model MOBILE versions 5.A through 6.2 (Chalumuri & Venigalla, 2004; M. M. Venigalla et al., 1999; M. Venigalla & Pickrell, 1997; M. Venigalla, Miller, & Chatterjee, 1995; Chatterjee, Reddy, Venigalla, & Miller, 1996) Research on high-resolution emission analysis and inventory by using the EPA's MOVES model (EPA 2014) is still evolving.

2.6 Greenhouse Gas Emissions (GHG) and Transportation

Estimating the carbon footprint of travel at geopolitical levels/ boundaries helps support local policy objectives and also analyze cross sectionals of localities to distinguish relations between development patterns (Parshall et al., 2010) The emissions estimations has been an important area of research in transportation and a variety of methods have been conceptualized for its estimation. The most important reason why the emissions are estimated to the smallest possible area is mostly for environmental inventory or policy appraisal. But the methodology behind deriving the emissions at a local scale can be broadly classified into grid based emissions and VMT based emissions. The methods suggested in the earlier studies Dalvi et al., (2006); Gurney et al., (2009); Olivier et al., (1999); Shu, Lam, & Reams (2010); Yuqin (2010); Andres (1996); Osses (2008); and Oda (2011); are either based on estimating emissions by a bottom up approach where emissions from a street level are aggregated into zones, or, by the top down approach where a large size emission data is transformed into small sized uniform grid. Vulcan is an emission inventory of fossil fuel built from census, traffic and digital road data sets available from the National County Database (NCD) from different forms (point, area) and scales (county, facility) at contiguous spatial 10x10 km^2 grids and at temporal scales with an assumption that more emissions occur near to sources Gurney (2009). Using road density as proxy for mid-sized cities and traffic counts, land use and road network as proxies for emission intensities for large cities, a spatial disaggregation approach was used to create 1km2 emission grids. Downscaling the CO2 emissions from a state level to a district level and using point interpolation method on the district points to derive a 10x10 grid mesh was a part of a large emission inventory effort in India (Dalvi et al., 2006). The improvised study by (Shu et al., 2010) utilizes a distance decay function in emission estimates, which assigns weights to the grids without losing volume during interpolation. It allocates more emissions to cells closer to the major highways than which are farther from them. The distance decays were also used by some of the other major studies by Wentz (2002); Cohen J (2005); Su J G (2009); and Zou (2009) also followed the distance decay methodology for pollution allocation.

Most local inventories fall into the basic categories of corporate, direct, total final and total primary and total embodied (Parshall et al., 2010) The direct final consumption is included the ones from direct sources (residential, commercial, industrial and transportation) but not the power sector. Total final consumption includes the energy from heat and electricity outside of the urban area (Parshall et al., 2010) . ICLEI (Local government for sustainability was the first to help local governments build GHG inventories on a corporate (buildings, signals, street lights, city operated vehicle fleet) and a community scale (residential, commercial, industrial, transportation and waste sectors (Parshall et al., 2010). It focused on energy related CO2 emissions, which account for direct consumption and electricity demand within geopolitical boundaries. Whereas VULCAN, another large GHG inventory effort, relies on publicly reported emissions from facilities, which are required to report pollutant emissions to state or federal governments.

The other broadly classified method of GHG emission estimation and allocation is by using VMT estimates. The various forms in which the VMT is estimated, methodology to derive the GHG emissions and their shortcomings are stated in a table below. It is to be noted that the local level attribution due to a change in policy is not a part of the application of any of the stated methodologies. This research goes a step ahead to address this requirement for informed decision making for policy implementation on a local level. It reports the direct fuel consumption of the on road transportation where the data is procured from NCD on a county level. Another study by Parshall et al., (2010) covers the transportation, building and industrial sector emissions represented on a 10x10km grid by fuel type. Though these studies have focused on representing emissions on smaller scales, they do not necessarily act as policy appraisal tools for transportation planning to incorporate sustainability by footprint reduction. This study addresses the above concern by incorporating a carbon footprint methodology into the transportation demand forecasting tool and making it a part and parcel of the planning process for local government policy appraisal.

GHG emissions are commonly reported in terms of a GHG inventory based on a set of accounting principles, which define the parameters, source that define the emission measurement (Deshazo, 2009). Similarly in order to evaluate policy effects on emission footprint of a region it is imperative that geographic and operational boundaries are defined. The geographic boundary is the physical location of the footprint contributing activities and operational boundaries defines the scope of emissions. The geographical boundaries in this study are the jurisdictional boundaries containing the traffic analysis zones (TAZs) within them. The scope of emissions is categorized into three levels of measurement direct, indirect and upstream/downstream emissions (Hillman et al., 2009). The direct emission inventory (associated with the direct energy use in cities) efforts put forward by WRI and ICLEI is already available to many cities. Another level which carbon management focuses on is the Economic input-output life cycle analysis (EIO-LCA), which is based on GHG emissions associated with household expenditures calibrated on the national scale. As LCA is an appropriate tool at the national scale to “account for upstream GHG emissions from all consumer behaviors” (Hillman et al., 2009)it is not appropriate for jurisdictional level. Not to mention that the expenditure data for all counties is not always available for all economic sectors, publicly, for applying the EIO-LCA at fine geographical scales. This study mainly takes the direct emissions approach but with a twist of policy implementation analysis using the demand model. To do this requires a set of data like inputs to the travel demand model and its resulting outputs for further post processing, certain levels of policy parameters to test the effect of implementation, a post processor air quality model. The required data for the study is described in the following section.

Table 2-3: VMT based GHG assessment tools –Applications and shortcomings

Tool	Description	Typical Application	Shortcomings
VMT Spreadsheet with emissions factors	Spreadsheet tool to estimate VMT. Combined with an emissions factor (e.g., MOVES) to estimate mobile-source GHG emissions.	Small-scale development projects and land use planning applications.	Insensitive to transportation changes, smart growth, urban form. Based on national survey data and needs local calibration
VMT Spreadsheet with 4D Smart Growth Adjustments with emissions factors	Spreadsheet tool to adjust trip generation and VMT estimates from local or national sources (e.g., Institute of Transportation Engineers) to account for smart growth and sustainable development practices. Mobile-source GHG emissions calculated using emissions factors.	Large-scale mixed-use development projects, large scale mixed-use land use plans, and comprehensive plans.	

Travel Demand Forecasting **(TDF)** Models with emissions factors	Common transportation planning tool that uses land use and transportation network data to estimate travel patterns. VMT output is paired with travel speeds, which leads to a more accurate estimate of mobile-source GHG emissions when combined with an emissions factor.	Large-scale development plans, comprehensive plans, Transportation projects/plans. May overestimate VMT and GHG emissions from smart growth projects.	Increases in travel due to induced growth may be understated. Spillover effect may be difficult to assess
Integrated land use planning models **(DRAM, EMPAL, UrbanSIM, UPlan)**	Forecast future land use growth based on proximity to and interaction with transportation system. Inputs are various measures of transportation accessibility and mobility. Used for generation of land use inputs for TDF models		Not directly applied to evaluate travel related GHG emission levels of land use or transportation planning scenarios. Models are complex, data intensive requiring special expertise. They also require integration for VMT generations and GHG emissions. Cannot allocate the GHG to individual jurisdictions for policy analysis.
Enhanced TDF Models (dynamic traffic assignment and traffic micro-simulation) with emissions factors	TDF models with additional features such as socioeconomic information, advanced traffic assignment, or 4D adjustments. This tool produces the most accurate VMT estimates when the model is validated to local conditions and combined with a detailed emissions factor like MOVES.	Same as TDF models, but can account for VMT and GHG reductions related to smart growth and mixed-use developments.	
Sketch Planning Tool- **PLACE3S**	Parcel-based land use/transportation planning tool with built in smart-growth adjustments. Available web-based interface. GHG emissions estimates can be improved if travel behavior is adjusted to match location conditions and software is upgraded to incorporate emissions factors from MOVES.	Small-scale to large-scale development projects and land use plans. Particularly effective for community-based planning activities.	Requires a steep learning curve. Requires individual software developer resources to customize software.

Accounting Software and Calculator- **ICLEI CACP Software**	GHG accounting software. Increased accuracy of mobile source GHG emissions estimates are generated when VMT is supplied with a separate VMT estimation tool like those described above.	Small-scale development projects and land use plans. Difficult to properly account for GHG emissions from larger developments and plans.	Software uses national derived emission rates that may not be representative of fleet in the study area. Calculating VMT reduction effects of smart growth development is difficult
Sketch Planning Tool and air quality modeling software - **URBEMIS-**	Air quality analysis tool with simple land use input data. More accurate mobile-source emissions estimates if emissions factors, trip generation rates, and trip lengths are validated to location conditions.	Small-scale development projects and plans.	Do not include the internal models like trip generation, distribution, mode choice or land use.
Sketch Planning Tool and air quality modeling software- **INDEX**	Parcel-based land-use or transportation planning tool with built in Smart-growth adjustments. Tool integrates with ArcGIS software. GHG emissions estimates can be improved if travel behavior is adjusted to match location conditions and software is upgraded to incorporate emissions factors from MOVES.	Small-scale to large-scale development projects and land use plans. Particularly effective for community-based planning activities. Runs using ArcGIS.	Requires a steep learning curve. Requires individual software developer resources to customize software.

Source: (Assessment of Greenhouse Gas Analysis Tools, 2009)

2.7 Summary of Literature Review

The primary takeaways from the literature review are as follows:

- Sustainable land use policies implemented at local level such as development of TODs along mass transit corridors have significant potential to reduce emissions.
- Estimation of vehicle miles of travel (VMT) using tools other than travel demand models may be tedious, may requires additional resources and may not capture jurisdictional emissions. Therefore, VMT estimation using travel demand models is functional for jurisdictional allocation of travel activity and resulting emissions.

- Regional travel demand models are not sensitive to neighborhood level land use policy variables and therefore cannot capture the policies' impact on mobility measures of effectiveness as well as emissions attributable to those policies.

3. STUDY PROCESS

Chapter 1 defined the problem and specified study goals and premises, which is followed by a comprehensive review of state of the practice is presented in Chapter 2. In this Chapter the steps in the study process, data, tools, methods used in the study are discussed.

3.1 Steps in the Study Process

The study process (the Process) involved a series of sequential and interrelated steps that required extensive data analyses, travel demand modeling exercises, post-processing results of analysis and modeling, and statistical verification of the results. The steps in the Process are as follows:

Step 1: Establish emission characteristics of TOD and Non-TOD land uses:

- Data: Household Travel Survey (HHTS) data collected by Metro Washington Council of Governments (MWCOG)
- Tools and methods: Primarily geographic information systems (GIS) and database analytics and statistical analysis software
- Purpose: Verify study premise #1

Step 2: Devise a methodology (referred to as 'the Methodology') for deriving emission impacts of smart-growth land use policies at local level using traditional TDM; and an experimental set up to test the Methodology:

- Tools: Knowledge-base from literature review and insights from Step 1

Step 3: Acquire tools and models for travel demand forecasting at regional and local levels:

– Tools: A travel demand modeling (TDM) platform that performs travel demand modeling, covers engineering and land use elements (Citilabs' CUBE Voyager was acquired for this research)

– Models: Regional and countywide travel demand forecasting models (the four-step travel demand forecasting models for MWCOG and Loudoun County, VA, respectively, were acquired for this research)

Step 4: Perform modeling analysis, analyze the results and conduct statistical validation of the results.

– Tools and methods: TDM platform, spreadsheets, databases and statistical analysis system – SAS.

– Purpose: Verify study premise #1

Step 5: Derive conclusions, make recommendations and acknowledge study limitations

3.2 Emission Footprint Analysis of TOD and Non-TOD Land Uses

Before setting out to conducting tedious travel demand modeling exercises to model emission footprints attributable to sustainable land use scenarios, it must first be ascertained that the emission footprints are sensitive to land use. To establish this sensitivity, as the first step of the study an emission footprint analysis is conducted for TOD and Non-TOD land uses.

The data used for this step in the Process is based on the 2007/2008 household travel survey (HHTS) obtained from the National Capital Region Transportation Planning Board (TPB) of MWCOG. This activity-based survey data provides a wealth of transit-oriented corridors, and diverse land use. The data includes a survey of 24-hour activity based travel patterns for 11,000 households in the greater Washington area, which includes northern Virginia and parts of Maryland. The survey was conducted between February 2007 and March 2008 and includes more than 25,000 person records, 16,000 vehicle records, and 130,000 trip records (MWCOG, 2009). The data for the next version of this survey, which will be conducted in 2017 and 2018, is not expected to be available till 2020. The jurisdictional boundaries of the modeled area and household travel survey sample are illustrated in Figure 3-1 (MWCOG, 2009).

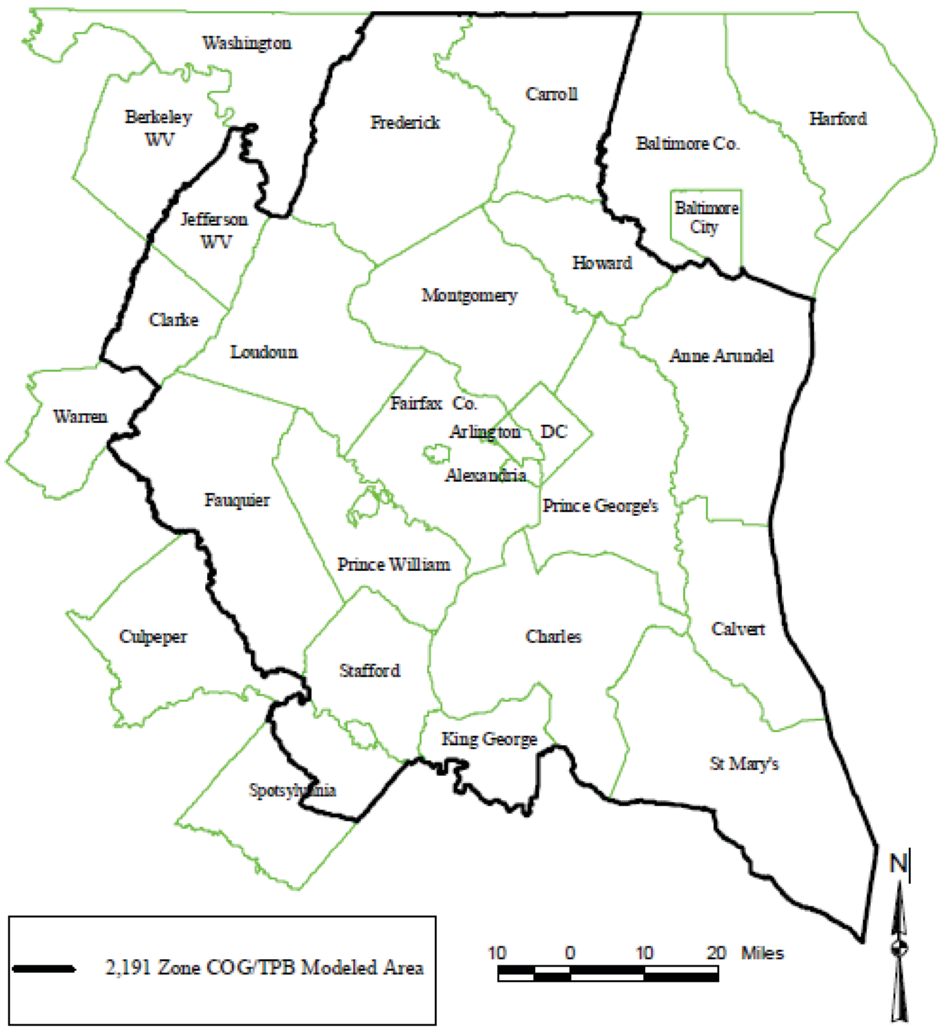


Figure 3-1: Jurisdictional Boundaries of TPB 2008 Travel Survey and the MWCOG Modeled Area

The HHTS data includes a household file, which contains information for household size of various sizes having one, two, three, or more vehicles, household income, number of vehicles, number of students per household, number of licensed drivers per household and number of bikes and workers per household amongst other data fields. The data also includes a trip file, which contains information on 87,000 trips (trip file) that was gathered throughout the data collection process (MWCOG, 2010). The file contains numerous trip attributes such as primary travel mode, and detailed travel mode.

In a study related to trip generation and mode split model development for TODs, Faghri, (2012) and Faghri & Venigalla (2013) performed a detailed analysis of the HHTS. Faghri, (2012) presented details of this data, refinement and analyses for identifying each household in the survey record with two land use variables: TOD and Non-TOD. Using GIS tools, TAZs within 0.25-mile and 0.50-mile radius of metro stations in the survey data are identified as TOD. As an example of this process, Figure 3-2 illustrates the TAZs inside the 0.25-mile radius of metro rail stations in the Rosslyn-Ballston Metrorail corridor in Virginia (RB Corridor). The corridor contains five metro transit stations that are well served by a reliable high-speed metro-rail as well as a bus transit network. Each transit station in the TOD corridor is the center of high-density development within 0.50-mile radius, and contains diverse land use from residential, office, retail to institutional and entertainment use.

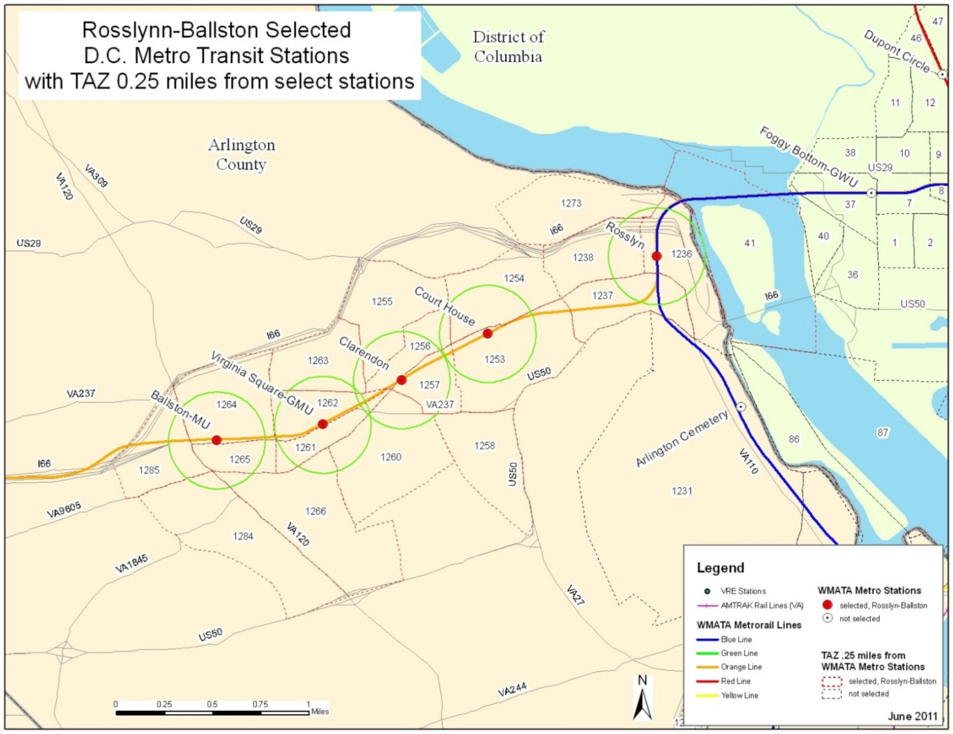


Figure 3-2: TOD Zone Identification for Roslyn-Ballston Corridor in Arlington, VA

3.2.1 Employing the TPB's HHTS Dataset

To verify research premise #1 of this research, travel variables of households for a select set of TODs and Non-TODs in the aforementioned TPB's HHTS dataset are analyzed. The objective of the analysis is to draw inferences about the relative emission footprints of these two land use types. The selection process for TAZs representing TOD and Non-TOD land uses is shown below. The emission footprint analysis itself is presented in Chapter 4.

3.3 Capturing Local Land Use Impacts on Travel: Regional vs. Sub-Regional

As stated in Chapter 2, the regional four-step travel demand models are not designed to estimate neighborhood-level smart growth initiatives like transit villages, but rather used mainly to guide regional highway and transit investments (Cervero, 2006). Large-scale regional travel models deal crudely with intra-zonal travel or travel within neighborhoods or districts. This happens because, before assigning trips to external major corridors land use changes are loaded onto a single centroid that is essentially considered as the "street network". Secondly, most models lack specifics of non-motorized travel because travel survey data do not capture those trips. Furthermore, region wide traffic assignment is done at a coarse level local, and many collector streets are not coded as digitized highway network links and therefore assigning all motorized and non-motorized trips to one or two major facilities and centroid connectors.

Very few regional travel models account for predicted trips by time-of-day and instead make such assumptions as a proportion of daily trips (e.g. 15%) would occur during the peak hour. The traffic assignment outputs must be extensively post-processed separately for a local network to assess and obtain a finer detail of the local land use impacts on local travel activity, let alone capturing emission signatures at local-level (Cervero R. , 2006). Therefore, regional models do not adequately capture the potential ridership benefits of smart-growth initiatives such as TOD. Another significant limitation of the regional models is the relatively large size of traffic analysis zones (TAZ). The proposed methodology addresses these key limitations.

3.4 Methodology for Estimating Emissions for Different Land Use Scenarios at Sub-Regional Level

Emission footprints attributed to household travel (in grams/hh) in general are distributed across the highway network on which travel occurs. As indicated in Chapter 2, due to lack of easy-to-use tools and/or availability of data, planners and researchers face challenges in taking measurements of these distributed emissions. Due to their installed-base and extensive use, there is value in adopting existing and widely used tools such as travel demand forecasting models for taking such measurements. However, the literature review also suggests that use of regional TDF tools is of little use to modeling emission impacts of neighborhood-level land use variables on the network.

If sub-regional models with finer or disaggregated set of TAZs could be developed a new or derived from regional TDF model, these models may offer enough sensitivity to neighborhood-level planning and the impacts of associated policy on emissions. Using a disaggregate TDF model at the heart, a Methodology (Figure 3-3) is proposed and tested to model household level emissions on a sub-regional network.

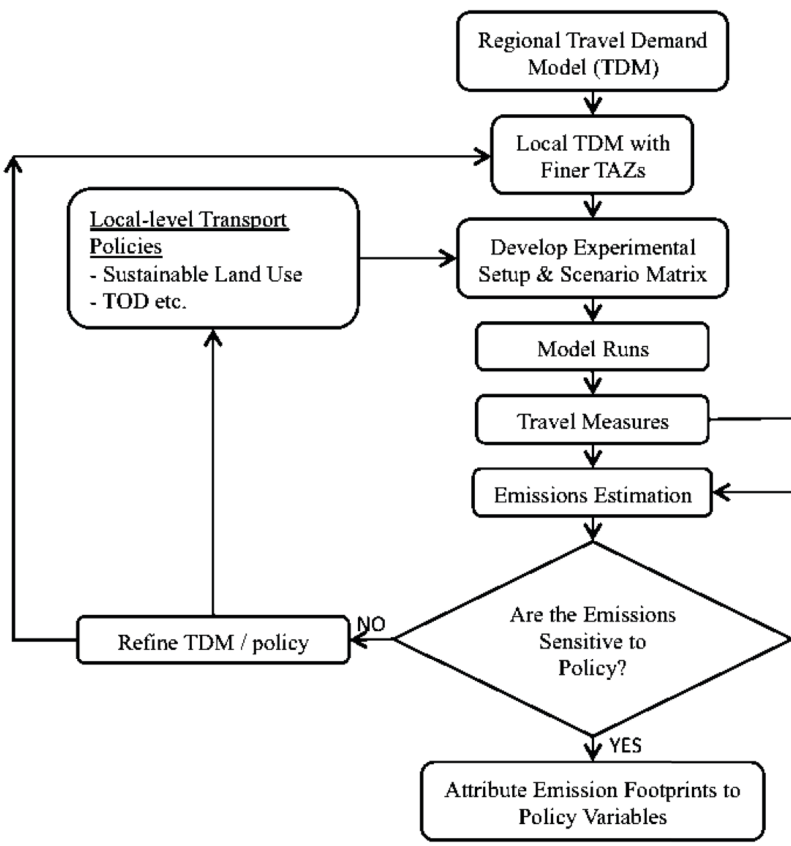


Figure 3-3: Proposed Methodology to Evaluate Sustainable Land Use Policies

3.4.1 Test-bed for Application of the Methodology

The most ideal way to examine the applicability of the proposed Methodology would be to design an experiment involving multiple local jurisdictions in multiple regions or within the same region. However, owing to enormous resources that are required to carry out this effort such an approach is infeasible. An alternative to studying multiple jurisdictions is to select a suitable model for a local jurisdiction where growth is brisk, smart-growth policies are actively being pursued and, most importantly, a new line-haul heavy-rail transit corridor is being built. Though study experiments can be designed with such jurisdiction as a test-bed, the opportunity to find such jurisdiction in mature metropolitan areas presents itself very rarely.

Based on population growth figures, Loudoun County, VA (the County) is ranked #7 nationally among counties with an estimated 2017 population of over 383,000. By 2020, the County's population is projected to grow by 96% and total employment by 122% from the 2005 levels. The County is a sub-region in the MWCOG regional plan area. Washington Metro Area Transit Authority's (WAMATA) Silver Line Metrorail operations commenced in 2014. By 2020 Metrorail would also serve Loudoun County for the first time since the Metrorail's existence. Because of rapid economic and population growth and the advent of the new rail transit corridor, the county's transportation infrastructure is expected to change in two primary ways, both of which are pertinent to the study goals:

1. Expansion of the existing Silver Line Metro, which would extend into Loudoun County at two transit stops and connecting to the nearby international airport. This could potentially result in increased use of transit.
2. Resulting roadway infrastructure changes due to the metro and future land use around the transit stations, thereby converting a lot of agricultural land into residential and commercial use resulting in increase in traffic.

In December 2012, the Loudoun County Board of Supervisors established a Dulles Metrorail Service District, a tax district created to help fund construction costs associated with Metrorail operations. Given the establishment of this District, in October 2013 the Board of Supervisors initiated a process to begin a Silver Line/Metrorail Tax District Comprehensive Plan to evaluate the development potential of the Dulles Metrorail Service District. The purpose of this effort was to evaluate the existing planned land uses around the future Metrorail Stations and to ensure that they strike a desirable balance among the following goals:

1. Prompt realization of tax revenues to support future Metrorail operations,
2. Maximizing future employment generation,
3. Achieving the desired land use pattern, and
4. Minimizing demands on the County's transportation infrastructure.

The extension of Silver Line metro is expected to trigger rapid changes to economic, demographic and market conditions thereby necessitating evaluation of development potential to maximize future employment and minimizing transportation infrastructure demand while achieving desirable land-use. Therefore, as the County transitions itself into the current realities and trends of changing demographic trends and market conditions, it strives to adapt policies and land development strategies that encourage successfully maintain the quality of life for its residents (Loudoun County, 2016). The population growth trends of Loudoun in comparison to Fairfax and Arlington County are shown in Figure 3-4.

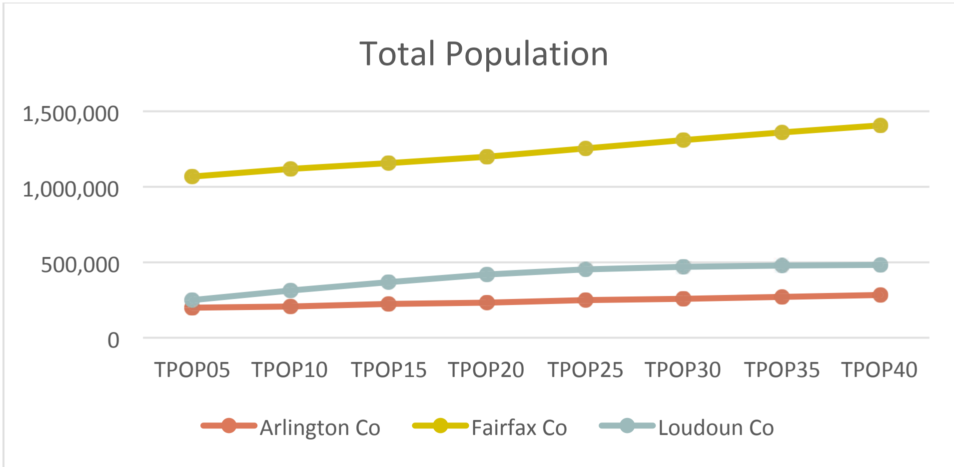


Figure 3-4: Population Trends across Counties in Northern Virginia

Thus, the new Silver Line Metro Rail Corridor in Loudoun County, which is the county's focus on sustainable growth, its investment in development of travel demand forecasting model for countywide transportation planning present a timely and very unique opportunity to study the impacts of coordinating these large transit investments and land use policies.

3.5 Experimental Set Up and Verification

The primary requirement for the proposed Methodology is that the measures of effectiveness to be studied should be sensitive to the land use variables. Therefore, it is imperative that an experimental set up be devised to pit these measures of effectiveness (response variables) against select land use and other transportation variables. For both travel survey data analysis and application of the Methodology, two different experimental set ups are devised.

3.5.1 Statistical Verification

In a broader sense, all methods, models and verification means are devised to simulate travel need and to gain confidence in the results. The most desirable way of verification would be when model results can replicate real world results under current conditions, a process known as validation. The study objectives and methods used are based on analysis of survey data and testing of hypothetical scenarios. Therefore, the study methods in this research are not amenable for validation of the results vis-à-vis real world observations. However, for making recommendations based on this research, it must be established that the study methods would produce statistically verifiable results that are sensitive to the independent variables of the study. To this effect, simple statistical methods, which are time-tested and widely accepted, are used to verify study results. Specifically, the survey data analysis results are verified using two-sample means testing; and the statistical significance of the results of the Methodology are verified using three-factor analysis of variance methods. Details of these statistical methods, analyses and verifications are presented in the subsequent sections.

4. EMISSION FOOTPRINTS OF HOUSEHOLD TRAVEL: TOD VS. NON-TOD

To verify study premise #1, the emissions characteristics of travel associated with TOD and Non-TOD land use scenarios are first studied using the household travel activity survey (HHTS) data for the MWCOG area. For comparative analyses purposes the land use of a TAZ is designated as TOD if that TAZ lies within 0.25-mile and 0.50-mile radius of a Metro station. However, for emission footprint analysis only the TAZs within 0.5-mile radius are treated as TODs while the TAZs outside this radius are treated as Non-TODs. In this chapter, a comparative analysis of emission footprints of these two land uses is presented.

4.1 Household Emission Footprints Analysis: The Process

As outlined in Chapter 3, using the ArcGIS' 'select by location' tools, several TAZs of the MWCOG planning area are identified as TODs and Non-TODs (Faghri 2012). The expanded process used by Faghri (2012) is illustrated in Figure 4-1.

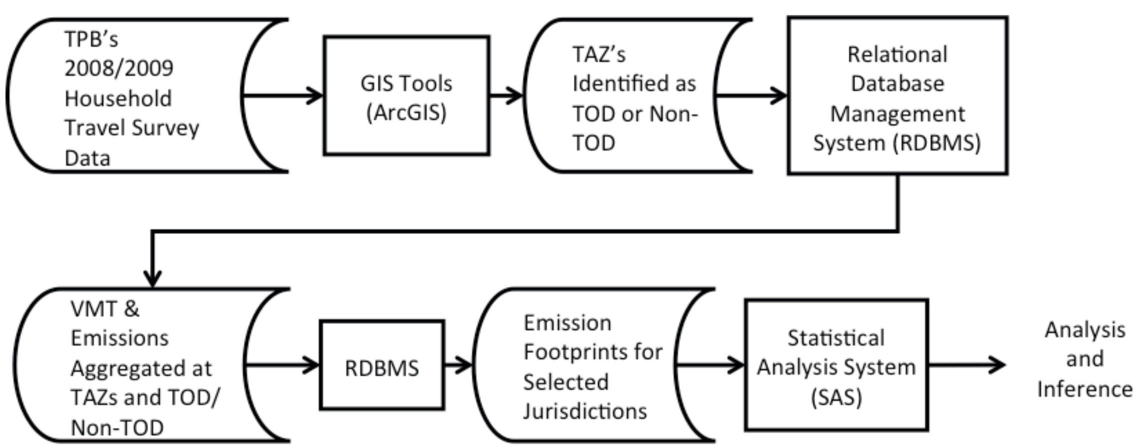


Figure 4-1: The Travel Survey Based Emission Footprint Analysis Process

Data mining techniques for travel survey databases outlined by Venigalla, Chalumuri and Mandapati (2005) are used in reducing HHTS database. At the time of TPB's conducting HHTS in 2008/2009, six jurisdictions were served by Metro rail. These jurisdictions include District of Columbia, City of Alexandria and Counties of Arlington, Fairfax, Montgomery and Prince George's County. All TAZs falling outside of 0.25-mile and 0.50-mile radii of the 86 Metro stations in the region are designated as Non-TOD areas. Further, several other suburban and exurban counties, which were not served by Metro rail at that time, are also included in the analyses. Treated as Non-TOD land uses, these counties include Anne Arundel, Charles, Fauquier, and Stafford (Exurban); and Howard and Prince William (Suburban). Table 4-1 presents the complete list of jurisdictions and their urban classification included in the emission footprint analysis.

Table 4-1: MWCOG Jurisdictions and Their Urban Classification Studied in the Emission Footprint Analysis

Census Fips	Jurisdiction	Urban Classification	Abbreviation
24003	Anne Arundel County	Exurban	AAC
51013	Arlington County	Urban Core	AC
24017	Charles County	Exurban	CC
51510	City of Alexandria	Urban Core	CA
11001	District of Columbia	Urban Core	DC
51059	Fairfax County	Suburban	FFC
51061	Fauquier County	Exurban	FqC
24027	Howard County	Suburban	HC
51107	Loudoun County	Not classified	LC
24031	Montgomery County	Suburban	MC
24033	Prince George's County	Suburban	PGC
51153	Prince William County	Suburban	PWC
51179	Stafford County	Exurban	SC
-	Other Rural counties	Other Rural	OC

Most TAZs designated as TOD contain mixed-use developments located within comfortable walking distance of Metro stations. For example, Rosslyn-Ballston transit corridor in Arlington, Virginia and Bethesda suburb of Maryland have compact development and are served by several Metro rail stations. Though the degree to which mixed-use land use around the Metro rail stations varies with the location of station, for this analysis it is assumed that through self-selection all TAZ's within the specified radii of Metro rail stations are of TOD land use.

4.2 Economic, Demographic and Travel Characteristics of TOD and Non-TOD

Examination of HHTS data indicates that vehicle ownership is much less in TOD zones than the Non-TOD zones (Faghri & Venigalla, 2013). For example, in Rosslyn-Ballston TOD corridor of Arlington County, the data terminates after the "5-vehicle" category indicating that no household has five (5) or more vehicles. Furthermore, the number of households in the TOD zone with no vehicles far exceeds the same category in the Non-TOD zone. An interesting observation associated with vehicle ownership in TOD zones is that majority of residents own at least one vehicle (Figure 4-2). This questions total reliance on transit use in TOD zones. Had this been the case, the number of people with no vehicles would have exceeded all other categories of vehicle ownership in TOD zones.

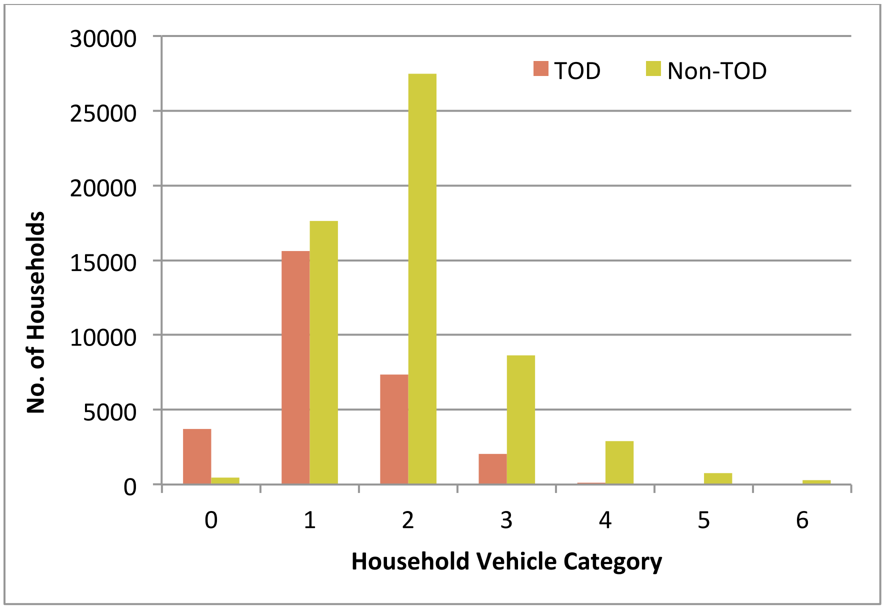


Figure 4-2: Vehicle Ownership in the TOD and Non-TOD Zones

To further examine the extent of personal automobile usage in TOD zones with respect to detailed travel mode, a comparative analysis of TOD vis-à-vis Non-TODs is performed. It is important to note that the TOD trips include trips that are either within a TOD zone or only one trip end is inside a TOD zone. However, Non-TOD trips only include trips that are completely outside a TOD zone.

As Figure 4-3 shows, percent usage of transit within TOD zones far exceeds Non-TOD zones. Similarly, usage of personal vehicles in TOD zones is lower than the usage in Non-TOD zones. However, it is noteworthy that personal vehicle usage is higher than transit usage inside TOD zones. A primary contributing factor to observation may be that the TOD zone data includes trips with one trip-end in a Non-TOD zone. In other words, while the trip origin may be in a TOD zone, the trip destination may be in a Non-TOD zone. In such cases, the traveler is forced to take personal vehicle even though the trip origin is in a TOD zone. This is a testament to the fact that even though the MWCOG area enjoys one of the widely used public transit systems in the nation, it's lack of complete service coverage to all areas of MWCOG results in higher use of vehicle mode even in TOD areas.

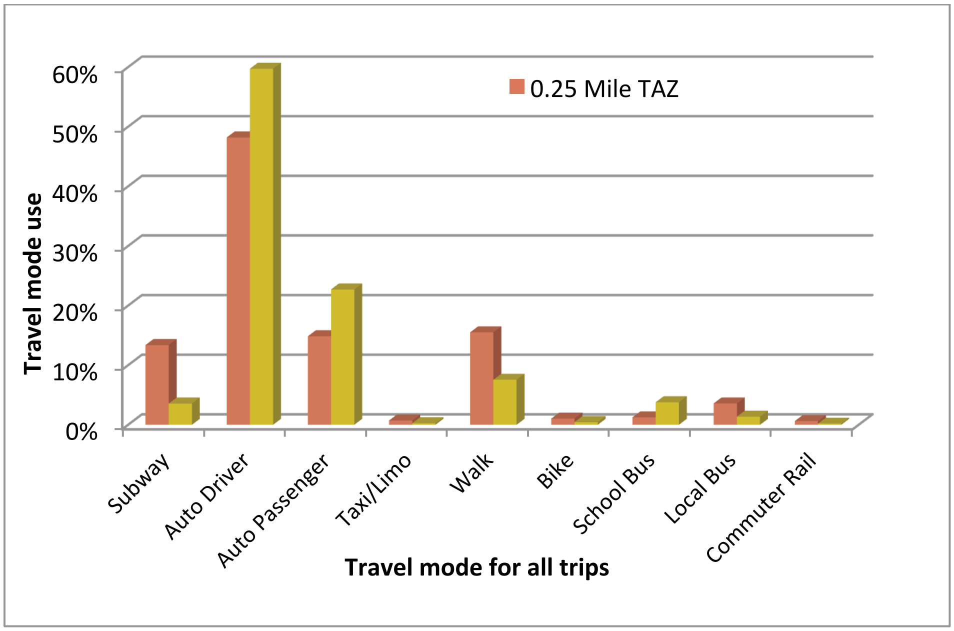


Figure 4-3: Travel mode for All Trips – TOD vs. Non-TOD

As a crosscheck the data is further examined to only include home-based work trips (Figure 4-4). Work trips are especially important, as they constitute majority of daily trips. For this analysis data coverage was expanded to include all 86 Washington Metro transit stations. As show in Figure 4-4 (and also in Table 4-2) all transit, walk, and bike travel modes constitute much larger share of travel in the TOD zones while the Non-TOD zones show larger share of auto mode. Furthermore, walk and bike, as the primary mode of travel, are more predominant in TOD areas than the Non-TOD areas.

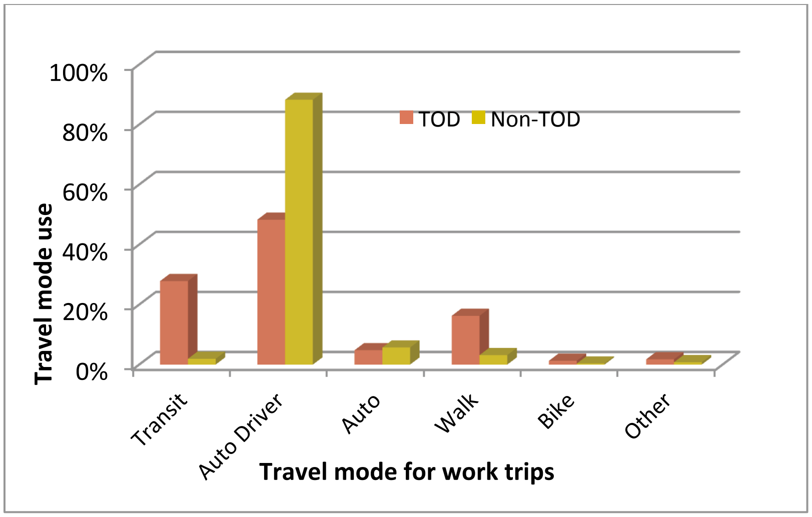


Figure 4-4: Share of Work Trips in Primary Travel Mode – TOD vs. Non TOD

Table 4-2: Work Trip Characteristics in TOD Zones within 0.25-mile Radius

Detailed Travel Mode (mode)	Work Trips (0.25-mile TAZs)	Work Trips (Beyond 0.25-mile TAZs)	Work Trips (All Region)
Subway	252,983	16,708	269,691
Auto Driver	556,333	163,0619	2,186,953
Auto Passenger	54,811	104,684	159,494
Taxi/Limo	8,770	3,628	12,397
Motorcycle	2,309	2,945	5,254
Walk	187,027	58,018	245,045
Bike	14,472	5,993	20,464
School Bus	1,401	1,876	3,277
Heavy Truck	1,060	1,485	2,545
Local Bus	43,661	1,4874	58,535
Commuter Metrorail	15,270	2,822	18,091
Commuter Bus	8,522	782	9,304
Light Metrorail	0	957	957
Metro Access	475	506	981
Shuttle Bus	5,835	2,599	8,433
Other	0	118	118
Total:	1,152,927	1,848,613	3,001,541

As the mode choice within TOD and Non-TOD indicates, auto-dependent travel characteristics of these land uses vary drastically. What is not known, however, is if the emission footprints of these land use types vary significantly from each other.

4.3 Vehicle Miles of Travel by TOD and Non-TOD Households

Travel distances of all trips made using automobiles are first aggregated at household level. These household-level vehicle miles of travel (VMT) are then weighted by the household sample weight. This step is then followed with derivation of the weighted averages of VMT per household for each of the study jurisdictions listed in Table 4-1. It should be reiterated here that even though for emission footprint analysis TAZs within 0.5-mile radius are considered as TODs, for comparative purposes VMT per household is derived for TAZ's within and outside the 0.25-mile radius are also computed and show in Table 4-3.

Table 4-3: Average Household Vehicle Miles of Travel (VMT/hh)

City / County	Radius from Metro Rail Stations			
	Quarter Mile		Half a Mile	
	Non-TOD (outside)	TOD (inside)	Non-TOD (outside)	TOD (inside)
Anne Arundel County	58.29		58.29	
Arlington County	**33.46**	**35.04**	**29.24**	**38.41**
Charles County	85.80		85.80	
City of Alexandria	**27.97**	**31.34**	29.23	27.65
District of Columbia	28.22	24.38	30.26	24.57
Fairfax County	49.36	37.01	49.74	37.53
Fauquier County	121.20		121.20	
Howard County	57.63		57.63	
Loudoun County	81.75		81.75	
Montgomery County	48.95	31.55	51.41	34.81
Prince George's County	53.48	41.76	54.19	43.56
Prince William County	67.83		67.83	
Stafford County	64.88		64.88	
Bold emphasis indicates a counter-intuitive occurrence where VMT/hh is lower for Non-TOD than for TOD.				

Intuitively it would be expected that VMT per household in Non-TOD areas would be higher than the same for the TOD counterparts for the same jurisdiction. However, as seen in Table 4-3, this is not the case for both Arlington County and City of Alexandria. For both 0.25-mile and 0.50-mile radii TODs, travel characteristics of Arlington County residents displayed a higher VMT per household for TOD zones than the Non-TOD zones. The same counter-intuitive trend is visible for the 0.25-mile radius TODs of City of Alexandria.

A careful examination of the HHTS records indicated a significant portion of the survey respondents living in the TOD zones of Arlington County and City of Alexandria reported fairly long reverse-commute trips. For example, several TOD residents of Arlington County took 50 miles or longer auto trips to suburban and exurban counties such as Anne Arundel County, Spotsylvania County, Frederick City (Maryland) and Frederick County (Virginia) and Loudoun County. These long reverse-commute trips skewed the household VMT of 0.25-mile TOD zones in both Arlington County and City of Alexandria. The VMT differences are consistent with conclusions by Zhang et al. (2012), which stated VMT in the TOD areas tend to be less than VMT in Non-TOD areas by up to 38% in the Washington D.C. area and 21% in Baltimore with otherwise similar land use patterns.

Table 4-4 presents VMT per household consolidated for three major urban categories identified in Table 4-1. As seen in the table, when Arlington County is excluded, household-level VMT for Non-TOD zones far exceeds that of the TOD zones, which is confirms intuition.

Table 4-4: Average Household Vehicle Miles of Travel (VMT/hh) by Urban Class

Urban Classification	Radius from Metro Rail Stations			
	Quarter Mile		Half a Mile	
	Non-TOD (outside)	TOD (inside)	Non-TOD (outside)	TOD (inside)
Exurban Counties	76.76		76.76	
Suburban Counties	55.15	36.20	56.35	38.07
Urban Core (Incl. Arlington)	29.42	26.89	29.75	27.51
Urban Core (Excl. Arlington)	28.15	25.00	29.94	24.96

4.4 Emission Footprints of Travel by TOD and Non-TOD Households

It should be reiterated here that for the purpose of emission footprint analysis, 'TOD land use' refers to TAZs within 0.50-mile radius of any of the 86 Metro rail stations. The approach to emission footprint analysis combines the VMT values derived in the previous section and aggregate emission rates developed for the MWCOG region shown in **Error! Reference source not found.** (MWCOG, 2009).

Table 4-5: Emission Rates (gm/mile) Used in the 2016 CLRP (MWCOG 2016)

Years	Ozone VOC	Ozone NOx	PM2.5 Direct	Precursor NOx
2016	0.337	0.407	0.02	0.45
2017	0.301	0.301	0.01	0.34
2025	0.204	0.142	0.01	0.16
2030	0.139	0.081	0.01	0.10
2040	0.098	0.043	0.01	0.06

The emission footprints (in grams per household) of each pollutant for each of the TOD and Non-TOD land use areas are then computed using Equation 4-1.

$$e_{p,lt} = \sum_z \left(\frac{\sum_{hh}(VMT_{lt,z,hh} \times er_p \times Wt_{hh})}{\sum_{hh}(Wt_{hh})}\right) / \sum_z \left(\frac{\sum_{hh}(VMT_{lt,z,hh} \times Wt_{hh})}{\sum_{hh}(Wt_{hh})}\right) \quad \text{..... Equation 4-1}$$

Where:

$e_{p,lt}$ = Emission footprints (gram/household) of pollutant type p, for land use *lt;*

$VMT_{lt,z,hh}$= Vehicle Miles of Travel in land use category *lt* and household *hh;*

p = Pollutant type (*Ozone VOC, Ozone NOx, $PM_{2.5}$ Direct* and *Precursor NOx*);

er_p = Emission rates (2016) shown in Table 4-5; and

Wt_{hh} = Household weight in the travel survey data.

As shown in the process illustration (Figure 4-1), results of the sample means analysis for each of the selected area are post-processed to derive emission footprints of *Ozone VOC*, *Ozone NOx*, and *$PM_{2.5}$ Direct* by facility type and area type. Table 4-6 through Table 4-9 present the summary results of emission analysis for *Ozone VOC, Ozone NOx, PM2.5 Direct* and *Precursor NOx,* respectively.

Table 4-6: Average Ozone VOC Emissions per Household (grams/hh)

County	Radius from Metro Rail Stations			
	Quarter Mile		Half a Mile	
	Non-TOD (outside)	TOD (inside)	Non-TOD (outside)	TOD (inside)
Anne Arundel County	19.64		19.64	
Arlington County	11.28	11.81	9.85	12.95
Charles County	28.92		28.92	
City of Alexandria	9.43	10.56	9.85	9.32
District of Columbia	9.51	8.22	10.20	8.28
Fairfax County	16.63	12.47	16.76	12.65
Fauquier County	40.84		40.84	
Howard County	19.42		19.42	
Loudoun County	27.55		27.55	
Montgomery County	16.50	10.63	17.32	11.73
Prince George's County	18.02	14.07	18.26	14.68
Prince William County	22.86		22.86	
Stafford County	21.86		21.86	

Table 4-7: Average Ozone NOx Emissions per Household (grams/hh)

County	Radius from Metro Rail Stations			
	Quarter Mile		Half a Mile	
	Non-TOD (outside)	TOD (inside)	Non-TOD (outside)	TOD (inside)
Anne Arundel County	23.73		23.73	
Arlington County	13.62	14.26	11.90	15.63
Charles County	34.92		34.92	
City of Alexandria	11.38	12.76	11.90	11.25
District of Columbia	11.49	9.92	12.32	10.00
Fairfax County	20.09	15.06	20.24	15.27
Fauquier County	49.33		49.33	
Howard County	23.45		23.45	
Loudoun County	33.27		33.27	
Montgomery County	19.92	12.84	20.92	14.17
Prince George's County	21.76	17.00	22.06	17.73
Prince William County	27.61		27.61	
Stafford County	26.40		26.40	

Table 4-8: Average PM2.5 Direct Emissions per Household (grams/hh)

County	Radius from Metro Rail Stations			
	Quarter Mile		Half a Mile	
	Non-TOD (outside)	TOD (inside)	Non-TOD (outside)	TOD (inside)
Anne Arundel County	1.17		1.17	
Arlington County	0.67	0.70	0.58	0.77
Charles County	1.72		1.72	
City of Alexandria	0.56	0.63	0.58	0.55
District of Columbia	0.56	0.49	0.61	0.49
Fairfax County	0.99	0.74	0.99	0.75
Fauquier County	2.42		2.42	
Howard County	1.15		1.15	
Loudoun County	1.64		1.64	
Montgomery County	0.98	0.63	1.03	0.70
Prince George's County	1.07	0.84	1.08	0.87
Prince William County	1.36		1.36	
Stafford County	1.30		1.30	

Table 4-9: Average Precursor NOx Emissions per Household (grams/hh)

County	Radius from Metro Rail Stations			
	Quarter Mile		Half Mile	
	Non-TOD (outside)	TOD (inside)	Non-TOD (outside)	TOD (inside)
Anne Arundel County	26.23		26.23	
Arlington County	15.06	15.77	13.16	17.29
Charles County	38.61		38.61	
City of Alexandria	12.59	14.10	13.15	12.44
District of Columbia	12.70	10.97	13.62	11.06
Fairfax County	22.21	16.65	22.38	16.89
Fauquier County	54.54		54.54	
Howard County	25.93		25.93	
Loudoun County	36.79		36.79	
Montgomery County	22.03	14.20	23.13	15.66
Prince George's County	24.06	18.79	24.39	19.60
Prince William County	30.52		30.52	
Stafford County	1.30		1.30	

It can be seen that the mean emission footprints for Non-TOD areas are generally higher than the footprints for TOD areas. However, NON-TOD land uses in Arlington County bucked this trend for all pollutants. This is to be expected because, as revealed in VMT analysis (Table 4-3), significant portion of household auto trips of the TOD land uses of Arlington County appear to be engaged in reverse commute trips of 50-miles or longer.

4.4.1 Means Comparison: Non-TOD vs. TOD

Despite the noticeably higher emission footprints of Non-TOD land uses; it is not known if these differences are statistically significant. The statistical significance of the differences can only be by conducting hypotheses testing on mean values of emission footprints presented in Table 4-6 through Table 4-9. Student's t-test is one of the most commonly used statistical significant tests for means comparison. The selection of households in the TPB travel survey data used in this analysis was done at random, which meets one of the criteria for t-test. Assuming that the VMTs associated with travel for the households are normally distributed, two-sample t-test would be appropriate for testing the following hypotheses:

Null Hypothesis, H_0:

$$\mu_{non-TOD,i} - \mu_{TOD,j} = 0;$$

Alternate Hypothesis, H_a:

$$\mu_{non-TOD,i} - \mu_{TOD,j} > 0; \text{ (One-tailed)}$$

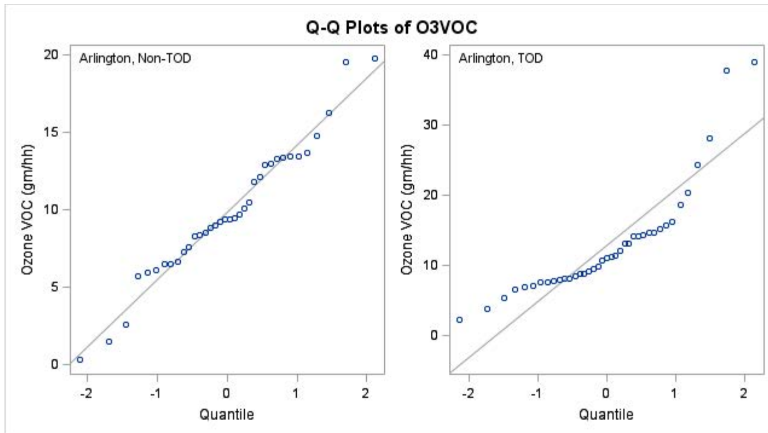
$$\mu_{non-TOD,i} - \mu_{TOD,j} \neq 0; \text{ (Two-tailed)}$$

Where:

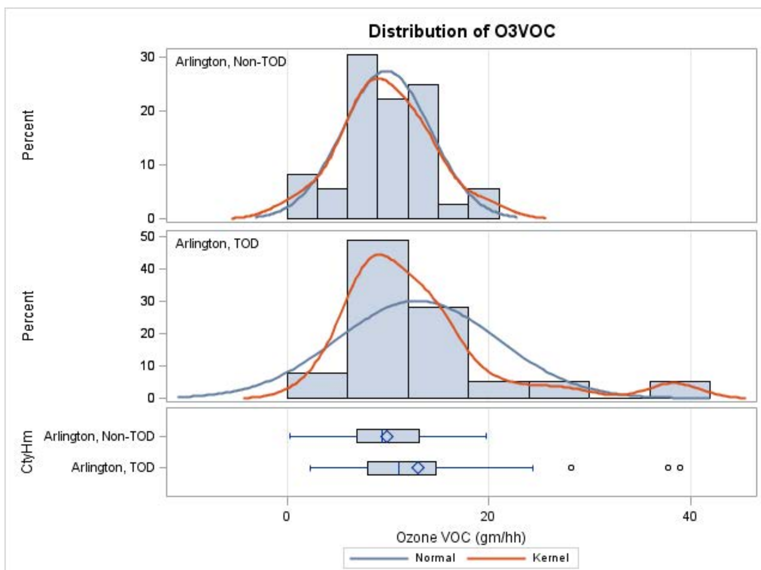
$\mu_{non-TOD,i}$ = Mean of emission footprint for a given Non-TOD area, *i; and*

$\mu_{TOD,j}$ = Mean of emission footprint for a given TOD area, *j*.

To test for Normality, mean values of emission footprints are also tested for Normal distribution assumption. Figure 4-5 provides a representative illustration of these tests for Non-TOD vs. TOD emission footprints of *Ozone VOC* for Arlington County. The figure indicates that *Ozone VOC* household-level emission footprints for both Non-TOD and TOD in Arlington County are normally distributed. Similar tests were conducted for all counties considered in the analysis (not shown). The tests for normality of emission household footprints of all four pollutants (namely*, Ozone VOC*; *Ozone NOx*; *PM 2.5 Direct*; and *Precursor NOx*) and for all TAZs across all counties (as illustrated in Figure 4-5) confirmed that the footprints aggregated at TAZ-level are random and independently distributed. Therefore, t-test is an appropriate statistical test for pairwise comparisons of means of emission footprints.



(a) Q-Q Plots



(b) Comparative histograms, normal and kernel densities, and box plots

Plots (a) and (b) show no obvious deviations from normality

Figure 4-5: Test for Normality of Ozone VOC Distribution Across Non-TOD and TOD TAZs in Arlington County

Using the t-test procedure in the Statistical Analysis System (SAS) software, pairwise comparisons were made on sample means for Non-TOD and TOD areas of the same jurisdiction.

Specifically, differences in emission footprints for *Ozone VOC, Ozone NOx, PM2.5 Direct* and *Precursor NOX* attributable to Non-TOD and TOD land uses for TAZs in six jurisdictions served by Metro rail service, namely, District of Columbia, City of Alexandria and Arlington, Fairfax, Montgomery, Prince George's counties are analyzed.

Mean differences of *Ozone VOC* emission footprints and the associated statistics on 95% confidence intervals, degrees of freedom (DF), t-values and probability of Type II errors for the both pooled (equal variance) and Satterthwaite methods (unequal variances) are shown in Table 4-10. The confidence limits shown for the standard deviations are of the equal-tailed variety.

Table 4-10: Two-sample t-Test Results for Ozone VOC Emission Footprints

Non-TOD vs. TOD Sample Means Tested	Var. Method	[1]Mean Diff. (gm/mi)	95% CL Mean Diff.		DF	t Value	Pr > |t|
District of Columbia	Pooled	1.9180	0.2026	3.6333	213	2.20	0.0286
	Satterthwaite	1.9180	0.1446	3.6913	124.21	2.14	0.0343
Arlington County	Pooled	-3.0920	-6.0744	-0.1095	73	-2.07	0.0424
	Satterthwaite	-3.0920	-6.0208	-0.1631	59.804	-2.11	0.0389
City of Alexandria	Pooled	0.5348	-2.1700	3.2396	51	0.40	**0.6931**
	Satterthwaite	0.5348	-2.2772	3.3469	38.42	0.38	**0.7025**
Fairfax County	Pooled	4.1152	0.4057	7.8247	280	2.18	0.0298
	Satterthwaite	4.1152	1.5788	6.6516	43.292	3.27	0.0021
Montgomery County	Pooled	4.1152	0.4057	7.8247	244	3.34	0.0010
	Satterthwaite	4.1152	1.5788	6.6516	242.6	4.66	<.0001
Prince George's County	Pooled	3.5826	-0.0608	7.2259	257	1.94	**0.0539**
	Satterthwaite	3.5826	-0.2107	7.3758	62.301	1.89	**0.0637**

Legend:

Bold emphasis indicates that the difference in sample means of the two land uses is not statistically significant at $\alpha = 5\%$.

[1] Negative value for 'Mean Diff.' indicates that emission footprints for Non-TOD TAZs are higher than footprints for TOD TAZs.

As Table 4-10 indicates, statistically significant differences exist between the TAZ-specific emissions footprints of TOD and Non-TOD land uses for Arlington, Fairfax and Montgomery counties and District of Columbia. However, the same cannot be said about Prince George's County (PGC) and City of Alexandria. The probability of Type-II error for PGC is less than 0.10, or the difference is significant at $\alpha = 10\%$.

Mean differences of *Ozone NOx* emission footprints and the associated statistics on 95% confidence intervals, degrees of freedom (DF), t values and probability of Type II errors for the both pooled (equal variance) and Satterthwaite methods (unequal variances) are shown in Table 4-11. As in the case of *Ozone VOC* footprints, statistically significant differences exist between the TAZ-specific *Ozone NOx* footprints of TOD and Non-TOD land uses for Arlington, Fairfax and Montgomery counties and District of Columbia. Also, the same cannot be said about the difference between Ozone NOx footprints of Non-TOD and TOD land use for the Prince George's County (PGC) and City of Alexandria.

Table 4-11: Two-sample t-Test Results for Ozone NOx Emission Footprints

Non-TOD vs. TOD Sample Means Tested	Var. Method	[1]Mean Diff. (gm/hh)	95% CL Mean Diff.		DF	t Value	Pr > |t|
District of Columbia	Pooled	2.3164	0.2447	4.3880	213	2.20	0.0286
	Satterthwaite	2.3164	0.1747	4.4581	124.21	2.14	0.0343
Arlington County	Pooled	-3.7342	-7.3361	-0.1323	73	-2.07	0.0424
	Satterthwaite	-3.7342	-7.2714	-0.1970	59.804	-2.11	0.0389
City of Alexandria	Pooled	0.6459	-2.6207	3.9125	51	0.40	**0.6931**
	Satterthwaite	0.6459	-2.7502	4.0420	38.421	0.38	**0.7025**
Fairfax County	Pooled	4.9697	0.4898	9.4497	280	2.18	0.0298
	Satterthwaite	4.9697	1.9065	8.0330	43.292	3.27	0.0021
Montgomery County	Pooled	6.7563	2.7695	10.7430	244	3.34	0.0010
	Satterthwaite	6.7563	3.9003	9.6122	242.6	4.66	<.0001
Prince George's County	Pooled	4.3267	-0.0734	8.7268	257	1.94	**0.0539**
	Satterthwaite	4.3267	-0.2544	8.9079	62.301	1.89	**0.0637**

Legend:
Bold emphasis indicates that the difference in sample means of the two land uses is not statistically significant at $\alpha = 5\%$.
[1] Negative value for 'Mean Diff.' indicates that emission footprints for Non-TOD TAZs are higher than footprints for TOD TAZs.

For both pollutants (*Ozone VOC* and *Ozone NOx*), there is no statistically significant difference between the emission footprints for Non-TOD and TOD for the City of Alexandria. This may be attributable to unique nature of land use within Alexandria. Also, probabilities of Type II errors are identical for differences in emission footprints of both pollutants. This is due to the fact all vehicular emissions are directly proportional to vehicle miles of travel. For this reason, emission footprint analysis for PM2.5 Direct and Precursor NOx would yield Type-II probabilities that are identical to the one shown in Table 4-10 and Table 4-11.

Thus, it may be concluded that for Fairfax, Montgomery and Prince George's counties, and District of Columbia emission footprints of TOD land uses are significantly lower than the footprints for Non-TOD land uses. However, Arlington County bucked the trend with higher emission footprints for TOD than the footprints for Non-TOD TAZs. Furthermore, it appears that in City of Alexandria the emissions for TOD zones are comparable to that of Non-TOD zones.

For further reference, additional tables pertaining to the t-test analysis, SAS code, input data and output files are provided in Appendix A.

4.5 All Pairwise Comparisons of Emission Footprints

Section 4.4 provided a pairwise comparison of emission footprints for Non-TOD and TOD within the same jurisdictions, which are served by Metro Rail. However, from academic and policy perspectives, it is useful to find out similarities and differences between pairs of jurisdictions across the regions. Due to sheer number of pairwise comparisons possible for all jurisdictions included in the analyses (Table 4-1) and their Non-TOD / TOD designates, where applicable, it is not practical to use Student's t-test for identifying those similarities (or dissimilarities).

When numerous pairwise comparisons are to be made, the most commonly used test of significance for all pairwise means comparison is Tukey's Honest Significant Difference (HSD) test or simply Tukey's Range Test (TRT). TRT is performed in combination with analysis of variance methods. However, TRT assumes equal variance of samples being tested. To verify if TRT can be used to perform pairwise comparisons across jurisdictions, tests of equality of variance variances for select pairs of Non-TOD and TOD land uses are performed. The results of this equality of variance tests using Folded F Method are summarized in Table 4-12.

Table 4-12: Equality of Variances using Folded F Method

Non-TOD vs. TOD Means Comparison for:	Num DF	Den DF	F Value	Pr > F
Arlington County	38	35	3.34	0.0005
City of Alexandria	20	31	1.34	**0.4514**
District of Columbia	68	145	1.18	**0.4169**
Fairfax County	254	26	2.80	0.0027
Montgomery County	174	70	7.30	<.0001
Prince George's County	44	213	1.08	**0.7003**
Bold emphasis indicates that the equal variance assumption may not be accurate.				

TRT provides reliable answers when population variances are similar. However, statistics shown in Table 4-12 are inconclusive as only three of the six pairs tested showed that variances of emission footprints for all TAZs across all counties are equal. Given the random sampling done for HHTS and normality of distribution of emissions footprints, for the purpose of all pairwise comparisons it is assumed that TRT would be applicable.

4.5.1 Results of Tukey's Range Tests

Using emission footprints as response variables and individual jurisdictions (i.e. counties) and their urban classification as class variables, General Linear Models procedure in SAS (PROC GLM) is performed along with associated TRT for nearly 200 possible pairs. The analyses produced 100s of pages of output. SAS output includes a number of range plots, which illustrate means and quartiles of emission footprints across the model's class variables. Figure 4-6 illustrates emission footprints of *Ozone VOC* for all counties included in the analysis. It is observed that emission footprints for Non-TOD TAZs are generally higher than the footprints for TOD TAZs.

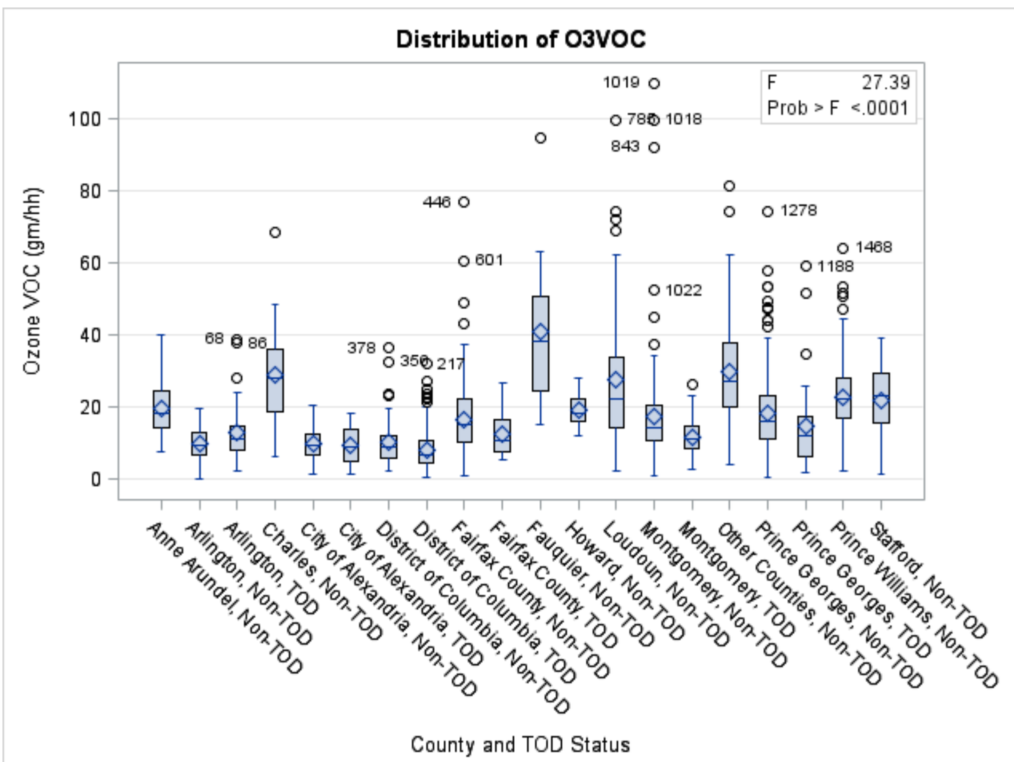


Figure 4-6: County-Specific Ozone VOC Emission Footprints

Figure 4-7 illustrates emission footprints of *Ozone VOC* for TAZs based on their urban classification. It can be clearly seen that emission footprints for Exurban and Other Rural counties have much higher emission footprints than their counterparts in the suburban and urban areas.

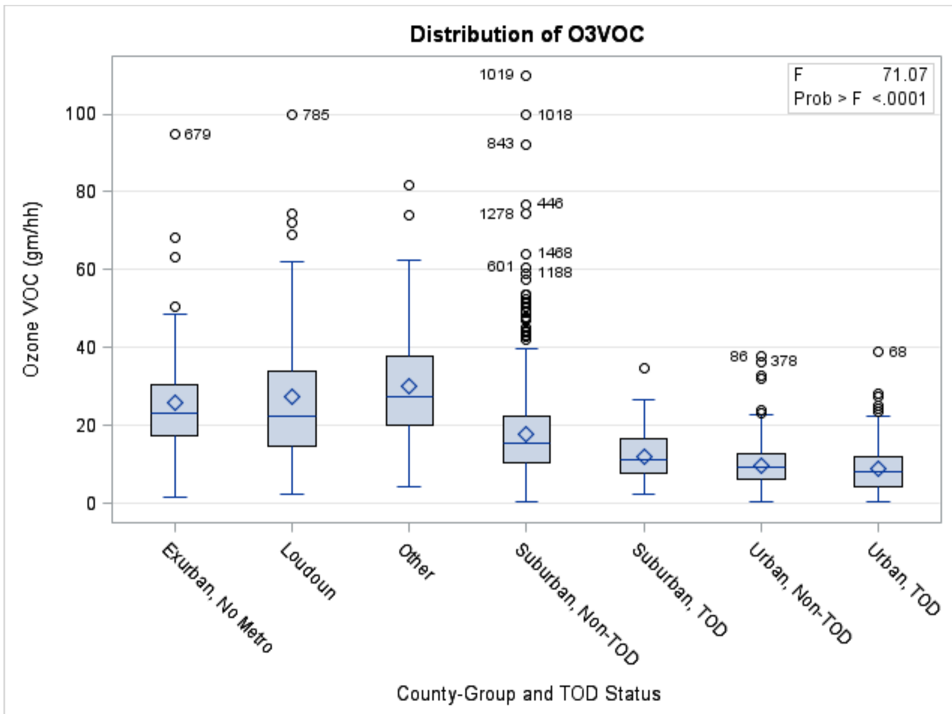


Figure 4-7: Ozone VOC Emission Footprints for Various Urban Classifications and Loudoun County

Synthesizing voluminous output from TRT into concise illustrations and observations has proven to be a challenge. Because of the proportionality of emissions with VMT, observations and conclusions based on the statistics for one emission footprint are also applicable to other three footprints. Therefore, results of TRT are summarized only for *Ozone VOC* footprints. Selected portions of the output are included in Appendix A. For illustrative purposes, a portion of the output for county-level pairwise comparisons of *Ozone VOC* footprints is shown in Figure 4-8. The last column in the output shown in the figure indicates whether or not the difference in emission footprint for the pair of locales is statistically significant ('blank' if not significant or '***' if significant). Top two rows in Figure 4-8 compare O3 VOC footprint for Fauquier County Non-TOD with other rural counties and Charles County Non-TOD, respectively. The statistic indicates that the difference between emission footprints for households in Fauquier County Non-TOD zones and that of Charles County is not statistically significant. On the other hand, Fauquier County Non-TOD zones have significantly higher (by 13.29 grams per household, as indicated by the column 'Difference in Means' column) *Ozone VOC* emissions than household in the Non-TOD zones of Loudoun County. The 23-page output illustrated in Figure 4-8 is consolidated into an easy to read chart shown in Figure 4-9.

The GLM Procedure

Tukey's Studentized Range (HSD) Test for O3VOC

Note: This test controls the Type I experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	1470
Error Mean Square	116.633
Critical Value of Studentized Range	5.02098

Comparisons significant at the 0.05 level are indicated by ***.

CtyHm Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
Fauquier, Non-TOD - Other Counties, Non-TOD	10.8032	-1.4020	23.0084	
Fauquier, Non-TOD - Charles, Non-TOD	11.9289	-2.1272	25.9849	
Fauquier, Non-TOD - Loudoun, Non-TOD	13.2939	0.9247	25.6630	***
Fauquier, Non-TOD - Prince Williams, Non-TOD	17.9866	5.7542	30.2190	***
Fauquier, Non-TOD - Stafford, Non-TOD	18.9809	2.9756	34.9861	***
Fauquier, Non-TOD - Anne Arundel, Non-TOD	21.1994	7.6843	34.7145	***
Fauquier, Non-TOD - Howard, Non-TOD	21.4235	7.0304	35.8166	***
Fauquier, Non-TOD - Prince Georges, Non-TOD	22.5818	10.7276	34.4360	***
Fauquier, Non-TOD - Montgomery, Non-TOD	23.5207	11.6021	35.4393	***
Fauquier, Non-TOD - Fairfax County, Non-TOD	24.0821	12.2746	35.8896	***
Fauquier, Non-TOD - Prince Georges, TOD	26.1643	13.2677	39.0610	***
Fauquier, Non-TOD - Arlington, TOD	27.8985	14.8085	40.9886	***
Fauquier, Non-TOD - Fairfax County, TOD	28.1973	14.4822	41.9123	***
Fauquier, Non-TOD - Montgomery, TOD	29.1149	16.6908	41.5390	***
Fauquier, Non-TOD - District of Columbia, Non-TOD	30.6454	18.1971	43.0936	***
Fauquier, Non-TOD - Arlington, Non-TOD	30.9905	17.7810	44.2000	***
Fauquier, Non-TOD - City of Alexandria, Non-TOD	30.9928	17.5915	44.3941	***
Fauquier, Non-TOD - City of Alexandria, TOD	31.5277	17.2567	45.7986	***
Fauquier, Non-TOD - District of Columbia, TOD	32.5633	20.5749	44.5518	***

Figure 4-8: Partial SAS Output for Tukey's Test of Pairwise Comparisons of O3 VOC Footprints

Result inconsistent with t-test
Result consistent with t-test

	Arlington, Non-TOD	Arlington, TOD	Charles, Non-TOD	City of Alexandria, Non-TOD	City of Alexandria, TOD	District of Columbia, Non-TOD	District of Columbia, TOD	Fairfax County, Non-TOD	Fairfax County, TOD	Fauquier, Non-TOD	Howard, Non-TOD	Loudoun, Non-TOD	Montgomery, Non-TOD	Montgomery, TOD	Prince George's, Non-TOD	Prince George's, TOD	Prince William, Non-TOD	Stafford, Non-TOD	Other Rural
Anne Arundel, Non-TOD	>			>		>	>			<									<
Arlington, Non-TOD			<					<		<		<	<			<	<		<
Arlington, TOD			<							<		<					<		<
Charles, Non-TOD				>	>	>	>	>	>				>	>	>	>			
City of Alexandria, Non-TOD										<		<	<		<		<		<
City of Alexandria, TOD										<		<			<		<		<
District of Columbia, Non-TOD								<		<		<	<		<		<		<
District of Columbia, TOD								<		<	<	<	<		<		<	<	<
Fairfax County, Non-TOD										<		<					<		<
Fairfax County, TOD										<		<					<		<
Fauquier, Non-TOD											>	>	>	>	>	>	>		
Howard, Non-TOD																			<
Loudoun, Non-TOD													>	>	>	>			
Montgomery, Non-TOD														>			<		<
Montgomery, TOD															<		<		<
Prince George's, Non-TOD																			<
Prince George's, TOD																		<	<
Prince William, Non-TOD																			<

Legend:
(1) Empty cells indicate that there is no significant difference in emission footprints of the two locales.
(2) '>' or '<' sign indicates that row locale's emission footprint is higher or lower, respectively, than the footprint for the column locale
(3) Example: Fairfax County Non-TOD zones have lower emission footprints than Loudoun County Non-TOD zones

Figure 4-9: County-by-County Pairwise Comparisons for Ozone VOC Emission Footprints

A generalized observation from Figure 4-9 is that emission footprints for Exurban and Other Rural Counties are significantly higher than their Suburban and Urban counterparts. As this observation itself is not surprising, the procedures and statistical methods used in developing this comparative assessment between pairs of jurisdictions within a region may be invaluable in policy-making exercises related to air quality monitoring. As mentioned earlier this comparative chart would be identical for other three pollutants analyzed, due mainly to their direct proportionality with VMT. However, as illustrated in Figure 4-9, notable disagreements are observed between the results of student's t-test and Tukey's Range Test. For example, student t-test observed statistically significant difference between Non-TOD and TOD zones of Arlington and District of Columbia where as Tukey's test indicated that these differences are not significant.

Because the results of equal variance analysis (Table 4-12) are inconclusive, results of TRT may be less reliable. Therefore, more appropriate statistical test for all the 190 pairwise comparisons shown in Figure 4-9 is the student t-test. Regardless of the test, the method described would be useful in policy analysis encompassing comparative assessment of land use types or jurisdictions.

4.6 Chapter Summary

TPB's 2008/2009 household travel survey data are innovatively used to identify TOD and Non-TOD land uses in the Metro Washington DC area. The data are then analyzed to capture emission footprints of households in the TOD and Non-TOD areas. Pairwise comparisons of means using Student's t-test indicated that for all but one jurisdiction emission footprints for Non-TOD zones are significantly higher than the footprints for TOD zones, thus verifying research premise #1. The only anomaly to this conclusion is Arlington County, where emission footprints for TOD are higher than the Non-TOD footprints. This anomaly may be attributable to long reverse commute trips originating from the TOD zones of Arlington County.

The Tukey's Range Tests performed for several pairs of jurisdictions and TOD status further consolidated research premise #1. The procedures and statistical methods used in developing this comparative assessment between pairs of jurisdictions within a region would be useful in policy-making exercises related to air quality monitoring.

5. EXPERIMENTAL IMPLEMENTATION OF THE METHODOLOGY

In Chapter 3 reasons for selecting Loudoun County, VA as the test-bed for the proposed Methodology are outlined. The proposed Methodology attempts to capture travel impacts and the associated emissions attributable to local land use changes using a sub-regional travel demand model. The objective of the Methodology is to act as an appropriate yardstick for smaller models to compare to finer and detailed results when compared to a regional model. This chapter presents details of end-to-end experimental implementation of the proposed Methodology using travel demand estimation for the test-bed with a select set of scenarios.

5.1 Developing Land Use Scenarios

The term 'end-to-end' implementation of the Methodology refers to application of the Methodology from the planning stage all the way through evaluation of performance measures. Therefore, implementation of the Methodology begins with development of land use scenarios. As mentioned in Chapter 3, one of the main reasons for selecting Loudoun County as the test-bed for implementing the Methodology is the commencement of Metro Rail's Silver Line service into the County. One of the stated objectives of the Silver Line Plan is to boost economic development; job creation and transit-oriented developments in the County and enable newer businesses and establish fiscal sustainability under current market conditions. The County's brisk population and economic growth and the extension of Silver Line corridor into the County, would encourage competing developments to introduce a mixed use, compact development, transit village type of developments around the metro stations.

5.1.1 The Development Process

The goals of proposed land use scenarios for the County include examining the opportunities for growth in the vital areas of the county in terms of prompt tax realization for future metro stations, determining options that would maximize future employment generation, and achieving desirable land use patterns and minimize demands on County's transportation system. The 2030 Countywide Transportation Plan with full build out of the transportation system planned for 2030 is illustrated in Figure 5-1. The figure also illustrates two Silver Line metro station locations that are expected to be completed by 2020.

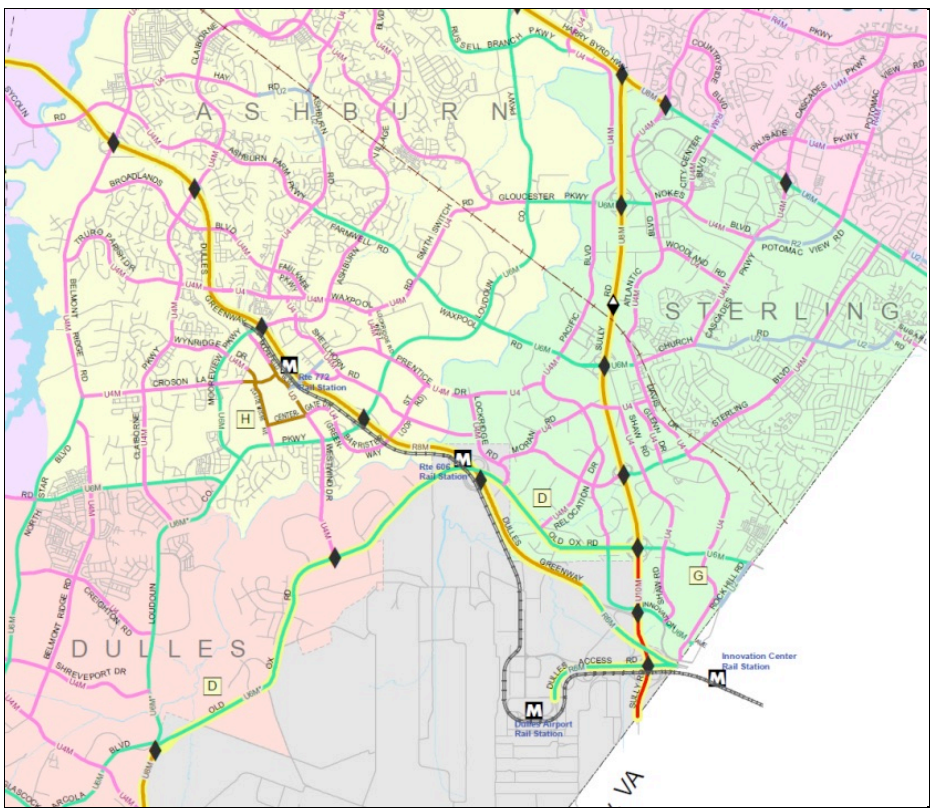


Figure 5-1: 2030 Countywide Transportation Plan, Location of Metro Stations and Surrounding Study Areas

Source : (Loudoun, https://www.loudoun.gov/ctp)

The land use scenarios developed for this study are derived from the scenarios developed for the County. The process of developing the scenarios required that a Silver Line Policy Area be defined that would be envision mixed use, transit accessible, walkable developments within one mile radius of the metro (Figure 5-2). Development of County's planning scenarios and the experimental scenarios of this study were done concurrently. The process involved background research on existing conditions, and conducting two public workshops, stakeholder meetings and interviews. This enabled the stakeholders to gain a better understanding of the issues most important to the community and to develop important performance measures to evaluate each scenario.

The first step in the process involved recognizing the existing land use patterns within the policy area. The Silver Line Policy Area covers approximately 4,275 acres. As of September 2016, the following were the existing conditions. Roughly 1,975 of this acreage had already been developed, while 2,300 acres were undeveloped or minimally developed. Developed land or land under development included 114 acres of community facilities, 483 acres of data centers, 504 acres of flex and industrial uses, 448 acres of residential uses, 271 acres of office uses, 101 acres of retail uses, and 25 acres of utility uses. Only 33 acres of land developed was mixed use" (Loudoun, 2017).

The first workshop included presentations to the public and live polling for feedback regarding issues relating to development patters around the county. The workshops and subsequent feedback resulted in a preference to high-density mixed-use land pattern for the study area, the survey response for which is posted at www.silverlinescenarioplanning.com. Following the workshop the project team conducted an internal charrette to discuss and synthesize workshop results and develop performance measures. Three scenarios were developed and assessed for tradeoffs. In addition to other fiscal performance measures, the scenarios were evaluated for transportation impacts on the 2030-countywide transportation plan in terms of volume to capacity (V/C) ratios. V/C ratios were chosen to serve as high-level performance measure to examine if the system can support the future transportation demand resulting from the planning scenarios.

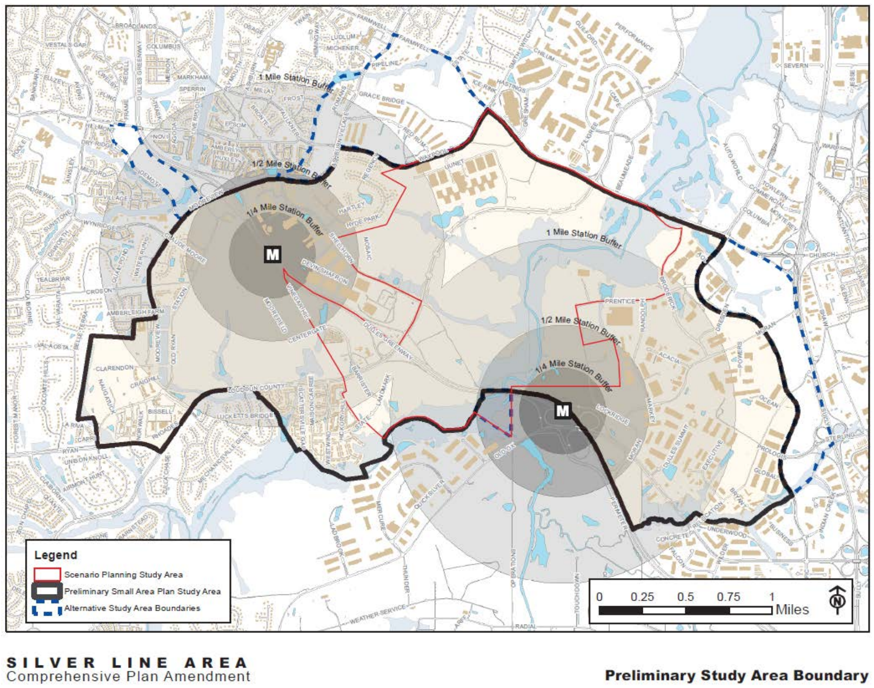


Figure 5-2: The Silver Line Policy Area in Loudoun County, VA (Loudoun, 2017).

Minimizing travel demand on the transportation system was examined in detail as a consideration for land use planning. The perspective in this regard is to create compact, walkable mixed use communities that could minimize the number and length of vehicle trips to an extent with support of local bus system and pedestrian and bike network. Planning process was also cognizant of the fact that the potential for new daily vehicle trips created by development around the Metrorail stations is unavoidable. Although not a viable as a TOD, data centers that have already been approved would be placed carefully due to their high tax revenue generating capability - without impacting the character of the surrounding developments.

Thus, potential land use scenarios around the future Silver Line Metro Rail Station areas were developed, through public inputs and stakeholder engagement process to contemplate future land use for the Silver Line Policy Area. Three policy scenarios were developed using public input and stakeholder engagement in this process (Loudoun County, 2016). The County's land use scenarios are adapted for this research to assess transportation impacts and capture sub-regional emission footprints based on these policies at the local level for the forecast year 2040. The Scenarios adapted and included for this study are as follows:

1. Business as Usual Scenario, also known as the Trend Scenario;
2. Housing Scenario; and
3. Transit Oriented Development (TOD) Scenario

A summary of households, population and employment, which are the key drivers of economic growth and travel demand, for the three scenarios are illustrated in Figure 5-3. The households and population for Housing and TOD scenarios are nearly identical and higher than the Trend scenario. However, employment projections associated with the TOD scenario are noticeably higher than the other two scenarios. Land use for existing conditions is shown in Figure 5-4.

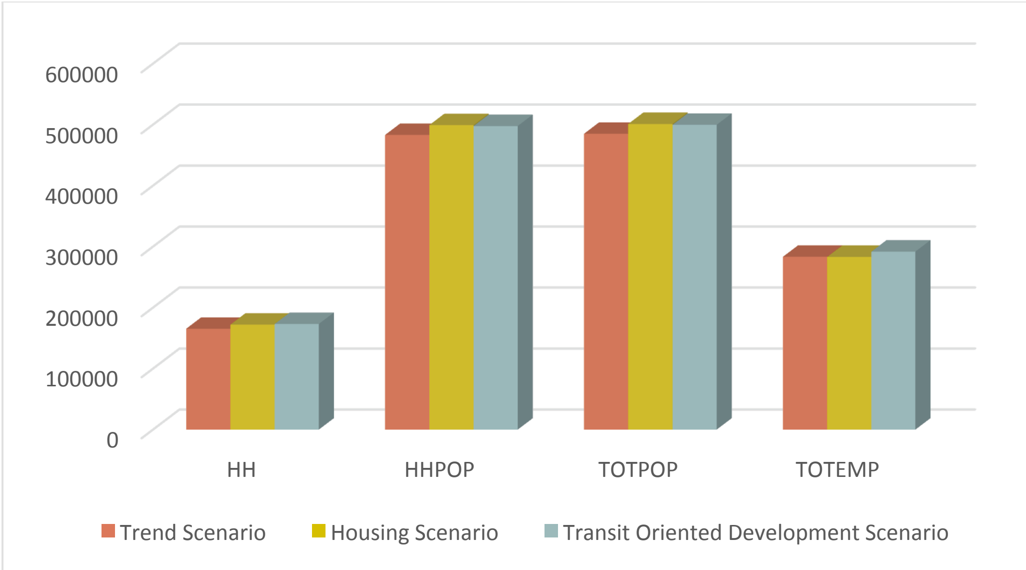


Figure 5-3: Demographic Projections for Land Use Scenarios

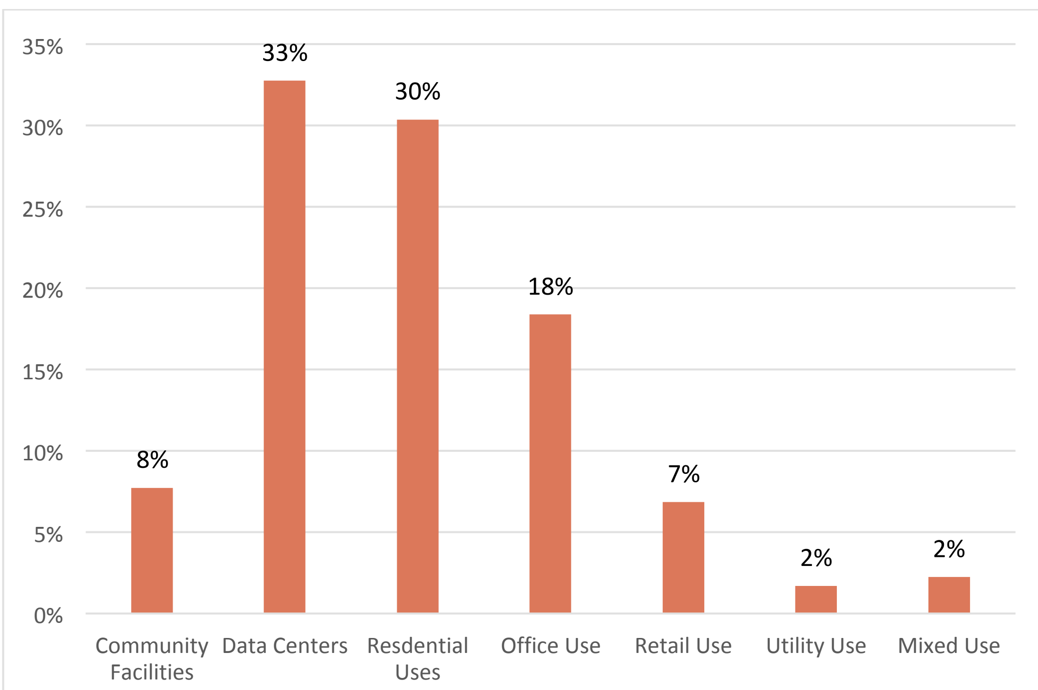


Figure 5-4: Current Land Use Status in the Silver Line Policy Area

5.1.2 Trend Scenario (TR)

This scenario calls for continuation of current planning and zoning policies for suburban-scale, auto-dependent developments surrounded by large surface parking supporting one or more 'keynote' employment uses: corporate headquarters, office towers with parking decks, and mid-rise office buildings and data centers that are permitted under current zoning. Thus, the Trend Scenario would serve as the 'control scenario' or 'base scenario' in the study experiment. Transportation investments in the study area follow closely the Loudoun Countywide Transportation Plan. Low-density development patterns and the physical distance between complementary uses (home, work and shopping) promote automobile travel (Loudoun, 2015). The build out potential for the Trend Scenario is illustrated in Figure 5-5.

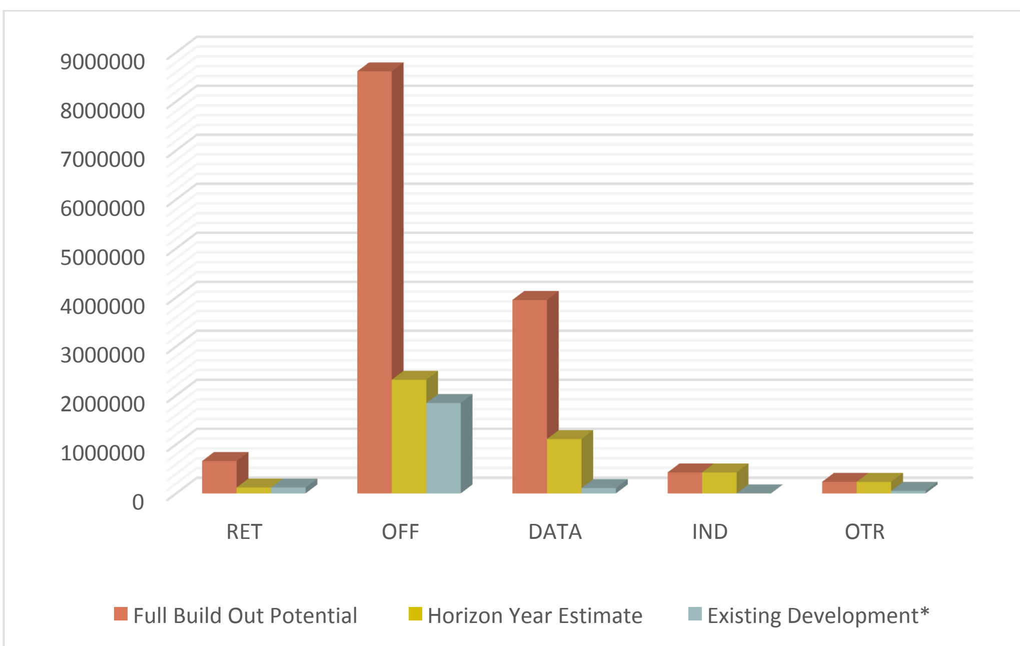


Figure 5-5: Build Out Potential Square Footage for Trend Scenario

As seen in Figure 5-5, the Trend Scenario shows 33% of its land use as Data Centers followed by 30% as residential use with only 2% of mixed use development planned which does not resonate with vision of county toward establishing a compact mixed use development around the metro stations.

5.1.3 Housing Scenario (HS)

Similar to what is prevalent in other parts of the County, housing choices development scenario represents a suburban development. This type of development pattern suburban-scale residential uses: single-family detached, single-family attached, multifamily attached, and multifamily stacked developments. The breakdown of potential for buildout of these developments is illustrated in Figure 5-6.

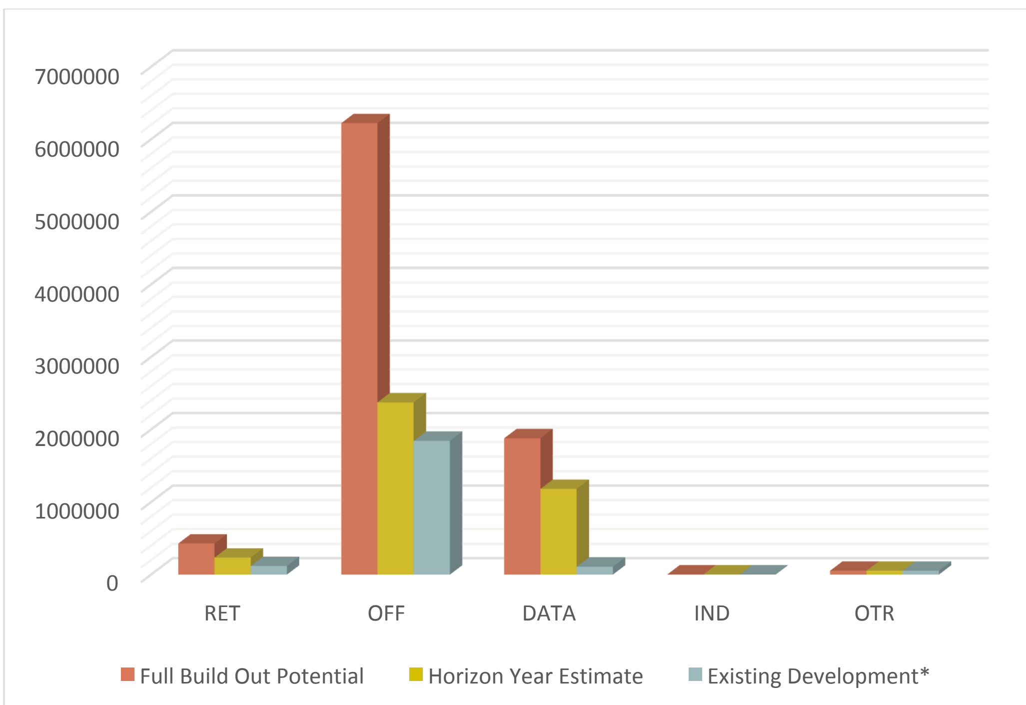


Figure 5-6: Build Out Potential Square Footage- Housing Scenario

Supporting suburban-scale, non-residential uses in the study area include: corporate headquarters, office towers with parking decks, mid-rise office buildings or shopping centers surrounded by parking lots, and data centers. Though the housing scenario contains several sustainable land use policies, it may be regarded as a ‘compromise’ between an ‘urban sprawl’ and a ‘fully compact development’ scenarios.

5.1.4 Transit Oriented Development Scenario (TOD)

Loudoun County defines Transit-Oriented Development (TOD) as a development served by, or planned to be served by, frequent transit service that is designed in a compact and dense urban form that facilitates convenient and comfortable bicycle and pedestrian access to applicable transit stations, drawing travelers to the transit station area, and supporting to the continued operation and growth of the transit system in the vicinity of the development. The TOD scenario represents shift from sub-urban planning to one that transitions to compact activity centers with a mix of uses and densities throughout. The Compact walkable areas plan to accommodate large number of non-residential options as significant employment centers within half a mile of transit stop. It envisions non-residential uses at 3.0-6.0 Floor Area Ratio. This scenario is tested for the impact of design and scale of development in the centers that would provide for a mixed-use environment with opportunities to live, work, shop and play in one community. It is also tested for a complete network of walkable streets supporting multiple modes of transportation, including efficient transit service to Metro Stations and local travel options within the activity centers. Land use mix and the build out potential for those land uses are shown in Figure 5-7.

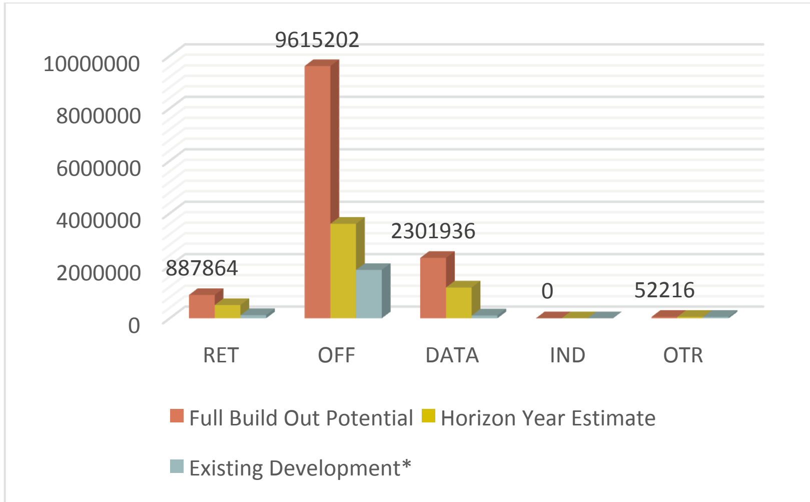


Figure 5-7: Build Out Potential Square Footage -TOD Scenario

The TOD scenario would accommodate bus transit service while encouraging walkability and pedestrian environment thereby encouraging better distribution of trips, shorter trip lengths. However, not to rule out the possibility of higher densities and increased activity at some intersections in the centers may result in increased congestion. Many residents and employees are expected to use Metrorail service to satisfy home-to-work and work-to-home trips into and out of the study area (Loudoun, 2015). The plan envisions about 3.6 million sq. ft. of office development for the TOD scenario.

5.1.5 Scenario Summary

The scenario comparison (Figure 5-8 through Figure 5-10) shows that TOD (or CD) Scenario allocates 10% more office use than the Trend scenario. Housing scenario allocates 35% less office space than trend scenario in terms of full build-out potential. The Housing scenario has highest population percentage whereas the employment percentages are the highest in the TOD scenario. It aligns with the trend of full build out potential square footage for office and data center uses for all three scenarios with allocated office are being highest for TOD scenario. However, the allocated area for data center uses for housing scenario are higher than in TOD scenario for the horizon year after which data center uses in TOD scenario supersede the housing scenario for full build out potential as shown in the Figure 5-9 (MWCOG, 2009) & (Loudoun, 2017).

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Figure 5-8: Demographic forecasts or Scenarios At Regional, Sub Regional and Policy Area Level.

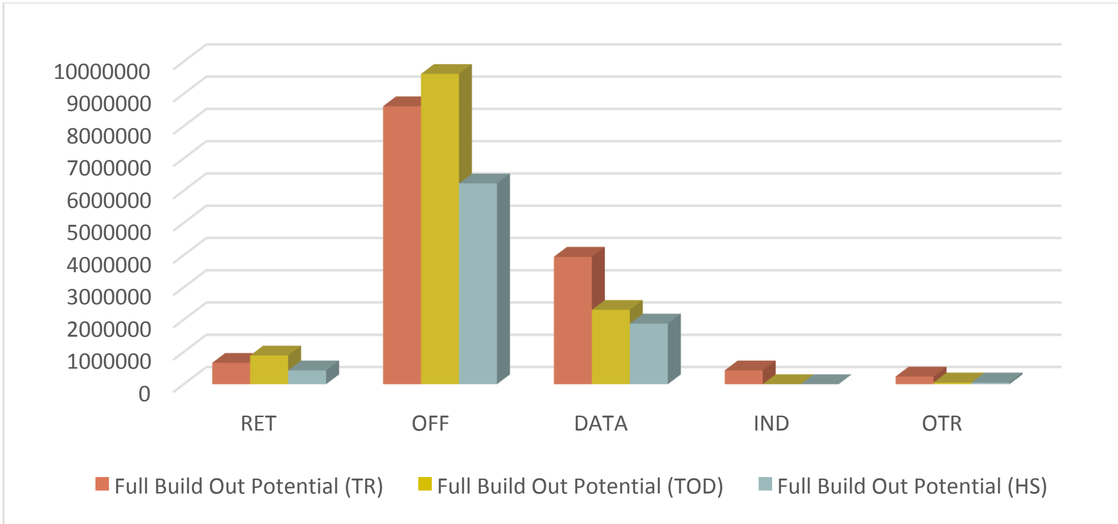


Figure 5-9: Full Build Out Potential Square Footage for Land Uses Across Scenarios

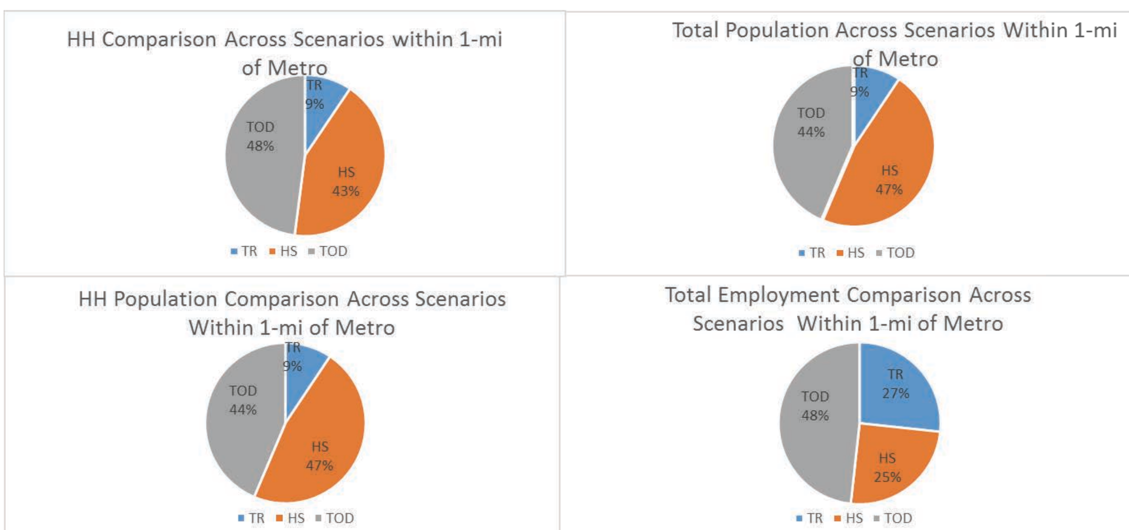


Figure 5-10: Socio-Economic Data Comparison Within 1-mile Radius of Metro Across Scenarios

The attributes for each land use form as outlined by the county are listed out in Table 5-1. Around 1-mile radius of the metro stations the TOD scenario shows highest number of dwelling units, average residential density and number of jobs when compare to trend and housing scenario. Such high densities and employment numbers usually lead to higher traffic but it is intriguing to explore how mode shift and TOD development pattern and infrastructure could play a role in reduction of emissions compared to the Non-TOD developmental patters.

Table 5-1: Comparison of Land Use Forms and Attribute Comparison for All Scenarios

	Desirable Land Use Patterns		
	Trend	TOD	Housing
Total Dwelling Units	618	9053	5,887
Avg. Residential Density	17.8 du/ac	56.7 du/ac	18.7 du/ac
Dwelling Units in LDN 60	0	3,141	5,445
Housing Affordability	Limited	Choices	Choices
Acres of Open Space	419 ac	694 ac	518 ac
Number of Students	142	2,082	1,411
Number of Jobs	13,632	21,292	13,851
Mix of New Jobs	Office/Data	Retail/Office/Data	Retail/Office/Data
Jobs-to-Housing Ratio	22.05 j/hh	2.35 j/hh	2.35 j/hh

Spreading outward from the Metro stops, medium intensity mixed use and urban residential is the planned development pattern; taking into consideration the location of the existing single-family residential land uses, which have already been constructed. Several data centers have developed recognizing the fiber optic and power infrastructure in this area. The Silver Line continues to support data center development in strategic locations where they will not conflict with proposed mixed-use and residential development.

Ashburn Station ¼-Mile Buffer: 1. Development proposals for land within ¼-mile of the Ashburn Station is envisioned to accommodate office developments and/or high-employment generating and developed with high densities uses that conform to the overall vision for a walkable urban development pattern.

Ashburn Station ½ -Mile Buffer: This area should is anticipated to develop similar to the ¼-mile area but at slightly lower densities. Since the ¼-mile area emphasizes developments with high employment generation, the ½-mile area is expected to develop with higher amounts of residential development and supportive retail services. Loudoun Gateway station ½-mile buffer land within approximately ½-mile of the Loudoun Gateway Metrorail is envisioned to function as a major destination and gateway to Loudoun County for Metrorail riders. The potential recommended land use scenarios were evaluated based on key factors such as:

- Placing the highest densities near Metro stations;
- Supporting walkable neighborhoods to live, work, shop, and play;
- Focusing forecast growth into key development areas;
- Providing park land and open space to meet community needs;
- Protecting operations at Washington Dulles International Airport;
- Providing a new urban multifamily housing product;
- Building a multi-modal roadway network;
- Allowing for phased development and interim uses; and
- Incorporating efficient transit service.

Growth and development in a compact form is focused on the areas closest to the future Metrorail stations. This scenario accommodates all growth forecast through 2040 in key development areas and retains additional land that can be used for open space, future development, or county facilities. The key development areas allow for strategically placed tax revenue generating data centers without creating demands on transportation infrastructure and other county services. The development areas also respect the Airport Impact Overlay Zone and nearby areas to provide protections for airport operations by recommending predominately nonresidential uses. The compact scenario provides for walkability, multi-modal transportation and transit service while creating a residential type land development pattern that is generally not currently available in the County" (Loudoun County, 2016).

Table 5-2: Socio Economic Attributes Around Metro Across Scenarios

Demographic	Scenario		
	TR	HS	TOD
Households (HH)	1,928	8,692	9,782
HH Population	4,023	20,135	18,687
Total Population	4,023	20,135	18,687
Total Employment	8,890	8,347	16,079

It is worth noting that a small change in land use looks insignificant when looked at the regional level but the same land use change seems significant on a county level. For example, when examining the land use scenarios for the county on a regional versus county level, the county level forecast seems more significant because of the relative scale. It is intuitive that similar logic applies to the impact of the land use changes over a region compared to sub-regional level. Therefore, any emission reduction that cannot be captured by a regional can potentially be captured using a sub-regional model with ease and allocated to the local jurisdiction for environmental and fiscal benefits without laborious post processing or losing resolution.

5.2 Application of the Methodology

The primary tool of the Methodology outlined in Chapter 3 is a sub-regional TDF model with finer TAZ. The sub-regional Loudoun County four-step model is used to assess the local land use impacts not only on travel activity but also on resulting emissions. For this, the three land use scenarios were set up as main scenarios. It was crucial that the impact of mode shift also be incorporated into the modeling methodology to incorporate the extension of Silver Line metro into the County. Therefore, mode shift sub scenarios were formulated under each land use scenario incrementing from 5% to 10%, and 15% for commuter trips between the county and other jurisdictions in the region connected by metro. These mode shift scenarios are incorporated as transit share increases primarily because the MWCOG model, on which the County model was built, did not include the silver line metro extension in the 2010 CLRP. It also gives an opportunity to understand the sensitivity of the model to transit and mode shift. This modeling framework aims to establish a link between policy decisions and future air quality and identify important factors that affect emissions and aid in improving air quality based on development patterns and strategies. Therefore, the impacts of local planning scenarios around a future mass transit line can be assessed by examining the sensitivity of the sub-regional model.

As population inflation and urban sprawl occurs and lifestyle tends to shift resulting in emission producing activities, air quality problems are on the rise. There is a gap in understanding how a wide range of factors along with potential developmental planning scenarios/ policies influence air quality at the urban and sub-regional scale with the inclusion of a mass transit line. Filling this gap and gaining insight into this issue will aid in developing informed decisions for protecting and improving public health and economic well-being.

As land use types were identified by county staff and decision makers, these scenarios were studied to develop a scenario which best balanced the benefits and tradeoffs for the county.

This involved study of parameters such as tax generation, fiscal impact, school population generation, travel activity, walkability, that determined the type of land use pattern that best suited county's goals that leverages the Silver Line policy area. Through public involvement, analysis of various metrics, and application of up-to-date planning principles, the study provided several thematic recommendations and a land use recommendation that served as the starting point for this Comprehensive Plan." (Loudoun, 2017). A methodical modeling system was developed and used to test each planning scenario in terms of their-

a. Transportation impacts with transit mode shift

b. Resulting emission contributions for a combination of land use scenarios and mode shift sub-scenarios.

Transportation impacts for the study area in consideration within the county were modeled using the County's four-step travel demand model that was recently updated in 2013 to be consistent with the updates of the MWCOG regional travel model. The model is set up and specified in Cube, a dynamic travel demand model software that is used to run this complex model and involves knowledge of Cube scripting to report, analyze and decipher transportation impacts resulting from the changing land use and transportation infrastructure.

5.3 Travel Demand Model for the Test-Bed

Loudoun County's Department of Transportation maintained its travel model that was developed in early 2000's that was run on DOS platform and used TP+/Viper program that was based on MWCOG's version 2.0 travel demand model. As MWCOG updated its travel model in the recent years with updated highway and transit networks, refined trip purposes and HOT lane modeling to name a few, it necessitated an update of the County model as well. A new version of the model was developed by AECOM utilizing Cube Voyager platform. The model structure was based on similar sub-urban area model such as Prince William, Stafford and Spotsylvania Counties. The County model covers the entire MWCOG region however with a comparatively a shorter run time compared to the MWCOG regional model and a simpler transit/mode choice model. The primary inputs to the County model are a TAZ system, detailed highway network, TAZ-specific socio-economic input file and transit shares by purpose that included all transportation infrastructures that is in the Countywide Transportation Plan (Loudoun, https://www.loudoun.gov/ctp) that was used for planning study (Loudoun County, 2016).

5.3.1 Hardware and Software

The sub-regional model runs on Cube Voyager, one of the latest available and dynamic travel demand modeling software packages in the transportation industry. The model is a series of complex steps involving mathematical equations, matrix building and iterations that comprises of 8 major steps which are briefly explained below with a screenshot of the flowchart as follows

1. Network preparation–In this step the zonal area types are calculated and speed-capacity tables are updated in the input highway network
2. Skimming–Paths are built to generate zone-to-zone travel distance and time here.
3. Trip Generation–Household size and income sub models are applied and trip generation process is performed by trip purpose here.
4. Trip Distribution–Friction factors are built and trip generation is performed here.
5. Mode Choice–Trip tables from trip distribution step are separated into highway and transit modes.
6. AM Feedback Loop-Speed feedback loop recycles constrained traffic speeds from highway assignment back into earlier modeling steps to attain equilibrium of model results.

7. Time of Day Model-This apportions daily resident travel among four time periods – AM peak period (6AM-9AM), PM peak period (4PM-7PM), Midday (9AM-3PM), Off Peak (7PM-6AM) before being assigned to highway network.
8. Highway Assignment- This step results in a loaded network with time of day statistics such as lane miles by facility type, level of service vehicle miles of travel and vehicle hours of travel.

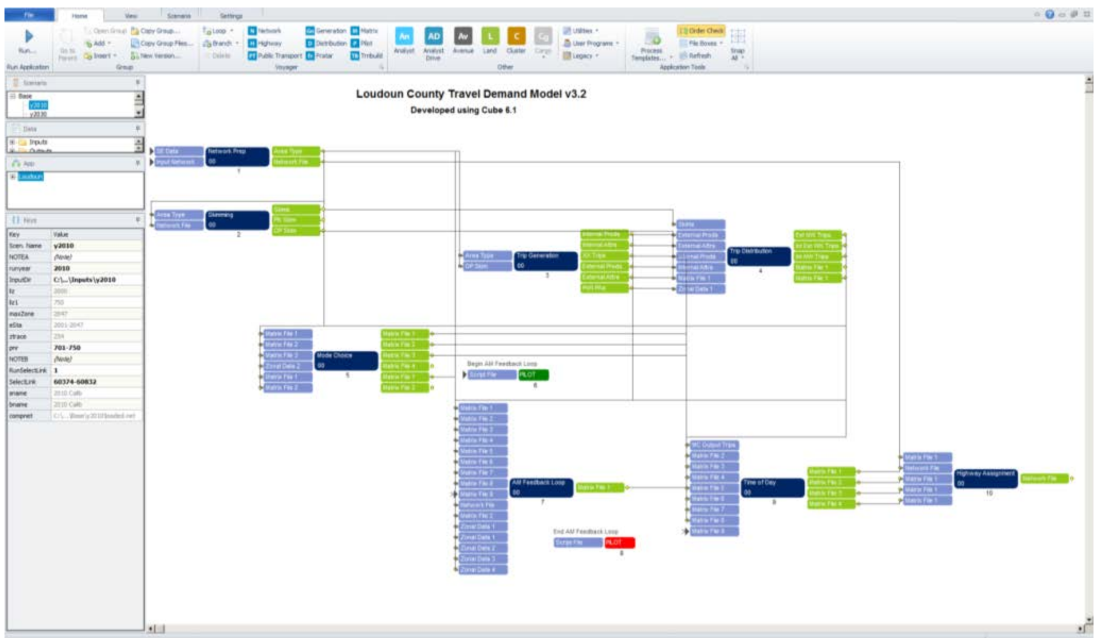


Figure 5-11: Loudoun County Model Flowchart

5.3.2 Road Network

The County's highway network was derived from the network used in the MWCOG 2010 highway network as of MWCOG model version 2.3.39. It is important to note that this model was used in the MWCOG's 2010 air quality conformity analysis and at that point there was no representation of the Silver Line metro in the County model. The land use information in the County model, stratified by the traffic analysis zones (TAZ) is as follows:

- Total households (i.e., occupied dwelling units)
- Population living in households (excludes people living in group quarters)
- Population living in group-quarters (as defined by the Census; includes nursing homes, dormitories, prisons, barracks, etc.)
- Industrial employment
- Retail employment
- Office employment
- Other employment
- Jurisdiction code (see Table 3-1)
- Median household income
- Truck zone flag
- Transit service flag (Loudoun County only)

5.3.3 Traffic Analysis Zones (TAZs)

Within the County, MWCOG has 282 zones, which were subdivided primarily by the County GIS staff to create 667 zones in developing the Loudoun County model. The disaggregation was performed by following census 2010 boundaries as well as by following features such as existing roads, streams, major power lines and future Countywide Transportation Plan (CTP) roads. The zones were numbered in the order of the MWCOG zones to which they belong. Zone numbers 668-700 are spare zone numbers reserved for future use. Zones 701-750 are reserved for park-and-ride lots. Zones 751-1952 are areas outside of Loudoun Co. Zones

1953-2000 are spare zone numbers reserved for future use. Zones 2001-2047 are the external stations as shown in Figure 5-2.

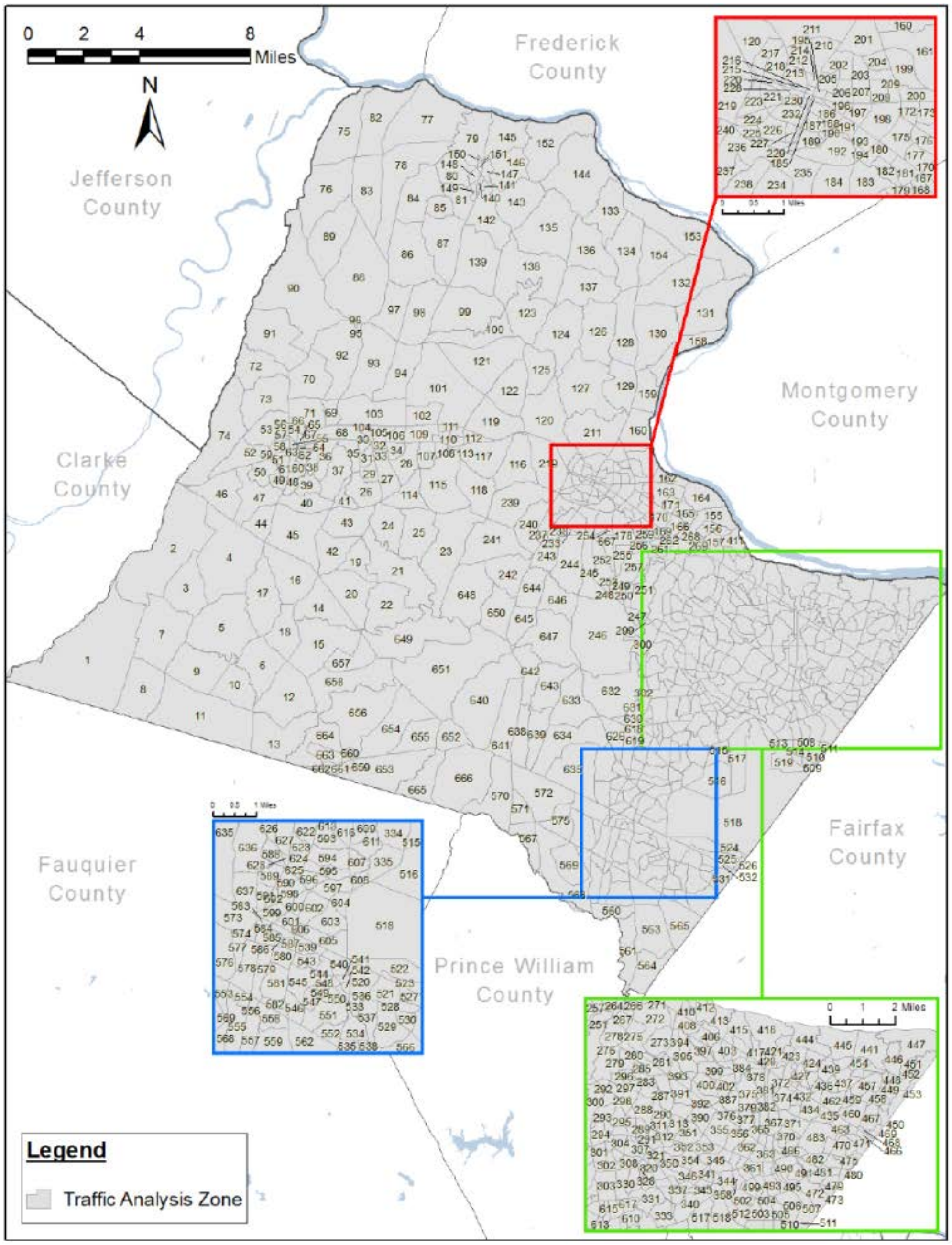


Figure 5-12: The Loudoun County Planning Model TAZ System

5.3.4 Economic Forecast

The economic forecast data for horizon years were obtained from MWCOG and represent Round 8.0 of the region's cooperative forecast for 2010.

5.3.5 Representing Transit Service

TAZ-specific inputs to the model represent an estimate of the level of transit service that is available in the zone with 0 through 3 representing no service to excellent transit service via a 'transit flag'. Bus routes coded in the MWCOG model for 2010 were used as the basis to determine the transit flag values (Figure 5-13). The modes that were used included only the Loudoun County intra-county buses (inter-county commuter ridership is handled separately). Shape-files of the bus stops along with the Loudoun County model TAZ layer were used and using GIS software the transit flags were determined using the following logic: if more than 50% of the zone area is covered by a 1 mile buffer, then transit flag=1; if more than 50% is covered by 0.5-mile buffer, then flag=2 and if more than 50% is covered by 0.25-mile buffer, then flag=3.

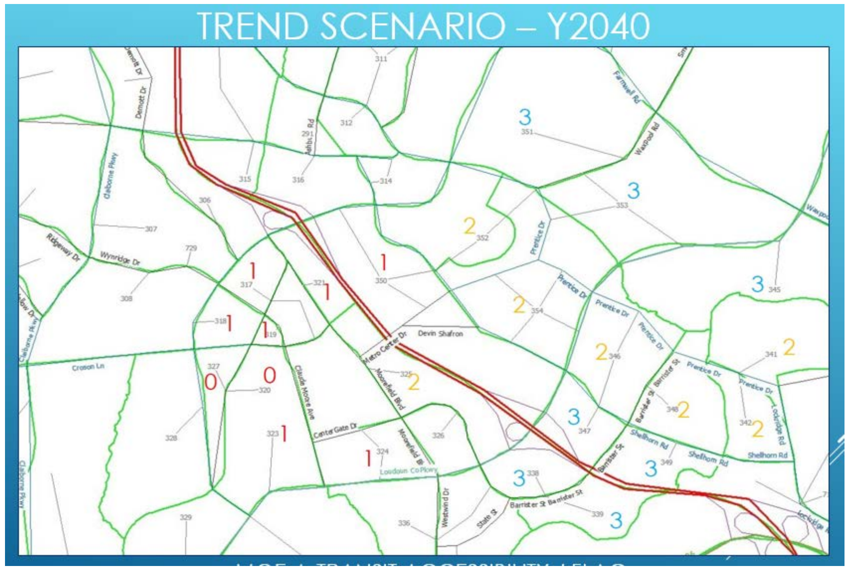


Figure 5-13: Transit Flags showing accessibility to transit for Trend Scenario

5.3.6 Accounting for Mode Choice

The County model uses a simplified mode choice procedure that is appropriately scaled to the level of transit planning issues in the County. In many models, the transit analysis input requirements are very detailed. However, this model in order to avoid very lengthy runtimes, uses straightforward inputs that are essentially the outputs from the MWCOG model. The transit percentages by purpose are between 23 MWCOG jurisdictions, of which are DC, Arlington, (for core and non-core), Alexandria, Fairfax, Prince William, Loudoun, Prince Georges etc. These transit shares are essentially used as a transit element for mode split step. Therefore, these transit files were essentially used as variable components to develop scenarios that incorporated the following:

a. Extension of Silver Line into Loudoun county

b. Development of transit oriented scenarios that vary from 0% through 15% transit share increase between sub-urban study area to other areas served by mass transit

The mode choice step takes into consideration four elements in the model:

1. Intra-County transit ridership
2. Regional commuter transit ridership
3. Park-and-ride lot demand
4. Auto occupancy model

The first three of the above components have specific input requirements that are described as follows:

- Intra-County transit ridership is transit travel that happens completely within Loudoun County and is stratified by transit attraction flag that takes values from 0-3 that generally describes transit accessibility for each TAZ. Any subsequent changes in local transit service would be reflected by changing the values of these variables in the zonal data file. The model estimates transit trips (developed and adjusted by examining similar other models) by applying these percentages to estimated person trips for each zone-to-zone movement within the county. This approach accounts for transit accessibility but not transit frequency and service coverage. No intra county transit shares were altered for scenario testing.

The modes that were used included only the Loudoun County intra-county buses (inter-county commuter ridership is handled separately). If these values need to be updated for a new scenario year, the user would need shape files of the local bus stops from the MWCOG model for that scenario year and the County model TAZ layer. However, the commuter transit trips are categorized by trip purpose. For this research, the transit shares for HBW trips between Loudoun and other jurisdictions was changed by 5% increments to assess the impact of transit shift along with other developmental patterns for potential reduction in emissions.

- Regional Commuter/ Inter County Trips are not “modeled” but are adopted from the MWCOG model between county-to-county (23x23 matrix) as percentage of person trips using transit. Scenario testing involved development of sub scenario for each land use scenario by altering the HBW commuter person trip percentage for 5, 10 and 15% as three separate mode shift scenarios A sample transit share file is shown in Figure 5-14 for context.

; Transit Share Table, HBW
; Simulation - Year: 2040 Alternative: Ver2.3.39_2040 Iteration: i4
; Purpose: Internal HBW Trips MODE: Transit Percentage

; DESTINATION

;	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	83.9	92.7	73.7	48.7	93.4	93.3	83.0	60.3	9.9	8.4	0	0	3.8	3.4	0	0	0	0	0	0	0	0	0
2	93.1	85.4	68.4	44.0	87.4	89.8	79.8	52.6	7.5	6.0	0	0	3.2	2.5	0	0	0	0	0	0	0	0	0
3	64.1	37.0	18.1	9.7	60.6	48.6	25.1	15.1	0.6	0.2	0	0	0.4	0.5	0	0	0	0	0	0	0	0	0
4	60.1	36.2	21.7	10.2	60.1	49.9	22.8	12.7	0.7	0.2	0	0	1.9	0.7	0	0	0.0	0	0	0	0	0	0
5	97.7	73.2	50.2	26.7	19.7	76.5	56.6	42.1	5.4	1.8	0	0	0	0.8	0	0	0	0	0	0	0	0	0
6	82.5	51.1	29.4	13.1	53.6	42.9	36.1	22.7	2.3	1.0	0	0	0.1	0.5	0	0	0	0	0	0	0	0	0
7	75.5	47.5	28.2	9.5	57.0	53.5	26.9	16.6	1.6	1.7	0	0	0.0	0.3	0	0	0	0	0	0	0	0	0
8	50.9	30.2	14.3	3.9	53.8	43.5	21.3	9.7	0.9	0.4	0	0	0	0.0	0	0	0	0	0	0	0	0	0
9	46.7	29.4	13.7	8.2	50.3	41.0	15.8	9.8	6.0	0.0	0	0	0	0.0	0	0	0	0	0	0	0	0	0
10	40.1	30.3	11.6	3.4	46.0	39.4	20.6	4.7	0.1	1.7	0	0	0	0.0	0	0	0	0	0	0	0	0	0
11	40.8	18.2	8.4	3.7	26.9	20.6	10.4	3.4	0.1	0.0	0.8	0	0.0	0.2	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	46.1	19.5	5.5	3.7	43.9	33.3	14.0	4.4	0.1	0.0	0	0	0.7	0.2	0	0	0	0	0	0	0	0	0
14	40.8	16.3	5.7	2.9	35.7	28.2	11.8	5.5	0.2	0	0	0	0.2	0.1	0	0	0	0	0	0	0	0	0
15	28.8	22.9	11.2	3.1	37.5	32.1	15.2	7.1	0.5	0.2	0	0	0.0	0.1	0.1	0.0	0.0	0	0	0	0	0	0
16	31.7	19.9	18.1	2.2	46.9	40.8	12.4	7.0	1.0	0.5	0	0	0.1	0.0	0.0	0.2	0.6	0	0	0	0	0	0
17	31.8	20.8	12.1	2.3	37.2	30.2	11.5	5.4	0.4	0.1	0	0	0.1	0.0	0	0.1	1.4	0	0	0	0	0	0
18	8.7	9.2	2.4	0.8	12.1	10.2	4.9	0.2	0.0	0.1	0	0	0	0.0	0	0	0	0	0	0	0	0	0
19	25.2	20.9	7.1	1.8	31.5	28.4	13.3	1.5	0.1	0.5	0	0	0	0.0	0	0	0	0	0.0	0	0.0	0	0
20	0	20.3	7.0	4.0	0	0.6	0.3	0.8	0.0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	0
21	22.3	19.6	7.9	0.7	28.9	24.9	14.2	1.6	0.0	1.1	0	0	0	0	0	0	0	0	0.1	0	0.0	0	0
22	1.1	2.0	0.5	0.1	5.7	5.9	4.2	0.4	0.0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 5-14: Home Based Work Transit Share Table for TOD5% Scenario

- Park-n-Ride Lots: In effect, this approach treats these lots only as generators of auto trips. This is valuable as a means of modeling vehicle trips near these lots, which can be substantial. But it is critical to understand that the County model does not separately estimate the demand for drive-to-transit service, *per se*. (Drive-to-transit ridership is implicitly included in the intra-County and inter-county transit estimates described in the previous two sections.) The PnR module described here is completely independent of the transit estimates described in the preceding two sections. In this model, adding new PnR lots will not reduce auto travel; in fact, it will *increase* it. No additional park and ride lots were added for scenario testing effort.

6. ANALYSIS AND RESULTS

This chapter presents results of the travel demand forecasting performed on Loudoun County planning scenarios outlined in Chapter 5.

6.1 Scenario Runs

The experimental setup included testing a combination of 12 scenarios in total, VMTs by facility type and area type are compiled for each of the 12 scenarios. The 12-scenario matrix is a combination of the following three land use patterns and four transit use assumptions:

Land use scenarios:

1. Trend Scenario (TD)
2. Housing Scenario (HS)
3. Transit Oriented Development (TOD)

Transit use assumptions:

1. HBW commuter transit trip percentages = ‘as is’ (no change)
2. Increase in HBW commuter transit trip percentages = 5%
3. Increase in HBW commuter transit trip percentages = 10%
4. Increase in HBW commuter transit trip percentages = 15%

Each of the scenario runs in the 12-scenario matrix included in the experiment needed approximately 30-hours for completion using the GMU computing resources, some of which were acquired exclusively for this research. Comparatively, using the same computing infrastructure, execution times for the TPB (MWCOG) model required more than six days for completing one run. Including the time needed for set-up, error handling, fine-tuning, and analyses; this task of the research required over six months for completion.

6.2 Estimates of Vehicle Miles of Travel

Vehicle Miles of Travel (VMT) is the key indicator for estimating mobile source emissions resulting from auto travel. Therefore, if any policy or strategy results in the reduction in VMT, it translates directly into reduction in emissions. Smart-growth strategies, land use planning and development, expansion of transit and pedestrian and bicycle infrastructure are some of the most popular approaches that state and regional agencies use a guideline to encourage reductions in VMT and therefore emissions. These strategies are overlapping in nature and different states focus and adopt different features of these strategies. However relatively small scale of land use strategies vis-à-vis the aggregate nature of the regional models makes the models insensitive to the impacts of these strategies on the transportation system and the environment.

It is anticipated that the disaggregate Methodology using the sub-regional travel demand model would alleviate this shortcoming of the regional models. The Loudon County model is scripted in such a way to output consolidated VMTs in the following classifications:

1. VMT by Area Type and Facility Type: These Area types are defined using MWCOG's definitions area types were determined based on 0.75-mile 'floating-point' density, which is the density calculated by adding the population (or employment) of a zone with that of zones whose centroids are within 0.75 miles radius from that zone and dividing the resulting population by the area of that zone and the area of zones whose centroids are within 0.75 miles radius from that zone. The assignment of the area type is based on the value of a zone's floating-point

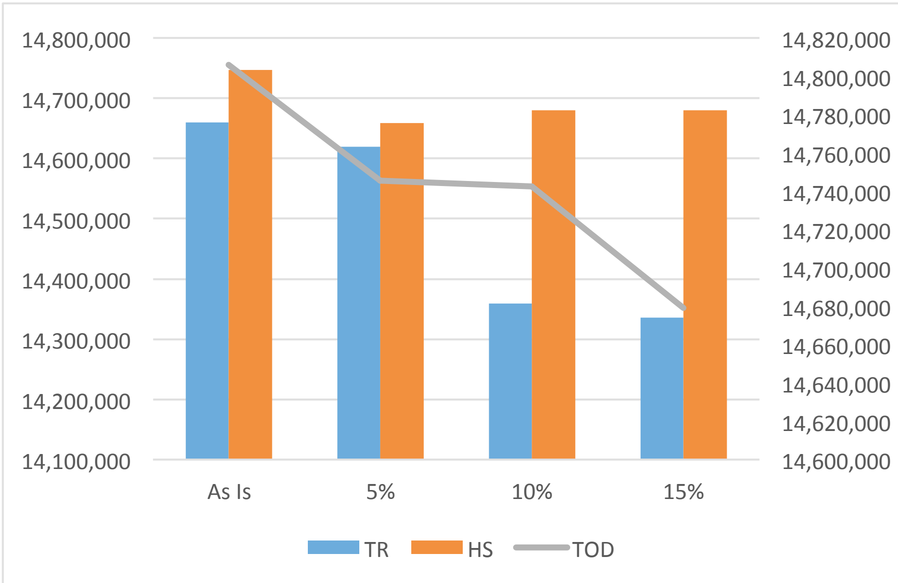
population and employment density, thereby categorizing them into high mixed density, medium mixed, medium employment, medium population low density and rural areas.

2. VMT by Major Route: Specifies VMT outputs by major routes that pass through within the county namely US routes 15, 28 and 50; VA routes 7, 267, 606, and 659
3. VMT by Functional Class: Specifies VMT by functional class Principal Arterial, Minor Arterial, Major Collector and Minor Collector.
4. Total VMT Total vehicle miles travelled for each scenario tested.

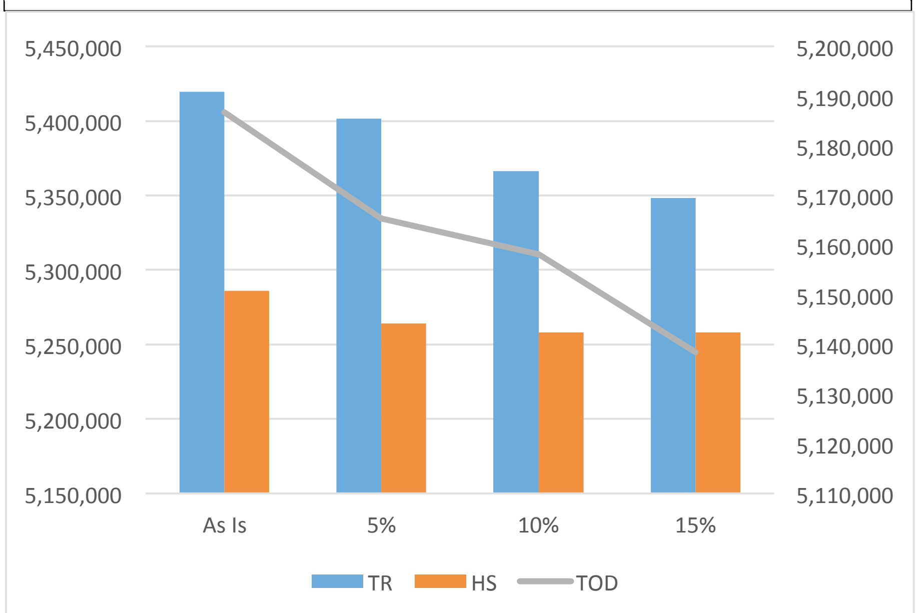
There are 8 facility types in a sample VMT output chart (Table 6-1) showing the facility types, area types for “As Is” transit share and all three-land use scenarios. The numbers in the table are also illustrated in Figure 6-1. To avoid clutter in this chapter, tables showing all VMT data output for all possible combinations of transit share, area type, facility types are included in Appendix B. The VMT data is post-processed for emission capture for the county for various scenarios that is discussed in the next section.

Table 6-1: VMTs By Area Type and Facility Type With No Change in Transit Share

Transit Share	2-Med-High Mixed Density			3-Med Employment Density			4-Med Pop Den			Total (Includes Low Density and Rural Areas)		
No Change	TS	HS	TOD	TS	HS	TOD	TS	HS	TOD	TD	HS	TOD
Freeway	676,686	705,510	707,055	2,150,359	2,144,964	2,146,331	240,683	241,889	242,447	4,229,356	4,246,009	4,255,624
Major Arterial	329,847	422,824	432,101	347,424	285,009	286,223	255,741	260,613	262,993	963,583	1,000,747	1,012,423
Minor Arterial	92,140	93,555	92,580	490,844	497,331	495,195	367,705	366,913	369,425	2,422,258	2,428,098	2,427,736
Major Collector	328,024	405,378	393,822	954,113	907,250	929,755	560,807	559,976	567,514	3,408,326	3,424,057	3,457,730
Minor Collector	123,646	161,848	185,120	273,381	239,901	224,950	173,174	174,265	175,727	728,067	733,576	742,662
Local	68,188	68,295	69,582	106,236	107,183	107,004	125,504	125,437	125,070	1,211,407	1,211,163	1,204,342
High Speed Ramp	74,241	74,815	77,081	106,881	107,299	104,937	5,133	5,123	5,148	245,164	245,707	245,791
Low Speed Ramp	70,391	74,073	74,510	113,324	110,476	110,358	19,123	18,930	18,846	235,867	236,877	236,814
Total	1,763,163	2,006,298	2,134,102	5,419,378	5,286,128	5,186,758	1,747,870	1,753,146	1,767,170	14,660,032	14,747,392	14,806,075



(a) Total VMT Within County For Scenarios Across All Transit Share



(b) Total VMT Within Medium Employment Density Area Type Across All Transit Share Scenarios

Figure 6-1: Total VMT- County Vs. Medium Employment Density Area for Transit Share “As Is”

The following observations are registered based on the countywide VMT for the Medium Employment Density areas:

1. When countywide total VMT figures for the three land use scenarios with no changes in transit share percentages are examined, TOD scenario starts off with the highest VMT. As the transit shift increases, VMT for TOD scenario consistently drops for the entire county whereas VMT for Housing Scenario consistently rises with increase in transit shares. It is noteworthy that even though TOD scenario incorporates higher employment at the high and medium employment density areas, the resulting countywide VMT for TOD scenario is still lower in contrast with the Housing scenario. Increased street connectivity and shifting of increased number of HBW work trips to transit in the TOD scenario versus the Housing, given that housing has increased population explains this phenomenon.
2. Total VMT also decreases for the TOD scenario by area type (for certain facility types), namely with medium employment density area (area type 3) when compared to the Housing scenario when transit mode shift is 'as is'. It suggests that area type and facility type around the policy area play a significant role in impacting vehicle miles of travel.
3. For a given area type, total VMT increases as mode shift increases. This suggests that there is a significant interaction for are type and transit shift. The total VMT figures, however, are not considered for principal arterials, local and unpaved roads because there is not very many roadways in the county are classified in these categories. It would be intriguing to see the impact outside of the policy area on freeways and local roads. VMT by facility type in contrast with totals and area type are illustrated in Figure 6-2 through Figure 6-5.

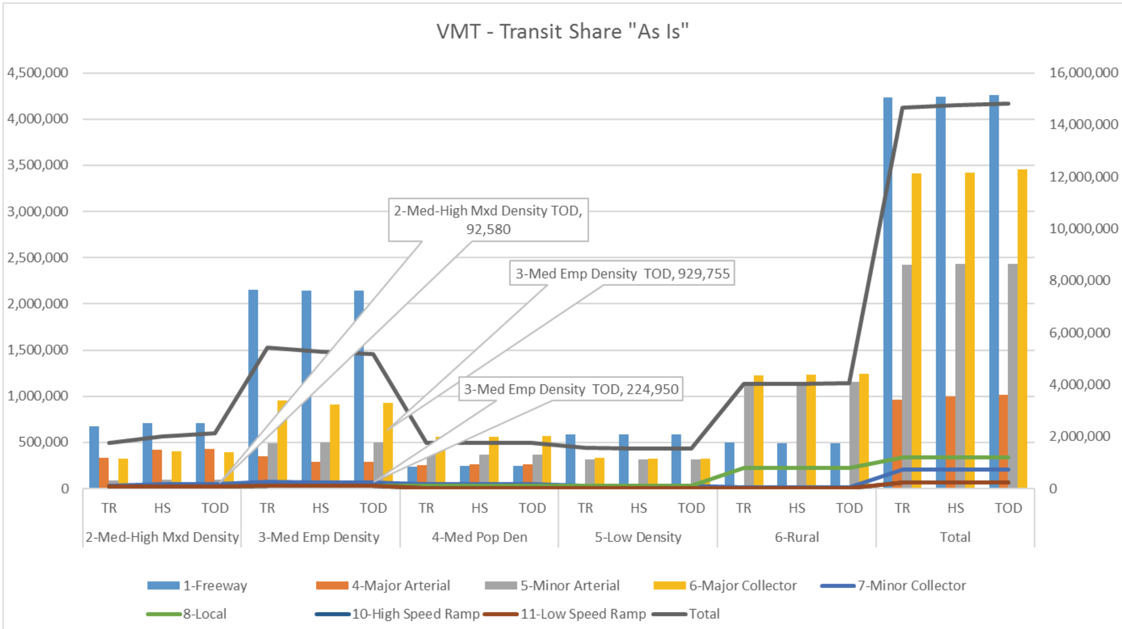


Figure 6-2: VMT By Facility and Area Types for Transit Share "As Is"

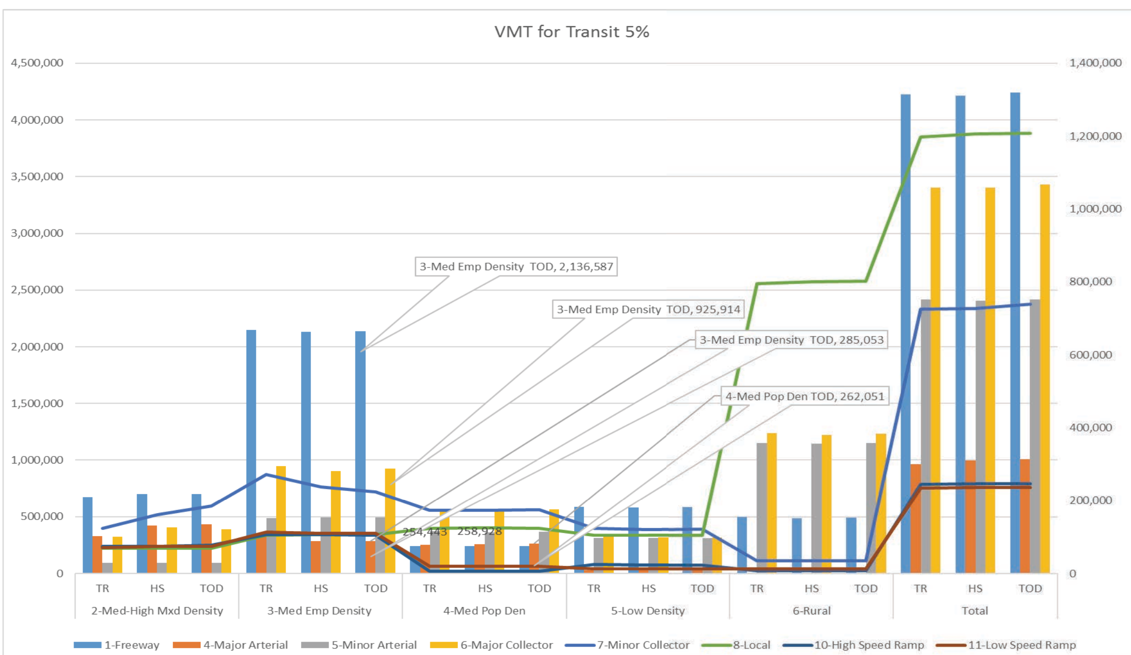


Figure 6-3: VMT By Facility and Area Types for Transit Share 5%

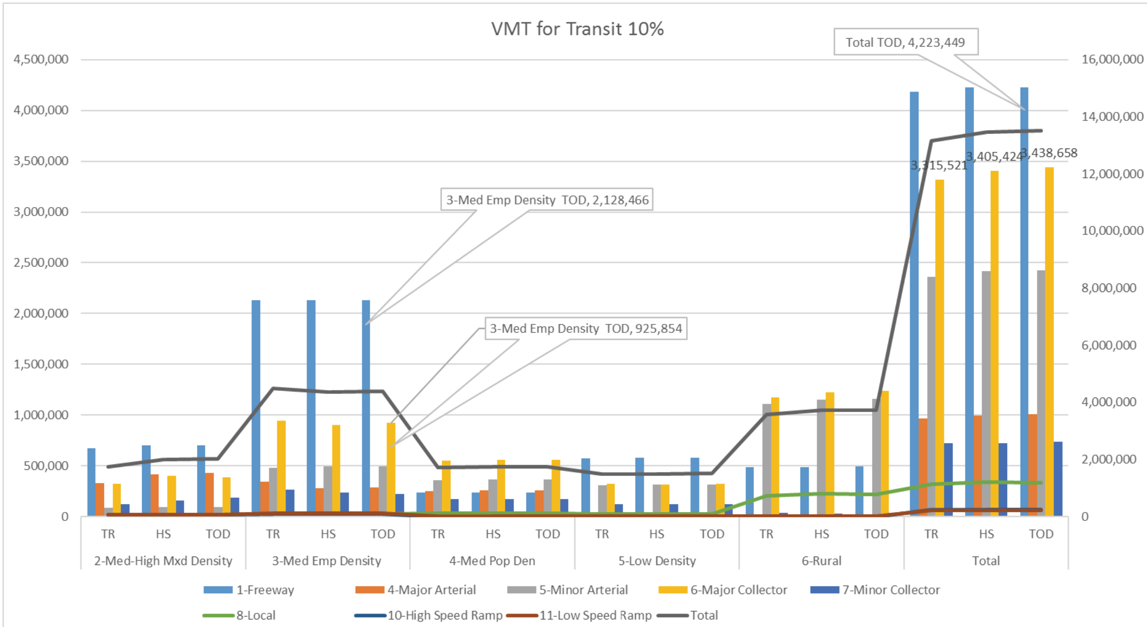


Figure 6-4: VMT By Facility and Area Types for Transit Share 10%

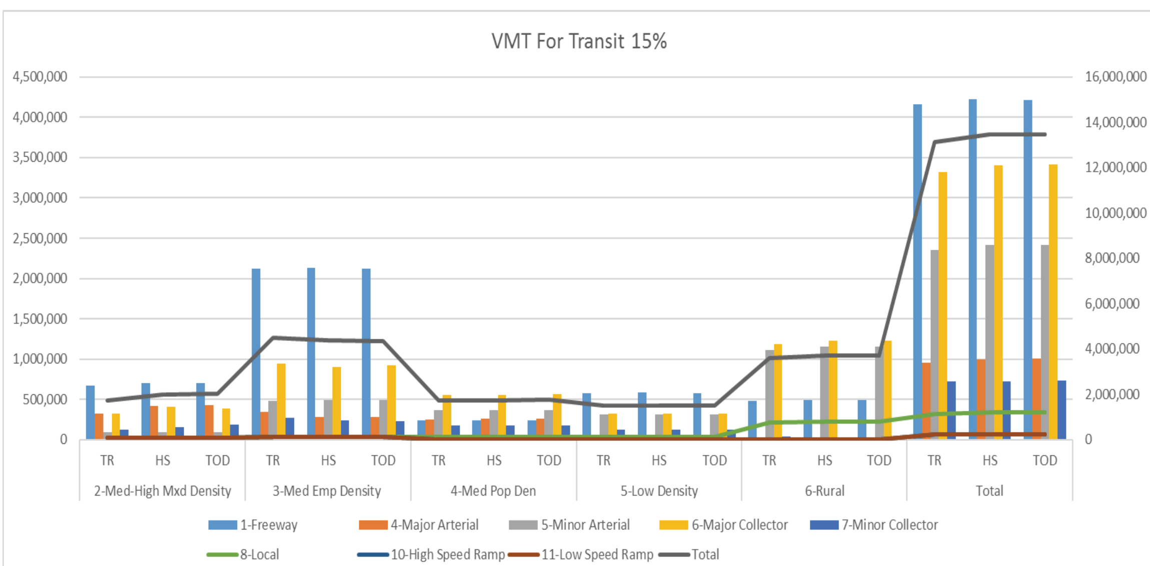


Figure 6-5: VMT By Facility and Area Types for Transit Share 15%

VMT observations by facility and area type across mode shifts:

1. It is noted that keeping mode shift constant, VMT across certain area types and facility types reduces for TOD versus trend scenario. For example, for transit "As Is" and major and minor collectors, TOD shows reductions in VMT in the medium mixed-use density areas of the Housing scenario when compared to the trend scenario. However, for a given area and facility type VMT are higher for the Housing scenario.
2. VMT reductions are observed for TOD scenario in the high and medium mixed-use density areas across facility types for most transit share combinations.
3. VMT is reduced by 123,000 miles on major collectors in the TOD scenario compared to the trend scenario with no change in transit. Approximately 25,000 miles are reduced on major collectors in the TOD scenario compared to the trend at transit shift of 5%. Approximately 62,000 miles of VMT reduction is observed on major arterials for TOD scenario when compared to the trend scenario. A VMT reduction is also seen across all mode shifts for freeways under the TOD scenario.
4. It is notable that the VMT increases for the TOD scenario across all mode shift and facility types for medium population density areas (area type 4), low density areas (area type 5) and rural areas increase under the TOD scenario.
5. Lastly, it is observed that after a certain increase in transit shares percentages, there is no significant reduction in VMT. The reason for this counter-intuitive observation is inexplicable. However, it may be attributed to model sensitivity towards transit percentages and needs to be completely analyzed and understood.

6.3 Modeling Emissions

Results of the travel demand model for each of the transportation plan alternatives under investigation are routinely post-processed to conduct emission inventory studies to comply with Conformity determination. Taking emission inventory using the EPA's MOVES model at the regional level is a tedious process. For example, the process developed at MWCOG involves taking inventory at local level for each of the 24 member jurisdictions takes several days. The total emissions are then aggregated at the regional level for Conformity determination (MWCOG Air Quality report, 2016). It is important to reiterate here that, the process used by MWCOG is not sensitive to model many local-level policy options such as sustainable land use.

The purpose of emissions analysis done at the local level is different from its purpose at the regional level. In consultation with the principal air quality analyst at MWCOG, an alternative approach to the tedious and time-consuming emission inventory method is used to derive aggregate emissions. The approach employs aggregate emission rates developed for the region Table 6-2

Table 6-2: Emission Rates (gm/mile) Used in the 2016 CLRP (MWCOG 2016)

Years	Ozone VOC	Ozone NOx	PM2.5 Direct	Precursor NOx
2016	0.337	0.407	0.02	0.45
2017	0.301	0.301	0.01	0.34
2025	0.204	0.142	0.01	0.16
2030	0.139	0.081	0.01	0.10
2040	0.098	0.043	0.01	0.06

The emissions of each of the pollutants are computed using the following equation.

$$E_{p,s,c} = \frac{er_p \times VMT_{c,s}}{1000} \qquad \text{….. Equation 6-1}$$

Where:

$E_{p,s,c}$ = Emissions (tons) of pollutant type *p*, for scenario *s* in category *c;*

VMT_c = Vehicle Miles of Travel in category *c;*

p = pollutant type (*Ozone VOC, Ozone NOx,* $PM_{2.5}$ *Direct* and *Precursor NOx*); and

c = category at which emissions are aggregated such as *facility type*, *area type* etc.

Results of the analysis for each scenario results are post-processed to derive emissions of *Ozone VOC*, *Ozone NOx*, and $PM_{2.5}$ *Direct* by facility type and area type. Table 6-3 presents a summary of these emissions for entire county.

Table 6-3: Estimated Total Emissions (tons) by Pollutant

Pollutant	Land Use Scenario	Transit Usage Scenario			
		As is	+5% increase	+10% increase	+15% increase
Ozone VOC	TR	1,436.68	1,432.74	1,407.16	1,404.92
	HS	1,445.24	1,436.56	1,438.60	1,438.60
	TOD	1,451.00	1,445.06	1,444.78	1,438.56
Ozone NOx	TR	630.38	628.65	617.43	616.44
	HS	634.14	630.33	631.22	631.22
	TOD	636.66	634.06	633.93	631.20
PM2.5 Direct	TR	146.60	146.20	143.59	143.36
	HS	147.47	146.59	146.80	146.80
	TOD	148.06	147.45	147.43	146.79
Precursor NOx	TR	879.60	877.19	861.53	860.15
	HS	884.84	879.53	880.78	880.78
	TOD	888.36	884.73	884.56	880.75

As described in Chapter 6, the economic and demographic forecasts for each of the land use scenarios are different. Hence, absolute values of travel measures (such as VMT) and emissions may not be compared between scenario pairs. The scenario specific emissions should therefore be normalized to a demographic or economic characteristic of each scenario. These characteristics can be total countywide population or households or employment. Since households are the building blocks of personal travel, total number of forecasted households for each of the three land use scenarios (shown in Table 6-4) is deemed as the appropriate normalization measure to compare emissions between scenario pairs.

Table 6-4: Number of Households in the Forecast for Each Land Use Scenario

Land use scenario	Forecasted Number of Households (HH)	Households, in 1000s (HH1k)
TR	165,275	165.3
HS	172,039	172.0
TOD	173,129	173.1

Computation for normalizing emissions for households is presented in Equation 6-2.

$$NE_{p,s,c} = \frac{er_p \times VMT_{c,s}}{1000 \times HH1k_s} \qquad \text{….. Equation 6-2}$$

Where:

$NE_{p,s,c}$ = Normalized emissions (tons per thousand households) of pollutant type *p*, for scenario s in category *c;* and

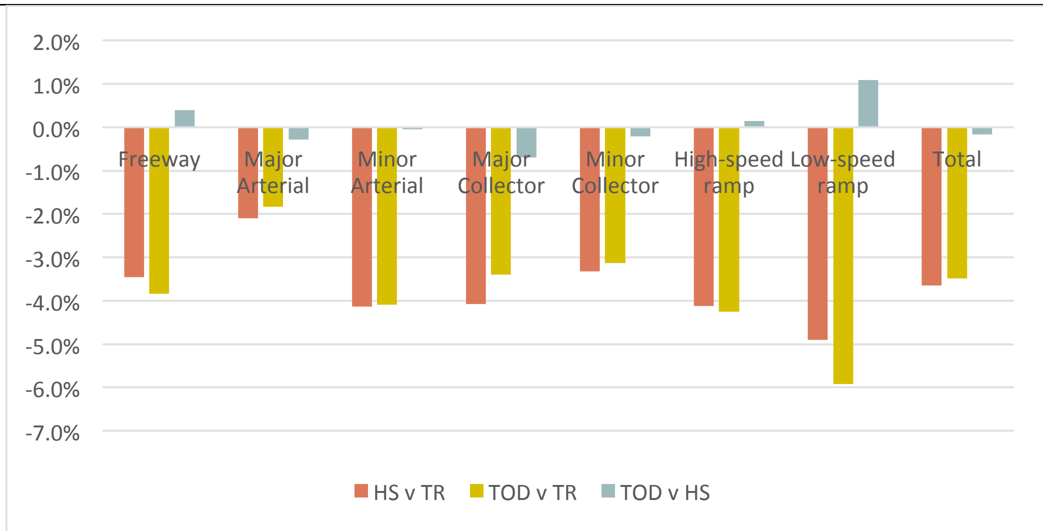
$HH1k_s$ = Thousands of forecasted households in scenario *s c*

Table 6-5: Estimated Total Normalized Emissions (tons per 1000 households)

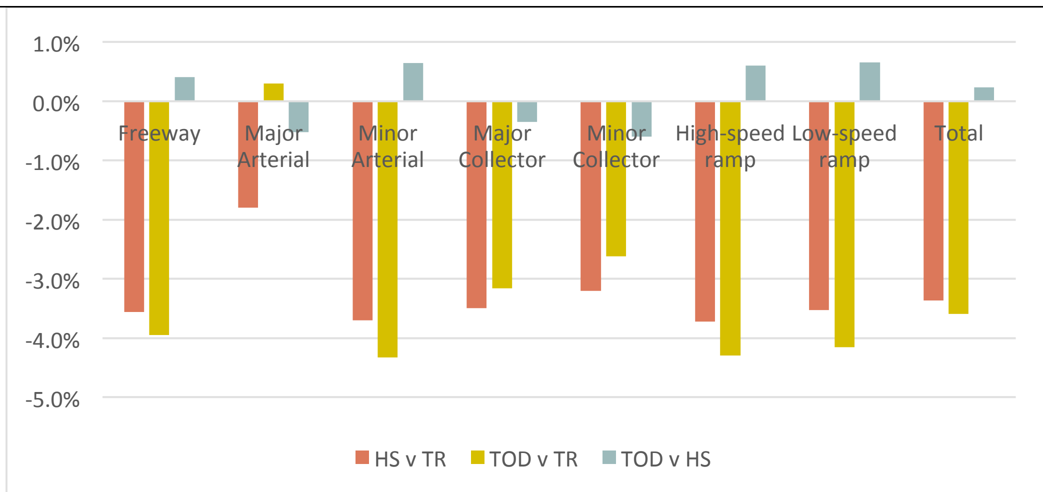
Pollutant	Land Use Scenario	Transit Usage Scenario			
		As is	+5% increase	+10% increase	+15% increase
Ozone VOC	TR	8.693	8.669	8.514	8.500
	HS	8.401	8.350	8.362	8.362
	TOD	8.381	8.347	8.345	8.309
Ozone NOx	TR	3.814	3.804	3.736	3.730
	HS	3.686	3.664	3.669	3.669
	TOD	3.677	3.662	3.662	3.646
$PM_{2.5}$ Direct	TR	0.887	0.885	0.869	0.867
	HS	0.857	0.852	0.853	0.853
	TOD	0.855	0.852	0.852	0.848
Precursor NOx	TR	5.322	5.307	5.213	5.204
	HS	5.143	5.112	5.120	5.120
	TOD	5.131	5.110	5.109	5.087

6.4 Emission Footprint Differences Between Land Use Types

When dealing with area-wide emissions, emission footprint is defined as the quantity of pollutant produced by thousand households. The differences in footprints of normalized emissions between each of the three land use pairs, namely, TR vs. HS; TR vs. TOD; and TOD vs. HS are then computed. In Appendix B a host of tables and charts illustrating these differences for a number of combinations are presented. For brevity, only the illustrations pertaining to differences in Ozone VOC emissions for all area types with medium employment density is presented in this section. Figures x through x+4 present these illustrations for transit shares ‘As Is’; ‘5% Increase’; ‘10% increase’ and ‘15% increase’, respectively.

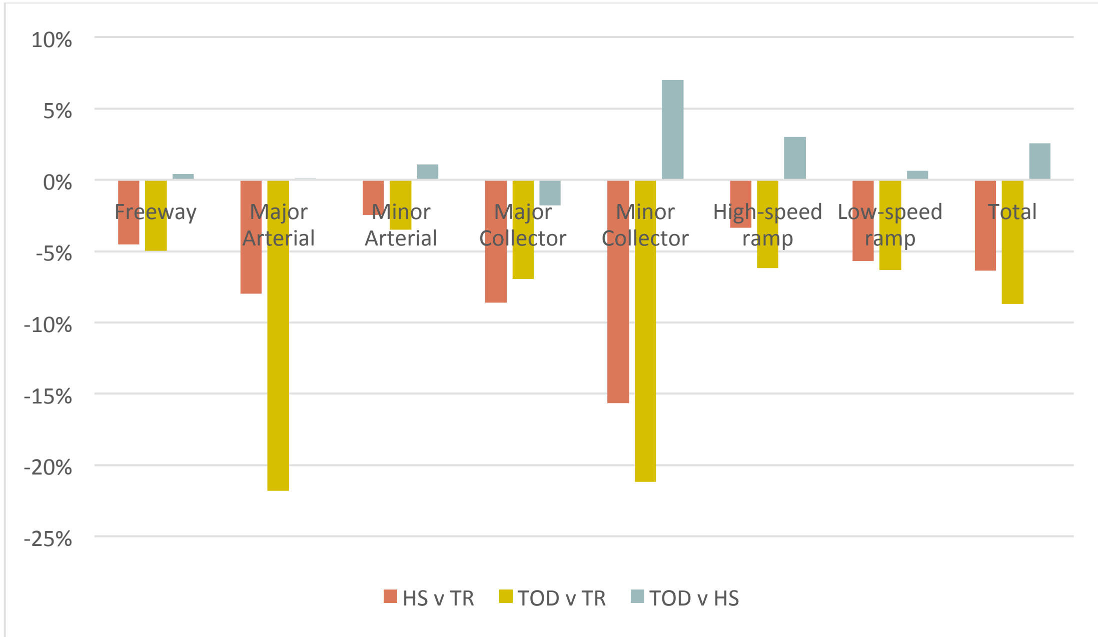


(a) For Areas with Medium Employment Density



(b) For all Area Types Combined

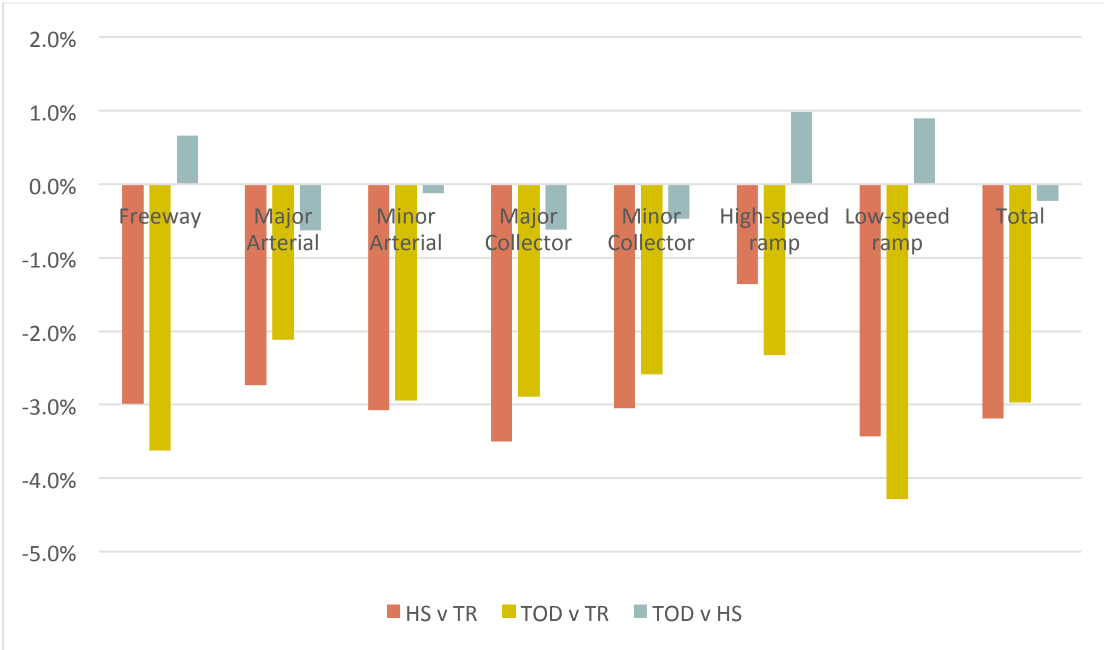
Figure 6-6: Differences in Ozone VOC Emissions Between Land Use Scenario Pairs for 'As Is' Transit Share



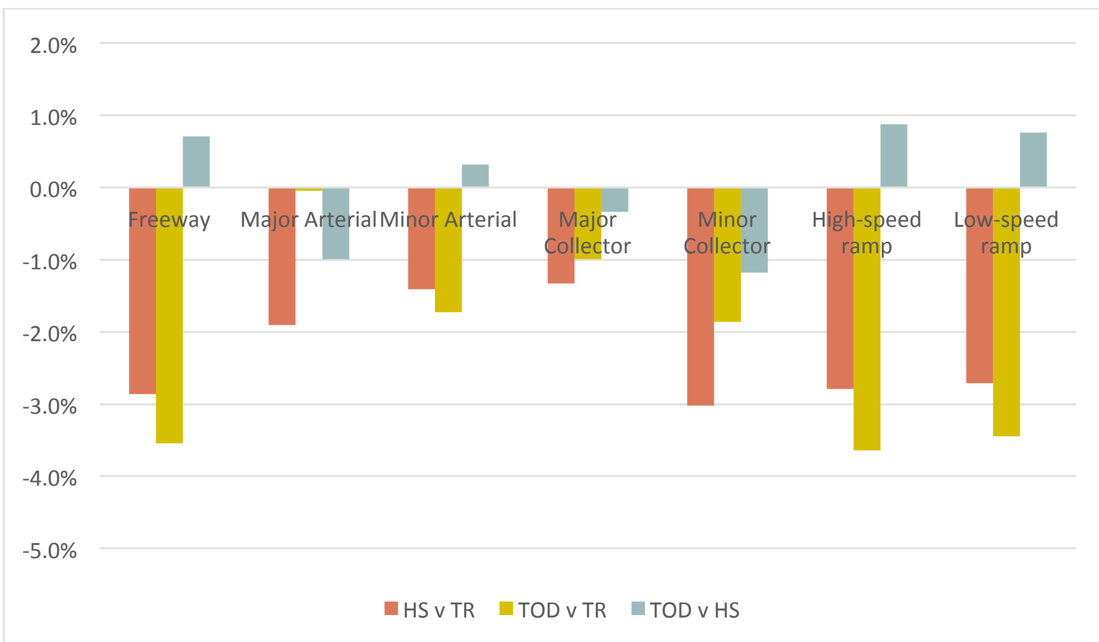
(a) For Areas with Medium Employment Density

(b) For all Area Types Combined

Figure 6-7: Differences in Ozone VOC Emissions Between Land Use Scenario Pairs for '5% Increase' in Transit Share

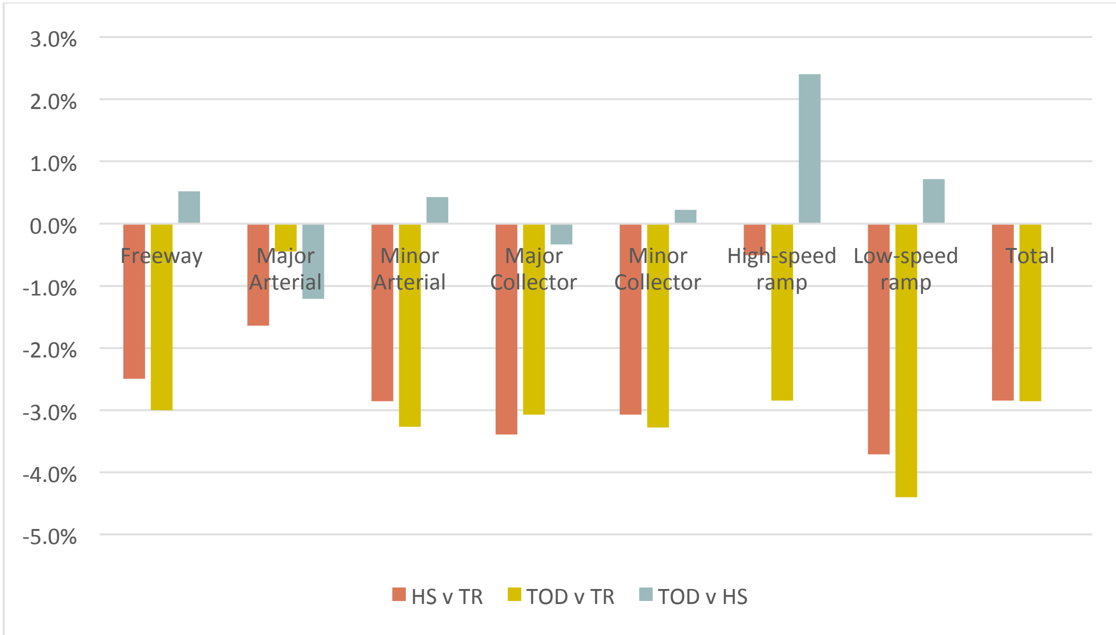


(a) For Areas with Medium Employment Density

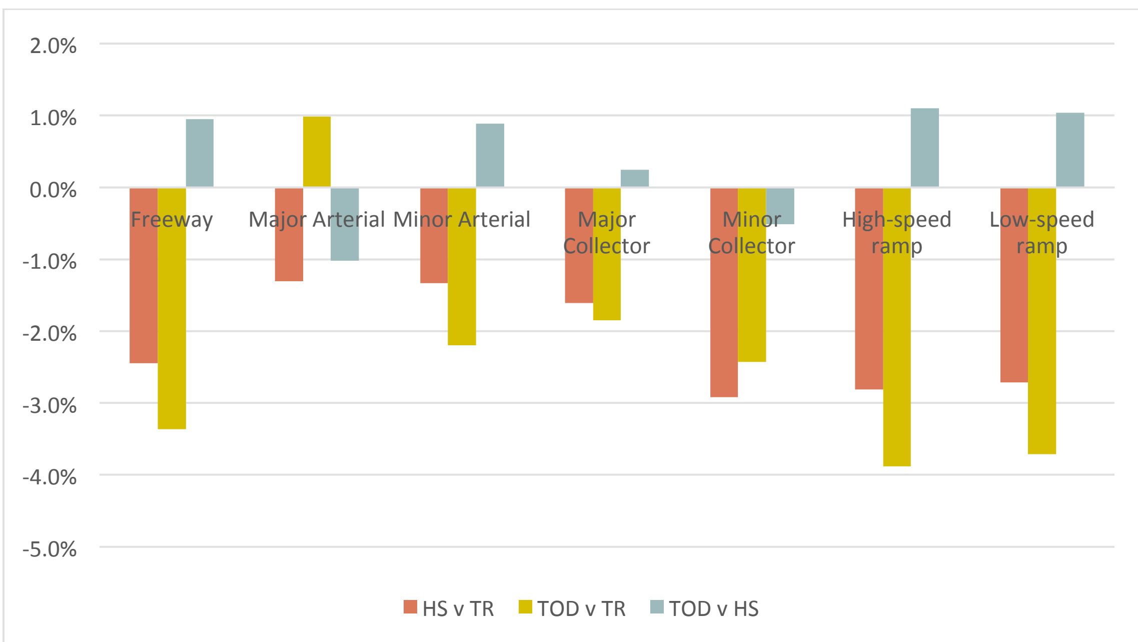


(b) For all Area Types Combined

Figure 6-8: Differences in Ozone VOC Emissions Between Land Use Scenario Pairs for ‘10% Increase’ in Transit Share



(a) For Areas with Medium Employment Density



(b) For all Area Types Combined

Figure 6-9: Differences in Ozone VOC Emissions Between Land Use Scenario Pairs for ‘15% Increase’ in Transit Share

The following observations are recorded based on the emissions analysis shown in Figure 6-6 through Figure 6-9 and Appendices B and C.

- At the outset, it is evident that the proposed Methodology can be effective in capturing emission signature attributable to land use scenarios;
- TOD scenario is seen to reduce total emissions by 22% compared to the Trend scenario.
- The fact that Housing and TOD are dense yet different land use patterns, could be explained by the increase in VMT, and therefore emissions on all facility types for in area types medium population, low density and rural.
- In a cross sectional view of difference in emissions between scenarios across transit percentages it is observed that at 'As Is' transit share, emission reduction of TOD from trend is 22%, however, for transit share of 15%, the TOD scenario shows only 15% reduced emissions from trend scenario which is lesser when compared to the emission reduction with no transit. This counter-intuitive observation raises some concerns about the implementation of transit share interaction with highway trips in the model.

Ozone VOC analysis is further analyzed for significance with statistical analysis using ANOVA to find the significant impact of the variables on VMT/ emissions, individually and in combination.

6.5 Analysis of Variance for Emission Signatures

As indicated in Figures 6-6 through 6-9, percent differences between Housing and Trend, and TOD and Trend scenarios vary with facility type (FT), area type (AT) and transit percentages

(TP), collectively referred to hereafter as control variables or treatment factors. Thus, the Methodology shows clear promise in capturing the impacts of local land use policies on the transportation system. However, it is not known is these percentage differences are statistically significant for different control variables.

An analysis of the variance (ANOVA) of percentage differences of scenario-emissions for each of the criteria pollutants vis-à-vis the control variables would not only assess the statistical significance of such a stratification, but would also act as a further validation of the Methodology. For example, the differences in emission signature may be derived for any combination of classification variables such as geographical districts, areas classified by population and/or housing density, facility type, employment etc. However, unless there is a statistical validation of such grouping, the Methodology and its applicability to sub-regional context would be in question. For clarity and simplicity treatment factors are limited the above mentioned three control variables.

6.5.1 The ANOVA Model

For simplicity, it is assumed that the emission signatures across control variable categories mentioned above are normally distributed. Further, it is also assumed that the design is randomized with treatment factors FT, AT and TP. The response variables for ANOVA are percent differences of each criteria pollutant emissions between Housing & Trend; TOD & Trend; & TOD and Housing scenario-pairs. Three groups of variable categories were included as independent variables in the analysis of variance for cold start percentages. These groups include the following categories:

- Facility Type, FT (seven levels – Freeways; Major arterials; Minor Arterials; Major Collector; Minor collector; High-speed ramp; and Low-speed ramp);

- Area Type, AT (four levels - Medium-high mixed density; Medium employment density; Medium population den; Low density; Rural);
- Transit Percentage, TP (four levels – 'as is'; 5% increase; 10% increase; 15% increase);

Thus, the three-way ANOVA model (also known as the three-way complete model) will be of the following form (Equation 6-3):

$$Y_{p,sp,t} = \mu + FT_i + AT_j + TP_k + (FT.AT)_{ij} + (FT.TP)_{ik}$$
$$+(AT.PT)_{jk} + (FT.AT.PT)_{ijk} + \varepsilon_{ujkt} \quad \text{.............................Equation 6-3}$$

Where:

$Y_{p,sp,t}$	Response (dependent) variable – percent difference in emissions of pollutant *p* between scenario pairs Housing (HS) vs. Trend (TR), and TOD vs. TR for observation at level *i* of *FT*, *j* of *AT, k* of *TR*;
μ	Mean of the model estimate
FT_i	Main effect due to facility type at levels *1 through i*
AT_j	Main effect due to area type at levels *1 through j*
TP_k	Main effect due to transit percentage at levels *1 through k*
$(FT.AT)_{ij}$	Two-way interaction between facility type and area type
$(FT.TP)_{ik}$	Two-way interaction between facility type and transit percentage
$(AT.PT)_{jk}$	Two-way interaction between area type and transit percentage
$(FT.AT.PT)_{ijk}$	Three-way interaction among facility type, area type and transit percentage
ε_{ujkt}	Error terms in the model, which are independent random variable

There will be only one value for the response variable *Y* in each cell *ijk.* Because the response variable is a proportion (i.e. percent difference), it is customary to transform the response variable to stabilize the variance. An appropriate transformation for this case is the arc sine transformation (Neter et al. 1996; Venigalla et al. 1995), which is performed as follows.

$$Y'_{p,sp,t} = 2\ ArcSin\ (\sqrt{Abs(Y)}) \quad \text{..............................Equation 6-4}$$

Where:

$Y'_{p,sp,t}$ Transformed response (dependent) variable derived from percent difference in emissions of pollutant p between scenario pairs Housing (HS) vs. Trend (TR), and TOD vs. TR for observation at level i of FT, j of AT, k of TR;

6.5.2 Results of ANOVA

Results of ANOVA (Table 6-6) indicate that emission differences between land use scenario pairs TOD vs. Trend are statistically significant for the main effects tested - namely Facility Type, Area Type and Transit Percentage – at 10% level of significance. However, Transit Percentage explains the variance in a relatively weak manner. The two-way interaction between Facility Type and Area Type has shown strong significance. This would mean, for example, that emissions on a freeway could be different depending on the area type where that freeway segment is located. At the same time, the two-way interactions involving Transit Percentage have shown no statistical significance. Furthermore, the three-way interaction among all main effects is not statistically significant.

Table 6-6: ANOVA results for Percent Difference in Emissions between TOD and Trend

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Model	105	30.021	0.286	45.600	**<.0001**
Error	6	0.038	0.006	-	-
FT	6	1.531	0.255	40.680	**0.000**
AT	3	16.087	5.362	855.140	**<.0001**
TP	3	0.076	0.025	4.050	**0.068**
FT x AT	18	11.392	0.633	100.930	**<.0001**
FT x TP	18	0.135	0.007	1.190	0.444
AT x TP	9	0.082	0.009	1.450	0.335
FTxATxTP	48	0.222	0.005	0.740	0.747
Bold emphasis is given to the effects which are significant at α = 10%					

The implication of these findings is noteworthy for the following reasons. It has already been established in Chapter 4 that emission footprints for TOD land use are significantly lower than the emission footprints for Non-TOD land uses. Also, it has been established in the literature that the four-step planning models are not sensitive to neighborhood level land use variables. That means, even though emission footprints of TODs are significantly lower, prior to this study the four-step models are not seen as viable tools to model the emission benefits of TODs and other compact development land uses. Thus, the proposed disaggregate Methodology successfully demonstrated that smaller emission footprints of TOD households can in fact be traced on to the sub-regional network.

Results of analysis of variance for percent difference in emissions between Housing and Trend scenarios are shown in Table 6-7. These results are similar to the results for TOD vs. Trend scenarios. The main effects (Area Type, Facility Type and Transit Percentage) are statistically significant at 10% level of significance. However, as in the case of TOD vs. Trend, Transit Percentage as an effect in two-way and three-way interactions doesn't explain the variance in difference in emissions. One possible explanation for this counter-intuitive observation is that the transit / mode shift component is crudely represented in the Loudoun County travel demand model. This study lacked resources necessary to develop a robust mode shift model necessary to accurately represent transit patronage.

Table 6-7: ANOVA results for Percent Difference in Emissions between HS and TR

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Model	105	23.31081899	0.22200780	20.26	**0.0005**
Error	6	0.06575969	0.01095995		
FT	6	1.13625502	0.18937584	17.28	**0.0015**
AT	3	13.14342883	4.38114294	399.74	**<.0001**
TP	3	0.11187720	0.03729240	3.40	**0.0942**
FT*AT	18	8.32957700	0.46275428	42.22	**<.0001**
FT*TP	18	0.04962440	0.00275691	0.25	0.9896
AT*TP	9	0.03002023	0.00333558	0.30	0.9464
FT*AT*TP	48	0.06841839	0.00142538	0.13	1.0000
Bold emphasis indicates that the effect is significant at $\alpha = 10\%$					

As demonstrated by Venigalla et al. (1999), emission rates vary by facility, area type and the interaction of facility and area type. Deriving such disaggregated emission rates (by facility type and area type) is not within the scope of this study, because the primary goal of the study is to demonstrate the effectiveness of the Methodology, rather than conducting a high-resolution emission inventory study. Furthermore, it is fair to assume that the conclusions based on aggregate emission rates are also applicable to conclusions based on high-resolution emission estimates. It should also be pointed out that for the same reasons, observations and inference made with respect to Ozone VOC are also applicable to other pollutants.

7. CONCLUSIONS AND RECOMMENDATIONS

This research is an attempt at challenging to cross boundaries and overcome limitations to developing a methodology for estimating emissions on the local scale. The research successfully demonstrated procedures to derive emission footprints at household level (grams/hh) using the household travel survey data. Furthermore, using the proposed disaggregate Methodology, which employs a sub-regional travel demand model, the research quantified emission impacts of sustainable land use policies on the sub-regional networks. Apportioning those emission reductions to the jurisdiction where the said policies are implemented would benefit local jurisdiction in improving their state of the art in transportation planning and seeking available state and federal incentives.

7.1 Conclusions

Analysis of the household travel survey data for the Washington DC metro area has indicated that emission footprints of TOD are significantly lower than the footprints of Non-TOD areas. Bucking this observation is a county (Arlington, VA) where extensive number of households living the TOD zones are engaged in fairly long reverse commuter trips. A multitude of pairwise comparisons concluded that the differences in emission footprints between urban and suburban areas, as well as suburban and exurban areas are significantly different. The study demonstrated the effective use of Tukey's Range Test as a simple methodology to compare pairs of jurisdictions (or land uses) with respect to similarities in their emission footprints.

As revealed in the literature survey, the consensus among prominent practitioners and researchers in land use transportation planning is that four-step travel demand forecasting process does not adequately capture the impacts of neighborhood level sustainable land use policies on mobility and emissions. However, the proposed Methodology, which uses a sub-regional travel demand model as the primary planning tool, can show sensitivity to transportation and land use policy variables. Application of the Methodology to a uniquely situated test-bed (Loudoun County, VA) demonstrated its effectiveness by ascribing changes in emissions attributable to local-level land use policy changes. The successful experimental implantation of the Methodology verified the study premise that that sub-regional models derived from regional model with a finer resolution of detail would be sensitive to local land use variables and capture emissions.

Though travel survey data can be used to estimate emission footprints at household level, survey data offers little help in attributing these emissions over the sub-regional network. Furthermore, travel surveys are backward looking and offer inadequate mechanism to forecast future emission footprints. The disaggregate Methodology presented in this research may be used by local jurisdictions with adequate resources to develop high-resolution model for estimating and forecasting emission impacts at sub-regional level. When used for sustainable land use policymaking, the Methodology could benefit local jurisdictions to capture emissions attributable to neighborhood level land use policy. The Methodology not only eliminates the need for intensive post processing that follows the use of a regional model but also enhances the resolution of impact on the jurisdictional level. The Methodology propagates the emission footprints from household level to the network level.

7.2 Research Contributions

7.2.1 Addressing Land Use Policy Implications Using the Methodology

As VMT is the prime measure with which auto emissions are captured, a sub-regional travel demand model for Loudoun County is used to determine the travel activity in the areas of potential growth around metro stations. This study, thus, is a beneficial exercise in exploring interaction of local land use polices around the future mass transit access and planned transportation investments on travel activity and emissions. As a demonstration of the usefulness of the proposed Methodology, the following policy implications are derived based on its application to Loudoun County.

1. VMT in a high employment density area is lower when compared to a medium employment density area for all land use scenarios due to dominant presence of major arterials and collectors that are present in the medium employment density area type. With respect to farther out of the scenario policy area, it is observed that even though high employment density is expected to generate higher travel activity, the presence of street connectivity and increase in transit access or mode shift, reduces VMT in high-density areas.
2. It is observed that VMT is higher in the medium employment areas. VMT also decreases with increasing transit usage, which suggests that merely developing high or mixed-use density communities with pedestrian connectivity may not be sufficient to reduce VMT and emissions, it needs to be combined with transit elements.
3. Medium mixed-use employment hubs attract people to live, work and play thereby increasing auto-dependent travel activity and emissions. One way to offset this increase is by increasing the likelihood of non-vehicle travel for commuter trips, transit linkages that connect the policy areas with the neighboring communities. Such policies would result in decreased emissions for the medium density areas.
4. The experiment proved that the sub-regional model is sensitive to land use policies, area type and available transportation facility types in the policy area. For example, a reduction of 25% Ozone VOC is possible for TOD land use scenario when compared

to business as usual (trend) scenario where no sustainable land use policies are applied.

5. Significant changes in emission are not observed when transit share increased over 5%. This observation is counter-intuitive and may be due to the limitation of the model's treatment of mode-shift. The sensitivity of transit mode-shift needs to be examined separately for better understanding of the model behavior.

7.2.2 How Local Jurisdictions Can Use this Research

This research has two important contributions in the field of land use, transportation and air quality research. First, this research establishes the link between land use, specifically TOD and Non-TODs with vehicle emissions via travel survey data. Secondly, the proposed Methodology primarily benefits local jurisdictions in demonstrating their land use policies to be effective in reducing transportation related emissions, thereby contributing towards improving regional air quality. In doing so, the jurisdictions can claim incentives from such federal programs as Congestion Mitigation Air Quality (CMAQ) and Transportation Landuse Connections (TLC).

The federal Congestion Mitigation Air Quality (CMAQ) program began as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). CMAQ funds are used to pay for a variety of projects that improve air quality in "non-attainment" and "maintenance" areas. Additionally, those states that have no nonattainment or maintenance areas (examples: Mississippi, Alabama, Alaska) still receive a minimum apportionment of CMAQ funding for either air quality projects or other elements of flexible federal aid highway spending. The CMAQ program supports not only surface transportation projects, but also many programs (including sustainable land use policies) that eventually contribute to air quality improvements and congestion relief. The CMAQ program provided more than $30 billion to fund over 30,000 projects for State DOTs, metropolitan planning organizations, and other local jurisdictions sponsors throughout the US. A State without a nonattainment or maintenance area may use its CMAQ funds for any CMAQ- or STP-eligible project.

In addition to CMAQ, the Transportation/Land Use Connections Program (TLC) aims to support local jurisdictions plan and design vibrant communities, share success stories, and promote regional air quality and policy goals. TLC has three integrated program components:

- TLC Technical Assistance, - provides focused consultant assistance to local jurisdictions working on creative, forward-thinking and sustainable plans and projects that encourages transit oriented development and improves air quality.
- Federal Transportation Alternatives/Surface Transportation Program Set-Aside (TAP)- TAP allocates federal reimbursable aid for capital improvements considered alternative to traditional highway construction
- Peer Exchange Network (TLC PeerX)- TLC PeerX provides opportunities for planners across the region to share and discuss best practices and innovative ideas stemming from successful past projects and regional planning issues. TLC PeerX includes webinars, forums, site visits, and other means of connecting the region's planners and promoting collaboration around TLC-related topics.

Some local jurisdictions are working to promote more developments closer to mass transit stations. Others are looking at ways to bring jobs, housing and shopping in closer proximity to reduce the need to drive everywhere. Still other places want to revitalize existing communities to make them more walkable and accessible for people without cars. For example, local governments across the Washington D.C region are recognizing the importance of integrating land use and transportation planning at the community level. In the Washington DC metro area, the Transportation Planning Board's TLC program supports local jurisdictions as they work through the challenges in planning and designing vibrant communities, share success stories and proven tools, and promote regional policy goals (MWCOG 2010). Furthermore, there is considerable focus by states on reducing VMT and achieve regional air quality goals. One of the challenges associated with meeting such goals are identifying measurement tools that can measure progress of a local jurisdiction towards benchmarks of air quality goals set at the local, regional and state level that includes the effect of strategies meant to reduce VMT.

Thus, the proposed Methodology could be employed to make additional transportation funds available to local jurisdictions (such as through CMAQ, and TLC) to adopt land use policies that while being consistent with regional environmental and air quality mandates. This methodology of capturing emission benefits at the jurisdictional level can effectively bridge local and regional transportation investment and land use policies.

7.3 Limitations, Recommendations and & Future Work

The Loudoun County travel demand model used as the test-bed was tested for sensitivity to commuter transit trips by using mode shift scenarios for home-based work trips. However, the model was not tested for sensitivity to local bus transit accessibility. This study lacked resources necessary to develop a robust mode shift model necessary to accurately represent transit patronage. An extension of this research would be to incorporate the impacts of local bus transit accessibility within TOD area for potential reduction in emissions as a combined effect with land use patterns and metro access.

High-resolution emission rates (i.e. by facility and area type) can be compiled and used in place of composite rates for detailed assessment and inventory of these scenarios. However, this approach requires post-processing of the traffic assignment results.

Airport rail connections reduce vehicle emissions by encouraging travelers to take transit rather than travel by auto to the airport. Regional airports are also encouraging cleaner vehicles for travelers, shuttle buses, and even in airplanes. Opportunities for additional emissions reductions include transitioning airport maintenance vehicles, shuttles and other fleets to alternative fuels can be assessed in the future.

Many other factors in the land use environment can have a significant impact on non-work travel and commuting behavior. However, the right combination of land-use (development) and non-land use initiatives (such as pricing) for achieving various mobility and environmental objectives remains a public policy challenge.

In the MWCOG model the County had 282 zones where are the test-bed sub-regional model for the County has 667, which is an increase in resolution of 136%. Clearly, the Methodology is proven to be effective at this resolution. However, it is not known at which level TAZ size would be optimal for taking such measurements of impacts. Conducting experiments by varying the sizes of TAZs is a costly and time-consuming endeavor, which many jurisdictions cannot undertake as routine business. Perhaps an academic study would establish optimal thresholds for increasing TAZ resolution.

APPENDIX A: STATISTICAL ANALYSIS, TOD VS. NON-TOD

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
67.210	22.650	27.354	1.344	30.244	AAC0Q	AAC0H	Exurb	Exurb
80.640	27.176	32.821	1.613	36.288	AAC0Q	AAC0H	Exurb	Exurb
74.500	25.107	30.322	1.490	33.525	AAC0Q	AAC0H	Exurb	Exurb
85.559	28.833	34.822	1.711	38.501	AAC0Q	AAC0H	Exurb	Exurb
35.038	11.808	14.260	0.701	15.767	AAC0Q	AAC0H	Exurb	Exurb
67.770	22.839	27.583	1.355	30.497	AAC0Q	AAC0H	Exurb	Exurb
50.741	17.100	20.651	1.015	22.833	AAC0Q	AAC0H	Exurb	Exurb
66.045	22.257	26.880	1.321	29.720	AAC0Q	AAC0H	Exurb	Exurb
52.086	17.553	21.199	1.042	23.439	AAC0Q	AAC0H	Exurb	Exurb
73.336	24.714	29.848	1.467	33.001	AAC0Q	AAC0H	Exurb	Exurb
119.133	40.148	48.487	2.383	53.610	AAC0Q	AAC0H	Exurb	Exurb
63.754	21.485	25.948	1.275	28.689	AAC0Q	AAC0H	Exurb	Exurb
46.047	15.518	18.741	0.921	20.721	AAC0Q	AAC0H	Exurb	Exurb
45.595	15.366	18.557	0.912	20.518	AAC0Q	AAC0H	Exurb	Exurb
51.083	17.215	20.791	1.022	22.987	AAC0Q	AAC0H	Exurb	Exurb
87.187	29.382	35.485	1.744	39.234	AAC0Q	AAC0H	Exurb	Exurb
66.349	22.360	27.004	1.327	29.857	AAC0Q	AAC0H	Exurb	Exurb
39.922	13.454	16.248	0.798	17.965	AAC0Q	AAC0H	Exurb	Exurb
84.135	28.354	34.243	1.683	37.861	AAC0Q	AAC0H	Exurb	Exurb
74.127	24.981	30.170	1.483	33.357	AAC0Q	AAC0H	Exurb	Exurb
62.230	20.971	25.327	1.245	28.003	AAC0Q	AAC0H	Exurb	Exurb
42.000	14.154	17.094	0.840	18.900	AAC0Q	AAC0H	Exurb	Exurb
54.691	18.431	22.259	1.094	24.611	AAC0Q	AAC0H	Exurb	Exurb
54.980	18.528	22.377	1.100	24.741	AAC0Q	AAC0H	Exurb	Exurb
54.679	18.427	22.254	1.094	24.606	AAC0Q	AAC0H	Exurb	Exurb
32.554	10.971	13.249	0.651	14.649	AAC0Q	AAC0H	Exurb	Exurb
22.758	7.669	9.262	0.455	10.241	AAC0Q	AAC0H	Exurb	Exurb
37.206	12.538	15.143	0.744	16.743	AAC0Q	AAC0H	Exurb	Exurb
27.443	9.248	11.169	0.549	12.349	AAC0Q	AAC0H	Exurb	Exurb
29.998	10.109	12.209	0.600	13.499	AAC0Q	AAC0H	Exurb	Exurb

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
83.600	28.173	34.025	1.672	37.620	AC1Q	AC1H	Urban1Q	Urban1H
42.020	14.161	17.102	0.840	18.909	AC0Q	AC1H	Urban0Q	Urban0H
1.000	0.337	0.407	0.020	0.450	AC0Q	AC0H	Urban0Q	Urban0H
11.241	3.788	4.575	0.225	5.059	AC1Q	AC1H	Urban1Q	Urban1H
24.081	8.115	9.801	0.482	10.836	AC1Q	AC1H	Urban1Q	Urban1H
55.532	18.714	22.601	1.111	24.989	AC1Q	AC1H	Urban1Q	Urban1H
26.026	8.771	10.593	0.521	11.712	AC1Q	AC1H	Urban1Q	Urban1H
20.421	6.882	8.311	0.408	9.189	AC1Q	AC1H	Urban1Q	Urban1H
23.258	7.838	9.466	0.465	10.466	AC1Q	AC1H	Urban1Q	Urban1H
45.293	15.264	18.434	0.906	20.382	AC1Q	AC1H	Urban1Q	Urban1H
32.944	11.102	13.408	0.659	14.825	AC0Q	AC1H	Urban0Q	Urban0H
17.692	5.962	7.201	0.354	7.961	AC0Q	AC0H	Urban0Q	Urban0H
7.787	2.624	3.169	0.156	3.504	AC0Q	AC0H	Urban0Q	Urban0H
39.058	13.163	15.897	0.781	17.576	AC0Q	AC1H	Urban0Q	Urban0H
22.488	7.578	9.153	0.450	10.120	AC0Q	AC1H	Urban0Q	Urban0H
39.508	13.314	16.080	0.790	17.779	AC0Q	AC0H	Urban0Q	Urban0H
27.901	9.402	11.356	0.558	12.555	AC0Q	AC0H	Urban0Q	Urban0H
36.151	12.183	14.714	0.723	16.268	AC1Q	AC1H	Urban1Q	Urban1H
6.727	2.267	2.738	0.135	3.027	AC1Q	AC1H	Urban1Q	Urban1H
27.067	9.121	11.016	0.541	12.180	AC1Q	AC1H	Urban1Q	Urban1H
42.268	14.244	17.203	0.845	19.021	AC1Q	AC1H	Urban1Q	Urban1H
72.179	24.324	29.377	1.444	32.481	AC1Q	AC1H	Urban1Q	Urban1H
33.880	11.417	13.789	0.678	15.246	AC0Q	AC1H	Urban0Q	Urban0H
34.905	11.763	14.206	0.698	15.707	AC0Q	AC0H	Urban0Q	Urban0H
28.419	9.577	11.566	0.568	12.788	AC1Q	AC1H	Urban1Q	Urban1H
25.438	8.572	10.353	0.509	11.447	AC1Q	AC1H	Urban1Q	Urban1H
24.024	8.096	9.778	0.480	10.811	AC1Q	AC1H	Urban1Q	Urban1H
19.822	6.680	8.067	0.396	8.920	AC1Q	AC1H	Urban1Q	Urban1H
23.755	8.005	9.668	0.475	10.690	AC1Q	AC1H	Urban1Q	Urban1H
26.188	8.825	10.659	0.524	11.785	AC1Q	AC1H	Urban1Q	Urban1H
16.142	5.440	6.570	0.323	7.264	AC1Q	AC1H	Urban1Q	Urban1H
33.400	11.256	13.594	0.668	15.030	AC0Q	AC1H	Urban0Q	Urban0H
42.607	14.359	17.341	0.852	19.173	AC0Q	AC1H	Urban0Q	Urban0H
39.609	13.348	16.121	0.792	17.824	AC0Q	AC0H	Urban0Q	Urban0H
43.720	14.734	17.794	0.874	19.674	AC0Q	AC0H	Urban0Q	Urban0H
40.470	13.638	16.471	0.809	18.212	AC0Q	AC0H	Urban0Q	Urban0H
29.514	9.946	12.012	0.590	13.281	AC0Q	AC1H	Urban0Q	Urban0H
115.500	38.923	47.008	2.310	51.975	AC1Q	AC1H	Urban1Q	Urban1H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
27.803	9.370	11.316	0.556	12.511	AC0Q	AC0H	Urban0Q	Urban0H
26.176	8.821	10.654	0.524	11.779	AC0Q	AC0H	Urban0Q	Urban0H
27.364	9.222	11.137	0.547	12.314	AC0Q	AC0H	Urban0Q	Urban0H
19.376	6.530	7.886	0.388	8.719	AC0Q	AC0H	Urban0Q	Urban0H
35.922	12.106	14.620	0.718	16.165	AC0Q	AC0H	Urban0Q	Urban0H
24.600	8.290	10.012	0.492	11.070	AC0Q	AC0H	Urban0Q	Urban0H
24.750	8.341	10.073	0.495	11.137	AC0Q	AC0H	Urban0Q	Urban0H
29.971	10.100	12.198	0.599	13.487	AC0Q	AC0H	Urban0Q	Urban0H
31.161	10.501	12.683	0.623	14.023	AC0Q	AC0H	Urban0Q	Urban0H
21.096	7.109	8.586	0.422	9.493	AC1Q	AC1H	Urban1Q	Urban1H
22.512	7.587	9.162	0.450	10.130	AC1Q	AC1H	Urban1Q	Urban1H
4.400	1.483	1.791	0.088	1.980	AC0Q	AC0H	Urban0Q	Urban0H
26.704	8.999	10.868	0.534	12.017	AC0Q	AC0H	Urban0Q	Urban0H
28.033	9.447	11.409	0.561	12.615	AC0Q	AC0H	Urban0Q	Urban0H
19.376	6.530	7.886	0.388	8.719	AC0Q	AC0H	Urban0Q	Urban0H
18.148	6.116	7.386	0.363	8.167	AC0Q	AC0H	Urban0Q	Urban0H
31.605	10.651	12.863	0.632	14.222	AC1Q	AC1H	Urban1Q	Urban1H
112.050	37.761	45.604	2.241	50.422	AC0Q	AC1H	Urban0Q	Urban0H
39.816	13.418	16.205	0.796	17.917	AC0Q	AC0H	Urban0Q	Urban0H
48.229	16.253	19.629	0.965	21.703	AC0Q	AC0H	Urban0Q	Urban0H
58.538	19.727	23.825	1.171	26.342	AC0Q	AC0H	Urban0Q	Urban0H
28.798	9.705	11.721	0.576	12.959	AC0Q	AC0H	Urban0Q	Urban0H
38.442	12.955	15.646	0.769	17.299	AC0Q	AC0H	Urban0Q	Urban0H
19.817	6.678	8.065	0.396	8.918	AC0Q	AC0H	Urban0Q	Urban0H
60.621	20.429	24.673	1.212	27.279	AC0Q	AC1H	Urban0Q	Urban0H
43.327	14.601	17.634	0.867	19.497	AC0Q	AC1H	Urban0Q	Urban0H
17.000	5.729	6.919	0.340	7.650	AC0Q	AC0H	Urban0Q	Urban0H
43.718	14.733	17.793	0.874	19.673	AC1Q	AC1H	Urban1Q	Urban1H
39.050	13.160	15.893	0.781	17.572	AC1Q	AC1H	Urban1Q	Urban1H
46.851	15.789	19.068	0.937	21.083	AC0Q	AC1H	Urban0Q	Urban0H
48.310	16.280	19.662	0.966	21.739	AC0Q	AC1H	Urban0Q	Urban0H
21.633	7.290	8.805	0.433	9.735	AC0Q	AC0H	Urban0Q	Urban0H
39.872	13.437	16.228	0.797	17.942	AC0Q	AC0H	Urban0Q	Urban0H
38.351	12.924	15.609	0.767	17.258	AC0Q	AC0H	Urban0Q	Urban0H
58.038	19.559	23.621	1.161	26.117	AC0Q	AC0H	Urban0Q	Urban0H
25.326	8.535	10.308	0.507	11.397	AC0Q	AC0H	Urban0Q	Urban0H
22.397	7.548	9.116	0.448	10.079	AC0Q	AC0H	Urban0Q	Urban0H
17.935	6.044	7.299	0.359	8.071	CA0Q	CA0H	Urban0Q	Urban0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
42.400	14.289	17.257	0.848	19.080	CA0Q	CA0H	Urban0Q	Urban0H
39.310	13.247	15.999	0.786	17.689	CA0Q	CA0H	Urban0Q	Urban0H
60.277	20.313	24.533	1.206	27.125	CA0Q	CA0H	Urban0Q	Urban0H
10.100	3.404	4.111	0.202	4.545	CA0Q	CA0H	Urban0Q	Urban0H
19.668	6.628	8.005	0.393	8.851	CA0Q	CA1H	Urban0Q	Urban0H
8.193	2.761	3.335	0.164	3.687	CA1Q	CA1H	Urban1Q	Urban1H
16.000	5.392	6.512	0.320	7.200	CA0Q	CA1H	Urban0Q	Urban0H
35.578	11.990	14.480	0.712	16.010	CA1Q	CA1H	Urban1Q	Urban1H
3.800	1.281	1.547	0.076	1.710	CA1Q	CA1H	Urban1Q	Urban1H
27.650	9.318	11.254	0.553	12.443	CA1Q	CA1H	Urban1Q	Urban1H
25.733	8.672	10.473	0.515	11.580	CA0Q	CA0H	Urban0Q	Urban0H
25.188	8.488	10.252	0.504	11.335	CA0Q	CA0H	Urban0Q	Urban0H
34.252	11.543	13.941	0.685	15.413	CA0Q	CA0H	Urban0Q	Urban0H
19.510	6.575	7.941	0.390	8.780	CA0Q	CA0H	Urban0Q	Urban0H
24.700	8.324	10.053	0.494	11.115	CA0Q	CA0H	Urban0Q	Urban0H
38.952	13.127	15.853	0.779	17.528	CA0Q	CA0H	Urban0Q	Urban0H
28.131	9.480	11.449	0.563	12.659	CA0Q	CA0H	Urban0Q	Urban0H
37.658	12.691	15.327	0.753	16.946	CA0Q	CA0H	Urban0Q	Urban0H
13.902	4.685	5.658	0.278	6.256	CA0Q	CA1H	Urban0Q	Urban0H
24.613	8.295	10.018	0.492	11.076	CA0Q	CA1H	Urban0Q	Urban0H
29.760	10.029	12.112	0.595	13.392	CA0Q	CA0H	Urban0Q	Urban0H
61.715	20.798	25.118	1.234	27.772	CA0Q	CA0H	Urban0Q	Urban0H
42.639	14.369	17.354	0.853	19.188	CA0Q	CA0H	Urban0Q	Urban0H
41.733	14.064	16.985	0.835	18.780	CA1Q	CA1H	Urban1Q	Urban1H
26.537	8.943	10.800	0.531	11.942	CA1Q	CA1H	Urban1Q	Urban1H
25.801	8.695	10.501	0.516	11.611	CA1Q	CA1H	Urban1Q	Urban1H
40.714	13.721	16.571	0.814	18.321	CA0Q	CA1H	Urban0Q	Urban0H
54.403	18.334	22.142	1.088	24.481	CA1Q	CA1H	Urban1Q	Urban1H
11.622	3.917	4.730	0.232	5.230	CA0Q	CA0H	Urban0Q	Urban0H
15.200	5.122	6.186	0.304	6.840	CA0Q	CA0H	Urban0Q	Urban0H
5.200	1.752	2.116	0.104	2.340	CA0Q	CA0H	Urban0Q	Urban0H
45.497	15.333	18.517	0.910	20.474	CA1Q	CA1H	Urban1Q	Urban1H
44.208	14.898	17.993	0.884	19.894	CA1Q	CA1H	Urban1Q	Urban1H
41.100	13.851	16.728	0.822	18.495	CA0Q	CA1H	Urban0Q	Urban0H
6.600	2.224	2.686	0.132	2.970	CA0Q	CA1H	Urban0Q	Urban0H
21.007	7.079	8.550	0.420	9.453	CA0Q	CA0H	Urban0Q	Urban0H
45.711	15.405	18.604	0.914	20.570	CA0Q	CA0H	Urban0Q	Urban0H
35.512	11.968	14.453	0.710	15.980	CA0Q	CA0H	Urban0Q	Urban0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
31.132	10.491	12.671	0.623	14.009	CA0Q	CA0H	Urban0Q	Urban0H
18.805	6.337	7.653	0.376	8.462	CA0Q	CA0H	Urban0Q	Urban0H
28.241	9.517	11.494	0.565	12.709	CA0Q	CA0H	Urban0Q	Urban0H
28.475	9.596	11.589	0.570	12.814	CA0Q	CA0H	Urban0Q	Urban0H
14.438	4.865	5.876	0.289	6.497	CA0Q	CA1H	Urban0Q	Urban0H
10.449	3.521	4.253	0.209	4.702	CA0Q	CA1H	Urban0Q	Urban0H
27.311	9.204	11.116	0.546	12.290	CA0Q	CA1H	Urban0Q	Urban0H
52.362	17.646	21.311	1.047	23.563	CA0Q	CA1H	Urban0Q	Urban0H
4.909	1.654	1.998	0.098	2.209	CA0Q	CA0H	Urban0Q	Urban0H
31.923	10.758	12.993	0.638	14.365	CA0Q	CA0H	Urban0Q	Urban0H
28.052	9.454	11.417	0.561	12.623	CA0Q	CA0H	Urban0Q	Urban0H
36.157	12.185	14.716	0.723	16.271	CA0Q	CA0H	Urban0Q	Urban0H
25.824	8.703	10.510	0.516	11.621	CA0Q	CA0H	Urban0Q	Urban0H
29.420	9.915	11.974	0.588	13.239	CA0Q	CA0H	Urban0Q	Urban0H
97.847	32.974	39.824	1.957	44.031	CC0Q	CC0H	Exurb	Exurb
203.099	68.444	82.661	4.062	91.395	CC0Q	CC0H	Exurb	Exurb
117.379	39.557	47.773	2.348	52.821	CC0Q	CC0H	Exurb	Exurb
84.100	28.342	34.229	1.682	37.845	CC0Q	CC0H	Exurb	Exurb
107.639	36.274	43.809	2.153	48.438	CC0Q	CC0H	Exurb	Exurb
77.000	25.949	31.339	1.540	34.650	CC0Q	CC0H	Exurb	Exurb
88.354	29.775	35.960	1.767	39.759	CC0Q	CC0H	Exurb	Exurb
50.262	16.938	20.457	1.005	22.618	CC0Q	CC0H	Exurb	Exurb
74.643	25.155	30.380	1.493	33.589	CC0Q	CC0H	Exurb	Exurb
78.639	26.501	32.006	1.573	35.387	CC0Q	CC0H	Exurb	Exurb
55.502	18.704	22.589	1.110	24.976	CC0Q	CC0H	Exurb	Exurb
57.476	19.369	23.393	1.150	25.864	CC0Q	CC0H	Exurb	Exurb
62.492	21.060	25.434	1.250	28.121	CC0Q	CC0H	Exurb	Exurb
18.600	6.268	7.570	0.372	8.370	CC0Q	CC0H	Exurb	Exurb
144.499	48.696	58.811	2.890	65.025	CC0Q	CC0H	Exurb	Exurb
48.822	16.453	19.871	0.976	21.970	CC0Q	CC0H	Exurb	Exurb
85.242	28.727	34.693	1.705	38.359	CC0Q	CC0H	Exurb	Exurb
92.659	31.226	37.712	1.853	41.697	CC0Q	CC0H	Exurb	Exurb
53.019	17.867	21.579	1.060	23.858	CC0Q	CC0H	Exurb	Exurb
88.676	29.884	36.091	1.774	39.904	CC0Q	CC0H	Exurb	Exurb
119.940	40.420	48.815	2.399	53.973	CC0Q	CC0H	Exurb	Exurb
115.366	38.878	46.954	2.307	51.915	CC0Q	CC0H	Exurb	Exurb
52.205	17.593	21.248	1.044	23.492	CC0Q	CC0H	Exurb	Exurb
41.192	13.882	16.765	0.824	18.536	DC1Q	DC1H	Urban1Q	Urban1H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
1.650	0.556	0.672	0.033	0.742	DC1Q	DC1H	Urban1Q	Urban1H
16.724	5.636	6.807	0.334	7.526	DC1Q	DC1H	Urban1Q	Urban1H
1.600	0.539	0.651	0.032	0.720	DC1Q	DC1H	Urban1Q	Urban1H
15.800	5.325	6.431	0.316	7.110	DC1Q	DC1H	Urban1Q	Urban1H
59.796	20.151	24.337	1.196	26.908	DC1Q	DC1H	Urban1Q	Urban1H
37.700	12.705	15.344	0.754	16.965	DC1Q	DC1H	Urban1Q	Urban1H
58.701	19.782	23.891	1.174	26.415	DC1Q	DC1H	Urban1Q	Urban1H
1.200	0.404	0.488	0.024	0.540	DC1Q	DC1H	Urban1Q	Urban1H
17.432	5.875	7.095	0.349	7.844	DC1Q	DC1H	Urban1Q	Urban1H
53.800	18.131	21.897	1.076	24.210	DC1Q	DC1H	Urban1Q	Urban1H
12.200	4.111	4.965	0.244	5.490	DC0Q	DC1H	Urban0Q	Urban0H
26.550	8.947	10.806	0.531	11.947	DC0Q	DC0H	Urban0Q	Urban0H
17.300	5.830	7.041	0.346	7.785	DC0Q	DC1H	Urban0Q	Urban0H
8.400	2.831	3.419	0.168	3.780	DC1Q	DC1H	Urban1Q	Urban1H
9.286	3.129	3.779	0.186	4.179	DC1Q	DC1H	Urban1Q	Urban1H
12.175	4.103	4.955	0.244	5.479	DC1Q	DC1H	Urban1Q	Urban1H
13.309	4.485	5.417	0.266	5.989	DC1Q	DC1H	Urban1Q	Urban1H
6.386	2.152	2.599	0.128	2.874	DC1Q	DC1H	Urban1Q	Urban1H
9.054	3.051	3.685	0.181	4.074	DC0Q	DC1H	Urban0Q	Urban0H
13.533	4.561	5.508	0.271	6.090	DC1Q	DC1H	Urban1Q	Urban1H
18.589	6.264	7.566	0.372	8.365	DC1Q	DC1H	Urban1Q	Urban1H
34.580	11.654	14.074	0.692	15.561	DC1Q	DC1H	Urban1Q	Urban1H
52.655	17.745	21.431	1.053	23.695	DC1Q	DC1H	Urban1Q	Urban1H
5.756	1.940	2.343	0.115	2.590	DC1Q	DC1H	Urban1Q	Urban1H
19.119	6.443	7.782	0.382	8.604	DC0Q	DC1H	Urban0Q	Urban0H
19.394	6.536	7.893	0.388	8.727	DC1Q	DC1H	Urban1Q	Urban1H
14.600	4.920	5.942	0.292	6.570	DC1Q	DC1H	Urban1Q	Urban1H
5.500	1.853	2.238	0.110	2.475	DC0Q	DC1H	Urban0Q	Urban0H
27.600	9.301	11.233	0.552	12.420	DC1Q	DC1H	Urban1Q	Urban1H
66.948	22.561	27.248	1.339	30.126	DC1Q	DC1H	Urban1Q	Urban1H
11.100	3.741	4.518	0.222	4.995	DC1Q	DC1H	Urban1Q	Urban1H
5.721	1.928	2.328	0.114	2.574	DC1Q	DC1H	Urban1Q	Urban1H
9.800	3.303	3.989	0.196	4.410	DC0Q	DC0H	Urban0Q	Urban0H
58.092	19.577	23.644	1.162	26.142	DC0Q	DC0H	Urban0Q	Urban0H
94.800	31.948	38.584	1.896	42.660	DC0Q	DC1H	Urban0Q	Urban0H
42.850	14.440	17.440	0.857	19.283	DC0Q	DC0H	Urban0Q	Urban0H
29.084	9.801	11.837	0.582	13.088	DC0Q	DC0H	Urban0Q	Urban0H
45.000	15.165	18.315	0.900	20.250	DC0Q	DC0H	Urban0Q	Urban0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
32.472	10.943	13.216	0.649	14.613	DC0Q	DC0H	Urban0Q	Urban0H
17.697	5.964	7.203	0.354	7.963	DC0Q	DC0H	Urban0Q	Urban0H
28.677	9.664	11.672	0.574	12.905	DC0Q	DC0H	Urban0Q	Urban0H
27.672	9.325	11.262	0.553	12.452	DC0Q	DC0H	Urban0Q	Urban0H
22.388	7.545	9.112	0.448	10.074	DC0Q	DC0H	Urban0Q	Urban0H
24.753	8.342	10.074	0.495	11.139	DC1Q	DC1H	Urban1Q	Urban1H
30.281	10.205	12.324	0.606	13.626	DC0Q	DC1H	Urban0Q	Urban0H
17.176	5.788	6.991	0.344	7.729	DC0Q	DC0H	Urban0Q	Urban0H
41.709	14.056	16.976	0.834	18.769	DC0Q	DC1H	Urban0Q	Urban0H
10.294	3.469	4.190	0.206	4.632	DC0Q	DC1H	Urban0Q	Urban0H
24.137	8.134	9.824	0.483	10.862	DC0Q	DC0H	Urban0Q	Urban0H
31.300	10.548	12.739	0.626	14.085	DC1Q	DC1H	Urban1Q	Urban1H
20.247	6.823	8.241	0.405	9.111	DC1Q	DC1H	Urban1Q	Urban1H
18.987	6.399	7.728	0.380	8.544	DC0Q	DC1H	Urban0Q	Urban0H
12.367	4.168	5.033	0.247	5.565	DC1Q	DC1H	Urban1Q	Urban1H
16.320	5.500	6.642	0.326	7.344	DC1Q	DC1H	Urban1Q	Urban1H
8.038	2.709	3.271	0.161	3.617	DC1Q	DC1H	Urban1Q	Urban1H
16.552	5.578	6.737	0.331	7.448	DC0Q	DC1H	Urban0Q	Urban0H
15.869	5.348	6.459	0.317	7.141	DC1Q	DC1H	Urban1Q	Urban1H
7.993	2.694	3.253	0.160	3.597	DC0Q	DC1H	Urban0Q	Urban0H
11.114	3.745	4.523	0.222	5.001	DC1Q	DC1H	Urban1Q	Urban1H
35.473	11.955	14.438	0.709	15.963	DC1Q	DC1H	Urban1Q	Urban1H
20.013	6.744	8.145	0.400	9.006	DC0Q	DC1H	Urban0Q	Urban0H
17.461	5.884	7.107	0.349	7.857	DC1Q	DC1H	Urban1Q	Urban1H
11.300	3.808	4.599	0.226	5.085	DC0Q	DC0H	Urban0Q	Urban0H
18.344	6.182	7.466	0.367	8.255	DC1Q	DC1H	Urban1Q	Urban1H
6.702	2.258	2.728	0.134	3.016	DC1Q	DC1H	Urban1Q	Urban1H
41.930	14.130	17.066	0.839	18.869	DC0Q	DC1H	Urban0Q	Urban0H
13.274	4.473	5.402	0.265	5.973	DC1Q	DC1H	Urban1Q	Urban1H
19.957	6.726	8.123	0.399	8.981	DC1Q	DC1H	Urban1Q	Urban1H
3.200	1.078	1.302	0.064	1.440	DC1Q	DC1H	Urban1Q	Urban1H
4.017	1.354	1.635	0.080	1.808	DC1Q	DC1H	Urban1Q	Urban1H
64.023	21.576	26.057	1.280	28.810	DC1Q	DC1H	Urban1Q	Urban1H
17.002	5.730	6.920	0.340	7.651	DC0Q	DC1H	Urban0Q	Urban0H
40.417	13.621	16.450	0.808	18.188	DC1Q	DC1H	Urban1Q	Urban1H
45.900	15.468	18.681	0.918	20.655	DC1Q	DC1H	Urban1Q	Urban1H
25.360	8.546	10.321	0.507	11.412	DC1Q	DC1H	Urban1Q	Urban1H
19.053	6.421	7.755	0.381	8.574	DC0Q	DC1H	Urban0Q	Urban0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
5.300	1.786	2.157	0.106	2.385	DC1Q	DC1H	Urban1Q	Urban1H
14.756	4.973	6.006	0.295	6.640	DC1Q	DC1H	Urban1Q	Urban1H
15.704	5.292	6.391	0.314	7.067	DC0Q	DC0H	Urban0Q	Urban0H
2.400	0.809	0.977	0.048	1.080	DC1Q	DC1H	Urban1Q	Urban1H
2.400	0.809	0.977	0.048	1.080	DC1Q	DC1H	Urban1Q	Urban1H
35.624	12.005	14.499	0.712	16.031	DC1Q	DC1H	Urban1Q	Urban1H
35.850	12.082	14.591	0.717	16.133	DC0Q	DC1H	Urban0Q	Urban0H
13.300	4.482	5.413	0.266	5.985	DC1Q	DC1H	Urban1Q	Urban1H
23.924	8.062	9.737	0.478	10.766	DC1Q	DC1H	Urban1Q	Urban1H
27.889	9.398	11.351	0.558	12.550	DC0Q	DC1H	Urban0Q	Urban0H
16.397	5.526	6.674	0.328	7.379	DC0Q	DC1H	Urban0Q	Urban0H
40.122	13.521	16.330	0.802	18.055	DC0Q	DC1H	Urban0Q	Urban0H
38.515	12.980	15.676	0.770	17.332	DC1Q	DC1H	Urban1Q	Urban1H
38.000	12.806	15.466	0.760	17.100	DC1Q	DC1H	Urban1Q	Urban1H
6.586	2.219	2.680	0.132	2.964	DC0Q	DC0H	Urban0Q	Urban0H
37.298	12.569	15.180	0.746	16.784	DC0Q	DC0H	Urban0Q	Urban0H
14.952	5.039	6.086	0.299	6.729	DC0Q	DC0H	Urban0Q	Urban0H
28.346	9.553	11.537	0.567	12.756	DC0Q	DC0H	Urban0Q	Urban0H
25.834	8.706	10.515	0.517	11.625	DC0Q	DC0H	Urban0Q	Urban0H
33.966	11.446	13.824	0.679	15.285	DC0Q	DC1H	Urban0Q	Urban0H
39.460	13.298	16.060	0.789	17.757	DC0Q	DC0H	Urban0Q	Urban0H
30.847	10.395	12.555	0.617	13.881	DC1Q	DC1H	Urban1Q	Urban1H
40.992	13.814	16.684	0.820	18.447	DC1Q	DC1H	Urban1Q	Urban1H
24.136	8.134	9.823	0.483	10.861	DC1Q	DC1H	Urban1Q	Urban1H
20.895	7.042	8.504	0.418	9.403	DC1Q	DC1H	Urban1Q	Urban1H
25.898	8.728	10.541	0.518	11.654	DC0Q	DC1H	Urban0Q	Urban0H
32.663	11.007	13.294	0.653	14.698	DC1Q	DC1H	Urban1Q	Urban1H
4.543	1.531	1.849	0.091	2.044	DC1Q	DC1H	Urban1Q	Urban1H
18.588	6.264	7.565	0.372	8.364	DC1Q	DC1H	Urban1Q	Urban1H
1.800	0.607	0.733	0.036	0.810	DC1Q	DC1H	Urban1Q	Urban1H
24.186	8.151	9.844	0.484	10.884	DC1Q	DC1H	Urban1Q	Urban1H
11.886	4.005	4.837	0.238	5.349	DC1Q	DC1H	Urban1Q	Urban1H
22.100	7.448	8.995	0.442	9.945	DC1Q	DC1H	Urban1Q	Urban1H
26.018	8.768	10.589	0.520	11.708	DC1Q	DC1H	Urban1Q	Urban1H
17.607	5.934	7.166	0.352	7.923	DC1Q	DC1H	Urban1Q	Urban1H
11.405	3.844	4.642	0.228	5.132	DC1Q	DC1H	Urban1Q	Urban1H
2.500	0.842	1.017	0.050	1.125	DC1Q	DC1H	Urban1Q	Urban1H
30.169	10.167	12.279	0.603	13.576	DC1Q	DC1H	Urban1Q	Urban1H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
8.518	2.870	3.467	0.170	3.833	DC1Q	DC1H	Urban1Q	Urban1H
25.519	8.600	10.386	0.510	11.483	DC0Q	DC0H	Urban0Q	Urban0H
39.086	13.172	15.908	0.782	17.588	DC0Q	DC0H	Urban0Q	Urban0H
18.825	6.344	7.662	0.376	8.471	DC0Q	DC0H	Urban0Q	Urban0H
21.656	7.298	8.814	0.433	9.745	DC1Q	DC1H	Urban1Q	Urban1H
39.797	13.412	16.197	0.796	17.909	DC0Q	DC1H	Urban0Q	Urban0H
37.813	12.743	15.390	0.756	17.016	DC1Q	DC1H	Urban1Q	Urban1H
42.535	14.334	17.312	0.851	19.141	DC1Q	DC1H	Urban1Q	Urban1H
70.416	23.730	28.659	1.408	31.687	DC1Q	DC1H	Urban1Q	Urban1H
30.648	10.328	12.474	0.613	13.792	DC1Q	DC1H	Urban1Q	Urban1H
27.852	9.386	11.336	0.557	12.533	DC1Q	DC1H	Urban1Q	Urban1H
26.647	8.980	10.845	0.533	11.991	DC0Q	DC1H	Urban0Q	Urban0H
17.500	5.897	7.122	0.350	7.875	DC1Q	DC1H	Urban1Q	Urban1H
21.274	7.169	8.658	0.425	9.573	DC1Q	DC1H	Urban1Q	Urban1H
21.887	7.376	8.908	0.438	9.849	DC0Q	DC0H	Urban0Q	Urban0H
11.800	3.977	4.803	0.236	5.310	DC0Q	DC0H	Urban0Q	Urban0H
42.473	14.314	17.287	0.849	19.113	DC0Q	DC1H	Urban0Q	Urban0H
17.758	5.984	7.227	0.355	7.991	DC0Q	DC0H	Urban0Q	Urban0H
52.955	17.846	21.553	1.059	23.830	DC0Q	DC0H	Urban0Q	Urban0H
34.723	11.702	14.132	0.694	15.625	DC0Q	DC0H	Urban0Q	Urban0H
17.402	5.864	7.082	0.348	7.831	DC0Q	DC0H	Urban0Q	Urban0H
22.123	7.456	9.004	0.442	9.956	DC0Q	DC0H	Urban0Q	Urban0H
26.850	9.048	10.928	0.537	12.082	DC0Q	DC0H	Urban0Q	Urban0H
36.954	12.454	15.040	0.739	16.629	DC0Q	DC0H	Urban0Q	Urban0H
24.200	8.155	9.849	0.484	10.890	DC0Q	DC0H	Urban0Q	Urban0H
54.500	18.367	22.182	1.090	24.525	DC0Q	DC0H	Urban0Q	Urban0H
27.466	9.256	11.179	0.549	12.360	DC0Q	DC1H	Urban0Q	Urban0H
28.154	9.488	11.458	0.563	12.669	DC0Q	DC0H	Urban0Q	Urban0H
54.430	18.343	22.153	1.089	24.493	DC0Q	DC1H	Urban0Q	Urban0H
8.000	2.696	3.256	0.160	3.600	DC0Q	DC1H	Urban0Q	Urban0H
27.895	9.401	11.353	0.558	12.553	DC0Q	DC1H	Urban0Q	Urban0H
18.510	6.238	7.534	0.370	8.330	DC0Q	DC0H	Urban0Q	Urban0H
21.492	7.243	8.747	0.430	9.672	DC0Q	DC0H	Urban0Q	Urban0H
69.232	23.331	28.177	1.385	31.154	DC0Q	DC0H	Urban0Q	Urban0H
17.472	5.888	7.111	0.349	7.862	DC0Q	DC0H	Urban0Q	Urban0H
28.047	9.452	11.415	0.561	12.621	DC0Q	DC0H	Urban0Q	Urban0H
24.923	8.399	10.144	0.498	11.216	DC1Q	DC1H	Urban1Q	Urban1H
26.937	9.078	10.963	0.539	12.121	DC1Q	DC1H	Urban1Q	Urban1H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
15.452	5.207	6.289	0.309	6.954	DC0Q	DC0H	Urban0Q	Urban0H
70.600	23.792	28.734	1.412	31.770	DC0Q	DC0H	Urban0Q	Urban0H
33.370	11.246	13.581	0.667	15.016	DC0Q	DC0H	Urban0Q	Urban0H
67.596	22.780	27.512	1.352	30.418	DC0Q	DC1H	Urban0Q	Urban0H
13.457	4.535	5.477	0.269	6.056	DC1Q	DC1H	Urban1Q	Urban1H
24.848	8.374	10.113	0.497	11.182	DC1Q	DC1H	Urban1Q	Urban1H
13.800	4.651	5.617	0.276	6.210	DC0Q	DC1H	Urban0Q	Urban0H
17.104	5.764	6.961	0.342	7.697	DC0Q	DC1H	Urban0Q	Urban0H
22.289	7.511	9.072	0.446	10.030	DC1Q	DC1H	Urban1Q	Urban1H
74.109	24.975	30.162	1.482	33.349	DC1Q	DC1H	Urban1Q	Urban1H
31.962	10.771	13.008	0.639	14.383	DC1Q	DC1H	Urban1Q	Urban1H
28.734	9.684	11.695	0.575	12.930	DC1Q	DC1H	Urban1Q	Urban1H
38.800	13.076	15.792	0.776	17.460	DC1Q	DC1H	Urban1Q	Urban1H
22.964	7.739	9.346	0.459	10.334	DC0Q	DC1H	Urban0Q	Urban0H
26.150	8.813	10.643	0.523	11.768	DC0Q	DC0H	Urban0Q	Urban0H
19.000	6.403	7.733	0.380	8.550	DC0Q	DC1H	Urban0Q	Urban0H
14.200	4.785	5.779	0.284	6.390	DC0Q	DC0H	Urban0Q	Urban0H
13.222	4.456	5.381	0.264	5.950	DC0Q	DC0H	Urban0Q	Urban0H
38.894	13.107	15.830	0.778	17.503	DC0Q	DC0H	Urban0Q	Urban0H
32.716	11.025	13.316	0.654	14.722	DC0Q	DC0H	Urban0Q	Urban0H
8.826	2.974	3.592	0.177	3.972	DC0Q	DC0H	Urban0Q	Urban0H
96.900	32.655	39.438	1.938	43.605	DC0Q	DC0H	Urban0Q	Urban0H
34.150	11.509	13.899	0.683	15.368	DC0Q	DC0H	Urban0Q	Urban0H
41.470	13.975	16.878	0.829	18.661	DC0Q	DC0H	Urban0Q	Urban0H
28.000	9.436	11.396	0.560	12.600	DC0Q	DC0H	Urban0Q	Urban0H
13.800	4.651	5.617	0.276	6.210	DC0Q	DC0H	Urban0Q	Urban0H
6.843	2.306	2.785	0.137	3.079	DC1Q	DC1H	Urban1Q	Urban1H
15.367	5.179	6.254	0.307	6.915	DC0Q	DC1H	Urban0Q	Urban0H
25.200	8.492	10.256	0.504	11.340	DC0Q	DC1H	Urban0Q	Urban0H
14.542	4.901	5.919	0.291	6.544	DC1Q	DC1H	Urban1Q	Urban1H
27.600	9.301	11.233	0.552	12.420	DC1Q	DC1H	Urban1Q	Urban1H
16.800	5.662	6.838	0.336	7.560	DC1Q	DC1H	Urban1Q	Urban1H
18.141	6.114	7.383	0.363	8.163	DC0Q	DC1H	Urban0Q	Urban0H
29.366	9.896	11.952	0.587	13.215	DC1Q	DC1H	Urban1Q	Urban1H
15.110	5.092	6.150	0.302	6.799	DC0Q	DC1H	Urban0Q	Urban0H
11.200	3.774	4.558	0.224	5.040	DC1Q	DC1H	Urban1Q	Urban1H
11.409	3.845	4.643	0.228	5.134	DC0Q	DC1H	Urban0Q	Urban0H
22.644	7.631	9.216	0.453	10.190	DC0Q	DC0H	Urban0Q	Urban0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
56.061	18.893	22.817	1.121	25.228	DC0Q	DC0H	Urban0Q	Urban0H
49.735	16.761	20.242	0.995	22.381	DC0Q	DC0H	Urban0Q	Urban0H
15.840	5.338	6.447	0.317	7.128	DC0Q	DC0H	Urban0Q	Urban0H
33.084	11.149	13.465	0.662	14.888	DC1Q	DC1H	Urban1Q	Urban1H
81.059	27.317	32.991	1.621	36.476	DC1Q	DC1H	Urban1Q	Urban1H
108.013	36.400	43.961	2.160	48.606	DC0Q	DC0H	Urban0Q	Urban0H
28.058	9.456	11.420	0.561	12.626	DC0Q	DC0H	Urban0Q	Urban0H
27.937	9.415	11.370	0.559	12.572	DC0Q	DC0H	Urban0Q	Urban0H
21.163	7.132	8.613	0.423	9.523	DC0Q	DC0H	Urban0Q	Urban0H
8.327	2.806	3.389	0.167	3.747	DC0Q	DC0H	Urban0Q	Urban0H
20.835	7.021	8.480	0.417	9.376	DC1Q	DC1H	Urban1Q	Urban1H
52.347	17.641	21.305	1.047	23.556	DC1Q	DC1H	Urban1Q	Urban1H
38.176	12.865	15.537	0.764	17.179	DC1Q	DC1H	Urban1Q	Urban1H
28.910	9.743	11.766	0.578	13.009	DC0Q	DC1H	Urban0Q	Urban0H
24.703	8.325	10.054	0.494	11.116	DC0Q	DC1H	Urban0Q	Urban0H
28.882	9.733	11.755	0.578	12.997	DC0Q	DC0H	Urban0Q	Urban0H
23.625	7.962	9.615	0.472	10.631	DC0Q	DC0H	Urban0Q	Urban0H
11.283	3.802	4.592	0.226	5.077	DC0Q	DC1H	Urban0Q	Urban0H
36.192	12.197	14.730	0.724	16.286	DC1Q	DC1H	Urban1Q	Urban1H
20.542	6.923	8.361	0.411	9.244	DC0Q	DC1H	Urban0Q	Urban0H
20.167	6.796	8.208	0.403	9.075	DC0Q	DC0H	Urban0Q	Urban0H
25.244	8.507	10.274	0.505	11.360	DC0Q	DC0H	Urban0Q	Urban0H
36.200	12.199	14.733	0.724	16.290	DC0Q	DC0H	Urban0Q	Urban0H
1.200	0.404	0.488	0.024	0.540	DC0Q	DC1H	Urban0Q	Urban0H
39.650	13.362	16.138	0.793	17.843	FFC0Q	FFC0H	Suburb0Q	Suburb0H
25.040	8.439	10.191	0.501	11.268	FFC0Q	FFC0H	Suburb0Q	Suburb0H
46.560	15.691	18.950	0.931	20.952	FFC0Q	FFC1H	Suburb0Q	Suburb0H
38.830	13.086	15.804	0.777	17.473	FFC0Q	FFC0H	Suburb0Q	Suburb0H
28.184	9.498	11.471	0.564	12.683	FFC0Q	FFC0H	Suburb0Q	Suburb0H
42.703	14.391	17.380	0.854	19.216	FFC0Q	FFC0H	Suburb0Q	Suburb0H
41.968	14.143	17.081	0.839	18.886	FFC0Q	FFC0H	Suburb0Q	Suburb0H
5.400	1.820	2.198	0.108	2.430	FFC0Q	FFC0H	Suburb0Q	Suburb0H
30.072	10.134	12.239	0.601	13.533	FFC0Q	FFC0H	Suburb0Q	Suburb0H
25.600	8.627	10.419	0.512	11.520	FFC0Q	FFC0H	Suburb0Q	Suburb0H
26.858	9.051	10.931	0.537	12.086	FFC0Q	FFC0H	Suburb0Q	Suburb0H
17.897	6.031	7.284	0.358	8.054	FFC0Q	FFC0H	Suburb0Q	Suburb0H
75.875	25.570	30.881	1.517	34.144	FFC0Q	FFC0H	Suburb0Q	Suburb0H
29.683	10.003	12.081	0.594	13.357	FFC0Q	FFC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
54.967	18.524	22.372	1.099	24.735	FFC0Q	FFC0H	Suburb0Q	Suburb0H
4.900	1.651	1.994	0.098	2.205	FFC0Q	FFC0H	Suburb0Q	Suburb0H
24.846	8.373	10.113	0.497	11.181	FFC0Q	FFC0H	Suburb0Q	Suburb0H
32.754	11.038	13.331	0.655	14.739	FFC0Q	FFC0H	Suburb0Q	Suburb0H
13.884	4.679	5.651	0.278	6.248	FFC0Q	FFC0H	Suburb0Q	Suburb0H
22.980	7.744	9.353	0.460	10.341	FFC0Q	FFC0H	Suburb0Q	Suburb0H
19.470	6.561	7.924	0.389	8.762	FFC0Q	FFC0H	Suburb0Q	Suburb0H
17.767	5.987	7.231	0.355	7.995	FFC0Q	FFC0H	Suburb0Q	Suburb0H
27.500	9.268	11.193	0.550	12.375	FFC0Q	FFC1H	Suburb0Q	Suburb0H
26.621	8.971	10.835	0.532	11.979	FFC0Q	FFC1H	Suburb0Q	Suburb0H
46.042	15.516	18.739	0.921	20.719	FFC0Q	FFC0H	Suburb0Q	Suburb0H
26.714	9.003	10.873	0.534	12.021	FFC0Q	FFC0H	Suburb0Q	Suburb0H
37.879	12.765	15.417	0.758	17.046	FFC0Q	FFC0H	Suburb0Q	Suburb0H
15.200	5.122	6.186	0.304	6.840	FFC0Q	FFC0H	Suburb0Q	Suburb0H
36.134	12.177	14.706	0.723	16.260	FFC0Q	FFC0H	Suburb0Q	Suburb0H
12.700	4.280	5.169	0.254	5.715	FFC0Q	FFC0H	Suburb0Q	Suburb0H
6.800	2.292	2.768	0.136	3.060	FFC0Q	FFC0H	Suburb0Q	Suburb0H
9.600	3.235	3.907	0.192	4.320	FFC0Q	FFC0H	Suburb0Q	Suburb0H
21.589	7.275	8.787	0.432	9.715	FFC1Q	FFC1H	Suburb1Q	Suburb1H
22.067	7.436	8.981	0.441	9.930	FFC0Q	FFC1H	Suburb0Q	Suburb0H
22.484	7.577	9.151	0.450	10.118	FFC1Q	FFC1H	Suburb1Q	Suburb1H
44.559	15.016	18.136	0.891	20.052	FFC0Q	FFC0H	Suburb0Q	Suburb0H
47.746	16.090	19.432	0.955	21.485	FFC0Q	FFC0H	Suburb0Q	Suburb0H
16.242	5.474	6.611	0.325	7.309	FFC0Q	FFC0H	Suburb0Q	Suburb0H
15.967	5.381	6.498	0.319	7.185	FFC0Q	FFC0H	Suburb0Q	Suburb0H
39.864	13.434	16.225	0.797	17.939	FFC0Q	FFC0H	Suburb0Q	Suburb0H
18.379	6.194	7.480	0.368	8.270	FFC1Q	FFC1H	Suburb1Q	Suburb1H
94.662	31.901	38.527	1.893	42.598	FFC0Q	FFC0H	Suburb0Q	Suburb0H
32.716	11.025	13.316	0.654	14.722	FFC1Q	FFC1H	Suburb1Q	Suburb1H
44.189	14.892	17.985	0.884	19.885	FFC0Q	FFC0H	Suburb0Q	Suburb0H
44.163	14.883	17.974	0.883	19.873	FFC0Q	FFC0H	Suburb0Q	Suburb0H
33.996	11.457	13.836	0.680	15.298	FFC0Q	FFC0H	Suburb0Q	Suburb0H
45.762	15.422	18.625	0.915	20.593	FFC0Q	FFC0H	Suburb0Q	Suburb0H
40.709	13.719	16.569	0.814	18.319	FFC0Q	FFC0H	Suburb0Q	Suburb0H
56.867	19.164	23.145	1.137	25.590	FFC0Q	FFC0H	Suburb0Q	Suburb0H
228.200	76.903	92.877	4.564	102.690	FFC0Q	FFC0H	Suburb0Q	Suburb0H
49.373	16.639	20.095	0.987	22.218	FFC0Q	FFC0H	Suburb0Q	Suburb0H
25.088	8.455	10.211	0.502	11.289	FFC0Q	FFC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
33.246	11.204	13.531	0.665	14.961	FFC0Q	FFC0H	Suburb0Q	Suburb0H
106.312	35.827	43.269	2.126	47.840	FFC0Q	FFC0H	Suburb0Q	Suburb0H
33.255	11.207	13.535	0.665	14.965	FFC0Q	FFC0H	Suburb0Q	Suburb0H
3.300	1.112	1.343	0.066	1.485	FFC0Q	FFC0H	Suburb0Q	Suburb0H
32.882	11.081	13.383	0.658	14.797	FFC1Q	FFC1H	Suburb1Q	Suburb1H
39.219	13.217	15.962	0.784	17.649	FFC1Q	FFC1H	Suburb1Q	Suburb1H
32.968	11.110	13.418	0.659	14.836	FFC0Q	FFC0H	Suburb0Q	Suburb0H
48.091	16.207	19.573	0.962	21.641	FFC0Q	FFC0H	Suburb0Q	Suburb0H
68.254	23.002	27.779	1.365	30.714	FFC0Q	FFC0H	Suburb0Q	Suburb0H
31.659	10.669	12.885	0.633	14.246	FFC0Q	FFC0H	Suburb0Q	Suburb0H
36.847	12.417	14.997	0.737	16.581	FFC0Q	FFC0H	Suburb0Q	Suburb0H
49.914	16.821	20.315	0.998	22.461	FFC0Q	FFC0H	Suburb0Q	Suburb0H
32.839	11.067	13.365	0.657	14.777	FFC0Q	FFC0H	Suburb0Q	Suburb0H
77.550	26.134	31.563	1.551	34.898	FFC0Q	FFC1H	Suburb0Q	Suburb0H
63.000	21.231	25.641	1.260	28.350	FFC0Q	FFC0H	Suburb0Q	Suburb0H
32.226	10.860	13.116	0.645	14.502	FFC1Q	FFC1H	Suburb1Q	Suburb1H
128.000	43.136	52.096	2.560	57.600	FFC0Q	FFC0H	Suburb0Q	Suburb0H
57.849	19.495	23.544	1.157	26.032	FFC0Q	FFC0H	Suburb0Q	Suburb0H
33.081	11.148	13.464	0.662	14.886	FFC0Q	FFC0H	Suburb0Q	Suburb0H
36.712	12.372	14.942	0.734	16.521	FFC0Q	FFC0H	Suburb0Q	Suburb0H
68.604	23.120	27.922	1.372	30.872	FFC0Q	FFC0H	Suburb0Q	Suburb0H
48.811	16.449	19.866	0.976	21.965	FFC0Q	FFC0H	Suburb0Q	Suburb0H
67.400	22.714	27.432	1.348	30.330	FFC1Q	FFC1H	Suburb1Q	Suburb1H
33.875	11.416	13.787	0.677	15.244	FFC0Q	FFC0H	Suburb0Q	Suburb0H
63.334	21.344	25.777	1.267	28.500	FFC0Q	FFC0H	Suburb0Q	Suburb0H
39.781	13.406	16.191	0.796	17.901	FFC0Q	FFC0H	Suburb0Q	Suburb0H
45.633	15.378	18.573	0.913	20.535	FFC0Q	FFC0H	Suburb0Q	Suburb0H
47.300	15.940	19.251	0.946	21.285	FFC0Q	FFC0H	Suburb0Q	Suburb0H
52.552	17.710	21.389	1.051	23.649	FFC0Q	FFC1H	Suburb0Q	Suburb0H
31.156	10.499	12.680	0.623	14.020	FFC1Q	FFC1H	Suburb1Q	Suburb1H
49.772	16.773	20.257	0.995	22.397	FFC0Q	FFC0H	Suburb0Q	Suburb0H
12.800	4.314	5.210	0.256	5.760	FFC0Q	FFC0H	Suburb0Q	Suburb0H
18.600	6.268	7.570	0.372	8.370	FFC0Q	FFC0H	Suburb0Q	Suburb0H
33.833	11.402	13.770	0.677	15.225	FFC0Q	FFC0H	Suburb0Q	Suburb0H
22.378	7.541	9.108	0.448	10.070	FFC1Q	FFC1H	Suburb1Q	Suburb1H
70.700	23.826	28.775	1.414	31.815	FFC0Q	FFC0H	Suburb0Q	Suburb0H
33.500	11.290	13.635	0.670	15.075	FFC0Q	FFC0H	Suburb0Q	Suburb0H
56.790	19.138	23.113	1.136	25.555	FFC0Q	FFC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
78.441	26.435	31.925	1.569	35.298	FFC0Q	FFC0H	Suburb0Q	Suburb0H
48.961	16.500	19.927	0.979	22.032	FFC0Q	FFC0H	Suburb0Q	Suburb0H
38.569	12.998	15.697	0.771	17.356	FFC0Q	FFC0H	Suburb0Q	Suburb0H
67.003	22.580	27.270	1.340	30.151	FFC0Q	FFC0H	Suburb0Q	Suburb0H
76.204	25.681	31.015	1.524	34.292	FFC0Q	FFC0H	Suburb0Q	Suburb0H
46.765	15.760	19.033	0.935	21.044	FFC0Q	FFC0H	Suburb0Q	Suburb0H
31.700	10.683	12.902	0.634	14.265	FFC0Q	FFC0H	Suburb0Q	Suburb0H
65.416	22.045	26.624	1.308	29.437	FFC0Q	FFC0H	Suburb0Q	Suburb0H
20.300	6.841	8.262	0.406	9.135	FFC0Q	FFC0H	Suburb0Q	Suburb0H
49.529	16.691	20.158	0.991	22.288	FFC1Q	FFC1H	Suburb1Q	Suburb1H
21.000	7.077	8.547	0.420	9.450	FFC0Q	FFC1H	Suburb0Q	Suburb0H
42.883	14.452	17.453	0.858	19.297	FFC0Q	FFC0H	Suburb0Q	Suburb0H
49.600	16.715	20.187	0.992	22.320	FFC0Q	FFC0H	Suburb0Q	Suburb0H
55.550	18.720	22.609	1.111	24.998	FFC0Q	FFC0H	Suburb0Q	Suburb0H
71.801	24.197	29.223	1.436	32.310	FFC0Q	FFC0H	Suburb0Q	Suburb0H
31.070	10.471	12.646	0.621	13.982	FFC0Q	FFC0H	Suburb0Q	Suburb0H
54.312	18.303	22.105	1.086	24.441	FFC0Q	FFC0H	Suburb0Q	Suburb0H
30.286	10.206	12.326	0.606	13.629	FFC1Q	FFC1H	Suburb1Q	Suburb1H
34.981	11.788	14.237	0.700	15.741	FFC1Q	FFC1H	Suburb1Q	Suburb1H
32.316	10.890	13.153	0.646	14.542	FFC1Q	FFC1H	Suburb1Q	Suburb1H
79.200	26.690	32.234	1.584	35.640	FFC1Q	FFC1H	Suburb1Q	Suburb1H
34.223	11.533	13.929	0.684	15.400	FFC0Q	FFC1H	Suburb0Q	Suburb0H
70.536	23.771	28.708	1.411	31.741	FFC0Q	FFC0H	Suburb0Q	Suburb0H
74.317	25.045	30.247	1.486	33.443	FFC0Q	FFC0H	Suburb0Q	Suburb0H
15.694	5.289	6.387	0.314	7.062	FFC0Q	FFC0H	Suburb0Q	Suburb0H
18.950	6.386	7.713	0.379	8.528	FFC0Q	FFC0H	Suburb0Q	Suburb0H
38.545	12.990	15.688	0.771	17.345	FFC0Q	FFC0H	Suburb0Q	Suburb0H
80.200	27.027	32.641	1.604	36.090	FFC0Q	FFC0H	Suburb0Q	Suburb0H
41.842	14.101	17.030	0.837	18.829	FFC0Q	FFC0H	Suburb0Q	Suburb0H
21.350	7.195	8.689	0.427	9.608	FFC0Q	FFC0H	Suburb0Q	Suburb0H
25.000	8.425	10.175	0.500	11.250	FFC0Q	FFC0H	Suburb0Q	Suburb0H
55.400	18.670	22.548	1.108	24.930	FFC0Q	FFC0H	Suburb0Q	Suburb0H
27.587	9.297	11.228	0.552	12.414	FFC0Q	FFC0H	Suburb0Q	Suburb0H
38.300	12.907	15.588	0.766	17.235	FFC0Q	FFC0H	Suburb0Q	Suburb0H
85.048	28.661	34.614	1.701	38.272	FFC0Q	FFC0H	Suburb0Q	Suburb0H
28.364	9.559	11.544	0.567	12.764	FFC0Q	FFC0H	Suburb0Q	Suburb0H
34.863	11.749	14.189	0.697	15.688	FFC0Q	FFC0H	Suburb0Q	Suburb0H
38.508	12.977	15.673	0.770	17.329	FFC0Q	FFC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
38.557	12.994	15.693	0.771	17.350	FFC0Q	FFC0H	Suburb0Q	Suburb0H
68.988	23.249	28.078	1.380	31.045	FFC0Q	FFC0H	Suburb0Q	Suburb0H
55.154	18.587	22.448	1.103	24.819	FFC0Q	FFC0H	Suburb0Q	Suburb0H
35.991	12.129	14.648	0.720	16.196	FFC0Q	FFC0H	Suburb0Q	Suburb0H
43.761	14.747	17.811	0.875	19.692	FFC0Q	FFC0H	Suburb0Q	Suburb0H
26.688	8.994	10.862	0.534	12.009	FFC0Q	FFC0H	Suburb0Q	Suburb0H
62.800	21.164	25.560	1.256	28.260	FFC0Q	FFC0H	Suburb0Q	Suburb0H
95.760	32.271	38.974	1.915	43.092	FFC0Q	FFC0H	Suburb0Q	Suburb0H
28.339	9.550	11.534	0.567	12.752	FFC0Q	FFC0H	Suburb0Q	Suburb0H
31.009	10.450	12.621	0.620	13.954	FFC0Q	FFC0H	Suburb0Q	Suburb0H
59.212	19.954	24.099	1.184	26.645	FFC0Q	FFC0H	Suburb0Q	Suburb0H
37.937	12.785	15.440	0.759	17.071	FFC0Q	FFC0H	Suburb0Q	Suburb0H
24.900	8.391	10.134	0.498	11.205	FFC0Q	FFC0H	Suburb0Q	Suburb0H
52.701	17.760	21.449	1.054	23.716	FFC1Q	FFC1H	Suburb1Q	Suburb1H
16.400	5.527	6.675	0.328	7.380	FFC1Q	FFC1H	Suburb1Q	Suburb1H
9.150	3.084	3.724	0.183	4.118	FFC0Q	FFC0H	Suburb0Q	Suburb0H
61.510	20.729	25.035	1.230	27.680	FFC0Q	FFC0H	Suburb0Q	Suburb0H
59.751	20.136	24.319	1.195	26.888	FFC0Q	FFC0H	Suburb0Q	Suburb0H
36.070	12.156	14.681	0.721	16.232	FFC0Q	FFC0H	Suburb0Q	Suburb0H
67.219	22.653	27.358	1.344	30.249	FFC0Q	FFC0H	Suburb0Q	Suburb0H
55.762	18.792	22.695	1.115	25.093	FFC0Q	FFC0H	Suburb0Q	Suburb0H
38.535	12.986	15.684	0.771	17.341	FFC0Q	FFC0H	Suburb0Q	Suburb0H
78.714	26.527	32.037	1.574	35.421	FFC0Q	FFC0H	Suburb0Q	Suburb0H
89.500	30.162	36.427	1.790	40.275	FFC0Q	FFC0H	Suburb0Q	Suburb0H
85.673	28.872	34.869	1.713	38.553	FFC0Q	FFC0H	Suburb0Q	Suburb0H
53.536	18.042	21.789	1.071	24.091	FFC0Q	FFC0H	Suburb0Q	Suburb0H
26.000	8.762	10.582	0.520	11.700	FFC0Q	FFC0H	Suburb0Q	Suburb0H
84.355	28.428	34.333	1.687	37.960	FFC0Q	FFC0H	Suburb0Q	Suburb0H
59.943	20.201	24.397	1.199	26.974	FFC0Q	FFC0H	Suburb0Q	Suburb0H
75.041	25.289	30.542	1.501	33.768	FFC0Q	FFC0H	Suburb0Q	Suburb0H
45.600	15.367	18.559	0.912	20.520	FFC0Q	FFC0H	Suburb0Q	Suburb0H
49.502	16.682	20.147	0.990	22.276	FFC0Q	FFC0H	Suburb0Q	Suburb0H
27.200	9.166	11.070	0.544	12.240	FFC0Q	FFC0H	Suburb0Q	Suburb0H
65.954	22.226	26.843	1.319	29.679	FFC0Q	FFC0H	Suburb0Q	Suburb0H
59.673	20.110	24.287	1.193	26.853	FFC0Q	FFC0H	Suburb0Q	Suburb0H
67.800	22.849	27.595	1.356	30.510	FFC0Q	FFC0H	Suburb0Q	Suburb0H
40.853	13.767	16.627	0.817	18.384	FFC0Q	FFC0H	Suburb0Q	Suburb0H
51.893	17.488	21.121	1.038	23.352	FFC0Q	FFC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
6.800	2.292	2.768	0.136	3.060	FFC0Q	FFC0H	Suburb0Q	Suburb0H
21.801	7.347	8.873	0.436	9.810	FFC0Q	FFC0H	Suburb0Q	Suburb0H
55.200	18.602	22.466	1.104	24.840	FFC0Q	FFC0H	Suburb0Q	Suburb0H
51.789	17.453	21.078	1.036	23.305	FFC0Q	FFC0H	Suburb0Q	Suburb0H
87.578	29.514	35.644	1.752	39.410	FFC0Q	FFC0H	Suburb0Q	Suburb0H
10.580	3.565	4.306	0.212	4.761	FFC0Q	FFC0H	Suburb0Q	Suburb0H
145.500	49.034	59.219	2.910	65.475	FFC0Q	FFC0H	Suburb0Q	Suburb0H
68.582	23.112	27.913	1.372	30.862	FFC0Q	FFC0H	Suburb0Q	Suburb0H
31.215	10.519	12.704	0.624	14.047	FFC0Q	FFC0H	Suburb0Q	Suburb0H
28.417	9.576	11.566	0.568	12.788	FFC0Q	FFC0H	Suburb0Q	Suburb0H
28.842	9.720	11.739	0.577	12.979	FFC0Q	FFC0H	Suburb0Q	Suburb0H
32.973	11.112	13.420	0.659	14.838	FFC0Q	FFC0H	Suburb0Q	Suburb0H
13.326	4.491	5.424	0.267	5.997	FFC0Q	FFC0H	Suburb0Q	Suburb0H
46.298	15.602	18.843	0.926	20.834	FFC0Q	FFC0H	Suburb0Q	Suburb0H
54.059	18.218	22.002	1.081	24.327	FFC0Q	FFC0H	Suburb0Q	Suburb0H
76.069	25.635	30.960	1.521	34.231	FFC0Q	FFC0H	Suburb0Q	Suburb0H
22.200	7.481	9.035	0.444	9.990	FFC0Q	FFC0H	Suburb0Q	Suburb0H
35.883	12.092	14.604	0.718	16.147	FFC0Q	FFC0H	Suburb0Q	Suburb0H
76.000	25.612	30.932	1.520	34.200	FFC0Q	FFC0H	Suburb0Q	Suburb0H
50.334	16.963	20.486	1.007	22.650	FFC1Q	FFC1H	Suburb1Q	Suburb1H
39.024	13.151	15.883	0.780	17.561	FFC0Q	FFC1H	Suburb0Q	Suburb0H
16.217	5.465	6.600	0.324	7.298	FFC0Q	FFC0H	Suburb0Q	Suburb0H
100.633	33.913	40.958	2.013	45.285	FFC0Q	FFC0H	Suburb0Q	Suburb0H
21.173	7.135	8.617	0.423	9.528	FFC0Q	FFC0H	Suburb0Q	Suburb0H
71.366	24.050	29.046	1.427	32.115	FFC0Q	FFC0H	Suburb0Q	Suburb0H
52.773	17.785	21.479	1.055	23.748	FFC0Q	FFC0H	Suburb0Q	Suburb0H
53.041	17.875	21.588	1.061	23.869	FFC0Q	FFC0H	Suburb0Q	Suburb0H
53.150	17.912	21.632	1.063	23.918	FFC0Q	FFC0H	Suburb0Q	Suburb0H
97.200	32.756	39.560	1.944	43.740	FFC0Q	FFC0H	Suburb0Q	Suburb0H
51.015	17.192	20.763	1.020	22.957	FFC0Q	FFC0H	Suburb0Q	Suburb0H
40.733	13.727	16.578	0.815	18.330	FFC0Q	FFC0H	Suburb0Q	Suburb0H
89.848	30.279	36.568	1.797	40.432	FFC0Q	FFC0H	Suburb0Q	Suburb0H
81.200	27.364	33.048	1.624	36.540	FFC0Q	FFC0H	Suburb0Q	Suburb0H
62.568	21.085	25.465	1.251	28.156	FFC0Q	FFC0H	Suburb0Q	Suburb0H
83.199	28.038	33.862	1.664	37.440	FFC0Q	FFC0H	Suburb0Q	Suburb0H
92.149	31.054	37.505	1.843	41.467	FFC0Q	FFC0H	Suburb0Q	Suburb0H
72.254	24.350	29.408	1.445	32.514	FFC0Q	FFC0H	Suburb0Q	Suburb0H
36.076	12.158	14.683	0.722	16.234	FFC0Q	FFC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
180.200	60.727	73.341	3.604	81.090	FFC0Q	FFC0H	Suburb0Q	Suburb0H
28.000	9.436	11.396	0.560	12.600	FFC0Q	FFC0H	Suburb0Q	Suburb0H
5.500	1.854	2.239	0.110	2.475	FFC0Q	FFC0H	Suburb0Q	Suburb0H
57.395	19.342	23.360	1.148	25.828	FFC0Q	FFC0H	Suburb0Q	Suburb0H
73.000	24.601	29.711	1.460	32.850	FFC0Q	FFC0H	Suburb0Q	Suburb0H
48.300	16.277	19.658	0.966	21.735	FFC0Q	FFC0H	Suburb0Q	Suburb0H
5.200	1.752	2.116	0.104	2.340	FFC0Q	FFC0H	Suburb0Q	Suburb0H
111.800	37.677	45.503	2.236	50.310	FFC0Q	FFC0H	Suburb0Q	Suburb0H
63.771	21.491	25.955	1.275	28.697	FFC0Q	FFC0H	Suburb0Q	Suburb0H
45.634	15.379	18.573	0.913	20.535	FFC0Q	FFC0H	Suburb0Q	Suburb0H
106.542	35.905	43.362	2.131	47.944	FFC0Q	FFC0H	Suburb0Q	Suburb0H
66.470	22.400	27.053	1.329	29.911	FFC0Q	FFC0H	Suburb0Q	Suburb0H
82.000	27.634	33.374	1.640	36.900	FFC0Q	FFC0H	Suburb0Q	Suburb0H
51.177	17.247	20.829	1.024	23.030	FFC0Q	FFC0H	Suburb0Q	Suburb0H
52.342	17.639	21.303	1.047	23.554	FFC0Q	FFC0H	Suburb0Q	Suburb0H
41.682	14.047	16.965	0.834	18.757	FFC0Q	FFC0H	Suburb0Q	Suburb0H
45.631	15.378	18.572	0.913	20.534	FFC0Q	FFC0H	Suburb0Q	Suburb0H
96.154	32.404	39.135	1.923	43.269	FFC0Q	FFC0H	Suburb0Q	Suburb0H
98.679	33.255	40.162	1.974	44.405	FFC0Q	FFC0H	Suburb0Q	Suburb0H
75.051	25.292	30.546	1.501	33.773	FFC0Q	FFC0H	Suburb0Q	Suburb0H
82.750	27.887	33.679	1.655	37.238	FFC0Q	FFC0H	Suburb0Q	Suburb0H
56.167	18.928	22.860	1.123	25.275	FFC0Q	FFC0H	Suburb0Q	Suburb0H
80.958	27.283	32.950	1.619	36.431	FFC0Q	FFC0H	Suburb0Q	Suburb0H
20.302	6.842	8.263	0.406	9.136	FFC0Q	FFC0H	Suburb0Q	Suburb0H
60.243	20.302	24.519	1.205	27.109	FFC0Q	FFC0H	Suburb0Q	Suburb0H
66.657	22.464	27.130	1.333	29.996	FFC0Q	FFC0H	Suburb0Q	Suburb0H
60.443	20.369	24.600	1.209	27.199	FFC0Q	FFC0H	Suburb0Q	Suburb0H
37.719	12.711	15.352	0.754	16.974	FFC0Q	FFC0H	Suburb0Q	Suburb0H
93.466	31.498	38.041	1.869	42.060	FFC0Q	FFC0H	Suburb0Q	Suburb0H
63.266	21.321	25.749	1.265	28.470	FFC0Q	FFC0H	Suburb0Q	Suburb0H
33.139	11.168	13.488	0.663	14.913	FFC0Q	FFC0H	Suburb0Q	Suburb0H
27.504	9.269	11.194	0.550	12.377	FFC0Q	FFC0H	Suburb0Q	Suburb0H
24.296	8.188	9.889	0.486	10.933	FFC0Q	FFC0H	Suburb0Q	Suburb0H
80.531	27.139	32.776	1.611	36.239	FFC0Q	FFC0H	Suburb0Q	Suburb0H
16.400	5.527	6.675	0.328	7.380	FFC0Q	FFC0H	Suburb0Q	Suburb0H
33.242	11.203	13.530	0.665	14.959	FFC0Q	FFC0H	Suburb0Q	Suburb0H
42.808	14.426	17.423	0.856	19.263	FFC0Q	FFC0H	Suburb0Q	Suburb0H
30.500	10.279	12.414	0.610	13.725	FFC0Q	FFC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
67.027	22.588	27.280	1.341	30.162	FFC0Q	FFC0H	Suburb0Q	Suburb0H
51.355	17.307	20.901	1.027	23.110	FFC0Q	FFC0H	Suburb0Q	Suburb0H
43.000	14.491	17.501	0.860	19.350	FFC0Q	FFC0H	Suburb0Q	Suburb0H
71.089	23.957	28.933	1.422	31.990	FFC0Q	FFC0H	Suburb0Q	Suburb0H
40.907	13.786	16.649	0.818	18.408	FFC0Q	FFC0H	Suburb0Q	Suburb0H
33.953	11.442	13.819	0.679	15.279	FFC0Q	FFC0H	Suburb0Q	Suburb0H
46.200	15.569	18.803	0.924	20.790	FFC0Q	FFC0H	Suburb0Q	Suburb0H
72.400	24.399	29.467	1.448	32.580	FFC0Q	FFC0H	Suburb0Q	Suburb0H
45.441	15.314	18.495	0.909	20.449	FFC0Q	FFC0H	Suburb0Q	Suburb0H
45.432	15.311	18.491	0.909	20.444	FFC0Q	FFC0H	Suburb0Q	Suburb0H
34.128	11.501	13.890	0.683	15.358	FFC0Q	FFC0H	Suburb0Q	Suburb0H
50.500	17.019	20.554	1.010	22.725	FFC0Q	FFC0H	Suburb0Q	Suburb0H
16.200	5.459	6.593	0.324	7.290	FFC0Q	FFC0H	Suburb0Q	Suburb0H
76.136	25.658	30.987	1.523	34.261	FFC0Q	FFC0H	Suburb0Q	Suburb0H
50.694	17.084	20.632	1.014	22.812	FFC0Q	FFC0H	Suburb0Q	Suburb0H
95.700	32.251	38.950	1.914	43.065	FFC0Q	FFC0H	Suburb0Q	Suburb0H
90.342	30.445	36.769	1.807	40.654	FFC0Q	FFC0H	Suburb0Q	Suburb0H
71.104	23.962	28.939	1.422	31.997	FFC0Q	FFC0H	Suburb0Q	Suburb0H
54.665	18.422	22.249	1.093	24.599	FFC0Q	FFC0H	Suburb0Q	Suburb0H
88.300	29.757	35.938	1.766	39.735	FFC0Q	FFC0H	Suburb0Q	Suburb0H
23.435	7.898	9.538	0.469	10.546	FFC0Q	FFC0H	Suburb0Q	Suburb0H
34.168	11.515	13.907	0.683	15.376	FFC0Q	FFC0H	Suburb0Q	Suburb0H
55.865	18.827	22.737	1.117	25.139	FFC0Q	FFC0H	Suburb0Q	Suburb0H
71.771	24.187	29.211	1.435	32.297	FFC0Q	FFC0H	Suburb0Q	Suburb0H
18.850	6.352	7.672	0.377	8.483	FFC0Q	FFC0H	Suburb0Q	Suburb0H
23.799	8.020	9.686	0.476	10.710	FFC0Q	FFC0H	Suburb0Q	Suburb0H
76.800	25.882	31.258	1.536	34.560	FFC0Q	FFC0H	Suburb0Q	Suburb0H
50.198	16.917	20.431	1.004	22.589	FFC0Q	FFC0H	Suburb0Q	Suburb0H
28.384	9.565	11.552	0.568	12.773	FFC0Q	FFC0H	Suburb0Q	Suburb0H
28.098	9.469	11.436	0.562	12.644	FFC0Q	FFC0H	Suburb0Q	Suburb0H
31.749	10.699	12.922	0.635	14.287	FFC0Q	FFC0H	Suburb0Q	Suburb0H
29.467	9.930	11.993	0.589	13.260	FFC0Q	FFC0H	Suburb0Q	Suburb0H
55.030	18.545	22.397	1.101	24.764	FFC0Q	FFC0H	Suburb0Q	Suburb0H
33.078	11.147	13.463	0.662	14.885	FFC0Q	FFC0H	Suburb0Q	Suburb0H
78.323	26.395	31.877	1.566	35.245	FFC0Q	FFC0H	Suburb0Q	Suburb0H
40.864	13.771	16.632	0.817	18.389	FFC0Q	FFC0H	Suburb0Q	Suburb0H
82.649	27.853	33.638	1.653	37.192	FFC0Q	FFC0H	Suburb0Q	Suburb0H
99.962	33.687	40.684	1.999	44.983	FFC0Q	FFC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
12.200	4.111	4.965	0.244	5.490	FFC0Q	FFC0H	Suburb0Q	Suburb0H
23.800	8.021	9.687	0.476	10.710	FFC0Q	FFC0H	Suburb0Q	Suburb0H
281.188	94.760	114.443	5.624	126.535	FqC0Q	FqC0H	Exurb	Exurb
150.059	50.570	61.074	3.001	67.527	FqC0Q	FqC0H	Exurb	Exurb
72.581	24.460	29.540	1.452	32.661	FqC0Q	FqC0H	Exurb	Exurb
187.700	63.255	76.394	3.754	84.465	FqC0Q	FqC0H	Exurb	Exurb
118.609	39.971	48.274	2.372	53.374	FqC0Q	FqC0H	Exurb	Exurb
44.738	15.077	18.209	0.895	20.132	FqC0Q	FqC0H	Exurb	Exurb
74.771	25.198	30.432	1.495	33.647	FqC0Q	FqC0H	Exurb	Exurb
64.544	21.751	26.269	1.291	29.045	FqC0Q	FqC0H	Exurb	Exurb
93.392	31.473	38.010	1.868	42.026	FqC0Q	FqC0H	Exurb	Exurb
113.190	38.145	46.068	2.264	50.935	FqC0Q	FqC0H	Exurb	Exurb
132.425	44.627	53.897	2.649	59.591	FqC0Q	FqC0H	Exurb	Exurb
59.445	20.033	24.194	1.189	26.750	HC0Q	HC0H	Suburb0Q	Suburb0H
41.437	13.964	16.865	0.829	18.647	HC0Q	HC0H	Suburb0Q	Suburb0H
48.458	16.330	19.723	0.969	21.806	HC0Q	HC0H	Suburb0Q	Suburb0H
61.904	20.862	25.195	1.238	27.857	HC0Q	HC0H	Suburb0Q	Suburb0H
51.401	17.322	20.920	1.028	23.130	HC0Q	HC0H	Suburb0Q	Suburb0H
70.576	23.784	28.725	1.412	31.759	HC0Q	HC0H	Suburb0Q	Suburb0H
79.755	26.877	32.460	1.595	35.890	HC0Q	HC0H	Suburb0Q	Suburb0H
51.306	17.290	20.881	1.026	23.088	HC0Q	HC0H	Suburb0Q	Suburb0H
78.560	26.475	31.974	1.571	35.352	HC0Q	HC0H	Suburb0Q	Suburb0H
67.205	22.648	27.353	1.344	30.242	HC0Q	HC0H	Suburb0Q	Suburb0H
36.044	12.147	14.670	0.721	16.220	HC0Q	HC0H	Suburb0Q	Suburb0H
83.814	28.245	34.112	1.676	37.716	HC0Q	HC0H	Suburb0Q	Suburb0H
54.230	18.275	22.072	1.085	24.403	HC0Q	HC0H	Suburb0Q	Suburb0H
47.852	16.126	19.476	0.957	21.533	HC0Q	HC0H	Suburb0Q	Suburb0H
56.834	19.153	23.132	1.137	25.575	HC0Q	HC0H	Suburb0Q	Suburb0H
48.022	16.184	19.545	0.960	21.610	HC0Q	HC0H	Suburb0Q	Suburb0H
55.497	18.703	22.587	1.110	24.974	HC0Q	HC0H	Suburb0Q	Suburb0H
66.841	22.525	27.204	1.337	30.078	HC0Q	HC0H	Suburb0Q	Suburb0H
40.979	13.810	16.679	0.820	18.441	HC0Q	HC0H	Suburb0Q	Suburb0H
52.410	17.662	21.331	1.048	23.584	HC0Q	HC0H	Suburb0Q	Suburb0H
62.909	21.200	25.604	1.258	28.309	LC0Q	LC0H	Loudoun	Loudoun
7.400	2.494	3.012	0.148	3.330	LC0Q	LC0H	Loudoun	Loudoun
44.185	14.890	17.983	0.884	19.883	LC0Q	LC0H	Loudoun	Loudoun
25.470	8.583	10.366	0.509	11.462	LC0Q	LC0H	Loudoun	Loudoun
84.881	28.605	34.547	1.698	38.196	LC0Q	LC0H	Loudoun	Loudoun

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
28.683	9.666	11.674	0.574	12.907	LC0Q	LC0H	Loudoun	Loudoun
36.817	12.407	14.984	0.736	16.568	LC0Q	LC0H	Loudoun	Loudoun
24.645	8.305	10.030	0.493	11.090	LC0Q	LC0H	Loudoun	Loudoun
49.000	16.513	19.943	0.980	22.050	LC0Q	LC0H	Loudoun	Loudoun
52.357	17.644	21.309	1.047	23.561	LC0Q	LC0H	Loudoun	Loudoun
46.241	15.583	18.820	0.925	20.808	LC0Q	LC0H	Loudoun	Loudoun
60.631	20.433	24.677	1.213	27.284	LC0Q	LC0H	Loudoun	Loudoun
36.236	12.212	14.748	0.725	16.306	LC0Q	LC0H	Loudoun	Loudoun
20.200	6.807	8.221	0.404	9.090	LC0Q	LC0H	Loudoun	Loudoun
59.665	20.107	24.284	1.193	26.849	LC0Q	LC0H	Loudoun	Loudoun
75.776	25.536	30.841	1.516	34.099	LC0Q	LC0H	Loudoun	Loudoun
113.543	38.264	46.212	2.271	51.094	LC0Q	LC0H	Loudoun	Loudoun
25.600	8.627	10.419	0.512	11.520	LC0Q	LC0H	Loudoun	Loudoun
65.167	21.961	26.523	1.303	29.325	LC0Q	LC0H	Loudoun	Loudoun
52.497	17.691	21.366	1.050	23.623	LC0Q	LC0H	Loudoun	Loudoun
155.800	52.505	63.411	3.116	70.110	LC0Q	LC0H	Loudoun	Loudoun
60.914	20.528	24.792	1.218	27.411	LC0Q	LC0H	Loudoun	Loudoun
71.016	23.932	28.903	1.420	31.957	LC0Q	LC0H	Loudoun	Loudoun
72.500	24.433	29.508	1.450	32.625	LC0Q	LC0H	Loudoun	Loudoun
52.931	17.838	21.543	1.059	23.819	LC0Q	LC0H	Loudoun	Loudoun
116.361	39.214	47.359	2.327	52.363	LC0Q	LC0H	Loudoun	Loudoun
92.949	31.324	37.830	1.859	41.827	LC0Q	LC0H	Loudoun	Loudoun
37.787	12.734	15.379	0.756	17.004	LC0Q	LC0H	Loudoun	Loudoun
40.900	13.783	16.646	0.818	18.405	LC0Q	LC0H	Loudoun	Loudoun
107.519	36.234	43.760	2.150	48.383	LC0Q	LC0H	Loudoun	Loudoun
213.400	71.916	86.854	4.268	96.030	LC0Q	LC0H	Loudoun	Loudoun
66.783	22.506	27.181	1.336	30.052	LC0Q	LC0H	Loudoun	Loudoun
184.401	62.143	75.051	3.688	82.980	LC0Q	LC0H	Loudoun	Loudoun
157.400	53.044	64.062	3.148	70.830	LC0Q	LC0H	Loudoun	Loudoun
70.315	23.696	28.618	1.406	31.642	LC0Q	LC0H	Loudoun	Loudoun
87.606	29.523	35.656	1.752	39.423	LC0Q	LC0H	Loudoun	Loudoun
59.163	19.938	24.079	1.183	26.624	LC0Q	LC0H	Loudoun	Loudoun
55.072	18.559	22.414	1.101	24.782	LC0Q	LC0H	Loudoun	Loudoun
63.653	21.451	25.907	1.273	28.644	LC0Q	LC0H	Loudoun	Loudoun
38.400	12.941	15.629	0.768	17.280	LC0Q	LC0H	Loudoun	Loudoun
39.086	13.172	15.908	0.782	17.589	LC0Q	LC0H	Loudoun	Loudoun
85.692	28.878	34.877	1.714	38.561	LC0Q	LC0H	Loudoun	Loudoun
98.214	33.098	39.973	1.964	44.196	LC0Q	LC0H	Loudoun	Loudoun

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
90.400	30.465	36.793	1.808	40.680	LC0Q	LC0H	Loudoun	Loudoun
76.800	25.882	31.258	1.536	34.560	LC0Q	LC0H	Loudoun	Loudoun
96.148	32.402	39.132	1.923	43.267	LC0Q	LC0H	Loudoun	Loudoun
53.300	17.962	21.693	1.066	23.985	LC0Q	LC0H	Loudoun	Loudoun
68.288	23.013	27.793	1.366	30.730	LC0Q	LC0H	Loudoun	Loudoun
35.438	11.943	14.423	0.709	15.947	LC0Q	LC0H	Loudoun	Loudoun
22.400	7.549	9.117	0.448	10.080	LC0Q	LC0H	Loudoun	Loudoun
144.486	48.692	58.806	2.890	65.019	LC0Q	LC0H	Loudoun	Loudoun
148.000	49.876	60.236	2.960	66.600	LC0Q	LC0H	Loudoun	Loudoun
204.737	68.996	83.328	4.095	92.132	LC0Q	LC0H	Loudoun	Loudoun
118.873	40.060	48.381	2.377	53.493	LC0Q	LC0H	Loudoun	Loudoun
103.928	35.024	42.299	2.079	46.768	LC0Q	LC0H	Loudoun	Loudoun
76.400	25.747	31.095	1.528	34.380	LC0Q	LC0H	Loudoun	Loudoun
173.800	58.571	70.737	3.476	78.210	LC0Q	LC0H	Loudoun	Loudoun
41.000	13.817	16.687	0.820	18.450	LC0Q	LC0H	Loudoun	Loudoun
156.400	52.707	63.655	3.128	70.380	LC0Q	LC0H	Loudoun	Loudoun
128.650	43.355	52.361	2.573	57.893	LC0Q	LC0H	Loudoun	Loudoun
42.441	14.303	17.274	0.849	19.098	LC0Q	LC0H	Loudoun	Loudoun
135.300	45.596	55.067	2.706	60.885	LC0Q	LC0H	Loudoun	Loudoun
18.536	6.246	7.544	0.371	8.341	LC0Q	LC0H	Loudoun	Loudoun
70.304	23.692	28.614	1.406	31.637	LC0Q	LC0H	Loudoun	Loudoun
87.736	29.567	35.709	1.755	39.481	LC0Q	LC0H	Loudoun	Loudoun
24.800	8.358	10.094	0.496	11.160	LC0Q	LC0H	Loudoun	Loudoun
220.700	74.376	89.825	4.414	99.315	LC0Q	LC0H	Loudoun	Loudoun
56.600	19.074	23.036	1.132	25.470	LC0Q	LC0H	Loudoun	Loudoun
61.700	20.793	25.112	1.234	27.765	LC0Q	LC0H	Loudoun	Loudoun
132.100	44.518	53.765	2.642	59.445	LC0Q	LC0H	Loudoun	Loudoun
91.761	30.923	37.347	1.835	41.292	LC0Q	LC0H	Loudoun	Loudoun
38.800	13.076	15.792	0.776	17.460	LC0Q	LC0H	Loudoun	Loudoun
46.208	15.572	18.807	0.924	20.794	LC0Q	LC0H	Loudoun	Loudoun
66.855	22.530	27.210	1.337	30.085	LC0Q	LC0H	Loudoun	Loudoun
84.800	28.578	34.514	1.696	38.160	LC0Q	LC0H	Loudoun	Loudoun
295.700	99.651	120.350	5.914	133.065	LC0Q	LC0H	Loudoun	Loudoun
39.715	13.384	16.164	0.794	17.872	MC0Q	MC0H	Suburb0Q	Suburb0H
35.112	11.833	14.291	0.702	15.801	MC0Q	MC0H	Suburb0Q	Suburb0H
89.398	30.127	36.385	1.788	40.229	MC0Q	MC0H	Suburb0Q	Suburb0H
18.317	6.173	7.455	0.366	8.243	MC0Q	MC0H	Suburb0Q	Suburb0H
31.017	10.453	12.624	0.620	13.958	MC0Q	MC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
30.397	10.244	12.372	0.608	13.679	MC0Q	MC1H	Suburb0Q	Suburb0H
29.073	9.798	11.833	0.581	13.083	MC0Q	MC0H	Suburb0Q	Suburb0H
33.600	11.323	13.675	0.672	15.120	MC0Q	MC0H	Suburb0Q	Suburb0H
79.642	26.839	32.414	1.593	35.839	MC0Q	MC0H	Suburb0Q	Suburb0H
14.284	4.814	5.814	0.286	6.428	MC0Q	MC1H	Suburb0Q	Suburb0H
53.895	18.163	21.935	1.078	24.253	MC1Q	MC1H	Suburb1Q	Suburb1H
21.648	7.295	8.811	0.433	9.742	MC1Q	MC1H	Suburb1Q	Suburb1H
38.481	12.968	15.662	0.770	17.316	MC1Q	MC1H	Suburb1Q	Suburb1H
54.023	18.206	21.987	1.080	24.310	MC0Q	MC1H	Suburb0Q	Suburb0H
36.582	12.328	14.889	0.732	16.462	MC0Q	MC0H	Suburb0Q	Suburb0H
18.448	6.217	7.508	0.369	8.302	MC0Q	MC0H	Suburb0Q	Suburb0H
35.126	11.838	14.296	0.703	15.807	MC0Q	MC0H	Suburb0Q	Suburb0H
43.745	14.742	17.804	0.875	19.685	MC0Q	MC0H	Suburb0Q	Suburb0H
28.444	9.586	11.577	0.569	12.800	MC0Q	MC0H	Suburb0Q	Suburb0H
19.499	6.571	7.936	0.390	8.774	MC0Q	MC0H	Suburb0Q	Suburb0H
28.515	9.610	11.606	0.570	12.832	MC0Q	MC1H	Suburb0Q	Suburb0H
27.679	9.328	11.265	0.554	12.455	MC0Q	MC1H	Suburb0Q	Suburb0H
29.235	9.852	11.899	0.585	13.156	MC0Q	MC0H	Suburb0Q	Suburb0H
28.245	9.519	11.496	0.565	12.710	MC0Q	MC1H	Suburb0Q	Suburb0H
28.206	9.505	11.480	0.564	12.693	MC1Q	MC1H	Suburb1Q	Suburb1H
26.807	9.034	10.910	0.536	12.063	MC1Q	MC1H	Suburb1Q	Suburb1H
26.797	9.030	10.906	0.536	12.058	MC1Q	MC1H	Suburb1Q	Suburb1H
8.400	2.831	3.419	0.168	3.780	MC1Q	MC1H	Suburb1Q	Suburb1H
39.953	13.464	16.261	0.799	17.979	MC0Q	MC1H	Suburb0Q	Suburb0H
13.049	4.398	5.311	0.261	5.872	MC0Q	MC1H	Suburb0Q	Suburb0H
32.356	10.904	13.169	0.647	14.560	MC0Q	MC0H	Suburb0Q	Suburb0H
38.165	12.862	15.533	0.763	17.174	MC1Q	MC1H	Suburb1Q	Suburb1H
28.707	9.674	11.684	0.574	12.918	MC0Q	MC0H	Suburb0Q	Suburb0H
18.897	6.368	7.691	0.378	8.504	MC0Q	MC0H	Suburb0Q	Suburb0H
15.667	5.280	6.377	0.313	7.050	MC0Q	MC1H	Suburb0Q	Suburb0H
30.006	10.112	12.212	0.600	13.503	MC0Q	MC0H	Suburb0Q	Suburb0H
56.863	19.163	23.143	1.137	25.588	MC1Q	MC1H	Suburb1Q	Suburb1H
50.497	17.017	20.552	1.010	22.724	MC1Q	MC1H	Suburb1Q	Suburb1H
56.856	19.161	23.141	1.137	25.585	MC0Q	MC1H	Suburb0Q	Suburb0H
45.358	15.286	18.461	0.907	20.411	MC0Q	MC1H	Suburb0Q	Suburb0H
25.629	8.637	10.431	0.513	11.533	MC1Q	MC1H	Suburb1Q	Suburb1H
23.942	8.068	9.744	0.479	10.774	MC1Q	MC1H	Suburb1Q	Suburb1H
24.200	8.155	9.849	0.484	10.890	MC1Q	MC1H	Suburb1Q	Suburb1H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
47.938	16.155	19.511	0.959	21.572	MC0Q	MC1H	Suburb0Q	Suburb0H
33.045	11.136	13.449	0.661	14.870	MC1Q	MC1H	Suburb1Q	Suburb1H
32.861	11.074	13.374	0.657	14.788	MC0Q	MC0H	Suburb0Q	Suburb0H
28.682	9.666	11.674	0.574	12.907	MC1Q	MC1H	Suburb1Q	Suburb1H
11.648	3.925	4.741	0.233	5.242	MC1Q	MC1H	Suburb1Q	Suburb1H
57.211	19.280	23.285	1.144	25.745	MC0Q	MC0H	Suburb0Q	Suburb0H
43.301	14.593	17.624	0.866	19.486	MC0Q	MC0H	Suburb0Q	Suburb0H
35.440	11.943	14.424	0.709	15.948	MC0Q	MC0H	Suburb0Q	Suburb0H
48.116	16.215	19.583	0.962	21.652	MC0Q	MC0H	Suburb0Q	Suburb0H
40.219	13.554	16.369	0.804	18.098	MC0Q	MC0H	Suburb0Q	Suburb0H
42.012	14.158	17.099	0.840	18.906	MC0Q	MC0H	Suburb0Q	Suburb0H
41.651	14.036	16.952	0.833	18.743	MC0Q	MC0H	Suburb0Q	Suburb0H
91.349	30.785	37.179	1.827	41.107	MC0Q	MC0H	Suburb0Q	Suburb0H
11.100	3.741	4.518	0.222	4.995	MC0Q	MC0H	Suburb0Q	Suburb0H
273.754	92.255	111.418	5.475	123.189	MC0Q	MC0H	Suburb0Q	Suburb0H
34.376	11.585	13.991	0.688	15.469	MC0Q	MC0H	Suburb0Q	Suburb0H
22.391	7.546	9.113	0.448	10.076	MC0Q	MC0H	Suburb0Q	Suburb0H
18.400	6.201	7.489	0.368	8.280	MC0Q	MC0H	Suburb0Q	Suburb0H
38.703	13.043	15.752	0.774	17.416	MC0Q	MC0H	Suburb0Q	Suburb0H
39.967	13.469	16.267	0.799	17.985	MC0Q	MC0H	Suburb0Q	Suburb0H
32.483	10.947	13.221	0.650	14.618	MC0Q	MC0H	Suburb0Q	Suburb0H
30.000	10.110	12.210	0.600	13.500	MC0Q	MC0H	Suburb0Q	Suburb0H
51.803	17.458	21.084	1.036	23.311	MC0Q	MC0H	Suburb0Q	Suburb0H
133.500	44.989	54.334	2.670	60.075	MC0Q	MC0H	Suburb0Q	Suburb0H
45.958	15.488	18.705	0.919	20.681	MC0Q	MC0H	Suburb0Q	Suburb0H
8.800	2.966	3.582	0.176	3.960	MC0Q	MC0H	Suburb0Q	Suburb0H
40.221	13.554	16.370	0.804	18.099	MC0Q	MC0H	Suburb0Q	Suburb0H
22.067	7.436	8.981	0.441	9.930	MC0Q	MC1H	Suburb0Q	Suburb0H
44.265	14.917	18.016	0.885	19.919	MC0Q	MC0H	Suburb0Q	Suburb0H
42.941	14.471	17.477	0.859	19.323	MC0Q	MC1H	Suburb0Q	Suburb0H
16.100	5.426	6.553	0.322	7.245	MC1Q	MC1H	Suburb1Q	Suburb1H
37.968	12.795	15.453	0.759	17.086	MC1Q	MC1H	Suburb1Q	Suburb1H
28.428	9.580	11.570	0.569	12.793	MC0Q	MC1H	Suburb0Q	Suburb0H
37.900	12.772	15.425	0.758	17.055	MC1Q	MC1H	Suburb1Q	Suburb1H
13.200	4.448	5.372	0.264	5.940	MC0Q	MC1H	Suburb0Q	Suburb0H
28.201	9.504	11.478	0.564	12.691	MC0Q	MC1H	Suburb0Q	Suburb0H
27.633	9.312	11.247	0.553	12.435	MC1Q	MC1H	Suburb1Q	Suburb1H
38.688	13.038	15.746	0.774	17.410	MC0Q	MC1H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
41.103	13.852	16.729	0.822	18.496	MC0Q	MC1H	Suburb0Q	Suburb0H
51.925	17.499	21.134	1.039	23.366	MC1Q	MC1H	Suburb1Q	Suburb1H
39.558	13.331	16.100	0.791	17.801	MC0Q	MC0H	Suburb0Q	Suburb0H
25.280	8.519	10.289	0.506	11.376	MC0Q	MC1H	Suburb0Q	Suburb0H
27.600	9.301	11.233	0.552	12.420	MC0Q	MC1H	Suburb0Q	Suburb0H
29.800	10.043	12.129	0.596	13.410	MC1Q	MC1H	Suburb1Q	Suburb1H
65.500	22.073	26.658	1.310	29.475	MC0Q	MC1H	Suburb0Q	Suburb0H
78.797	26.555	32.071	1.576	35.459	MC0Q	MC1H	Suburb0Q	Suburb0H
39.688	13.375	16.153	0.794	17.860	MC1Q	MC1H	Suburb1Q	Suburb1H
35.056	11.814	14.268	0.701	15.775	MC0Q	MC0H	Suburb0Q	Suburb0H
39.897	13.445	16.238	0.798	17.954	MC0Q	MC1H	Suburb0Q	Suburb0H
35.635	12.009	14.504	0.713	16.036	MC0Q	MC0H	Suburb0Q	Suburb0H
56.161	18.926	22.857	1.123	25.272	MC0Q	MC0H	Suburb0Q	Suburb0H
72.408	24.401	29.470	1.448	32.583	MC0Q	MC0H	Suburb0Q	Suburb0H
36.232	12.210	14.746	0.725	16.304	MC0Q	MC1H	Suburb0Q	Suburb0H
18.686	6.297	7.605	0.374	8.409	MC0Q	MC1H	Suburb0Q	Suburb0H
43.600	14.693	17.745	0.872	19.620	MC1Q	MC1H	Suburb1Q	Suburb1H
45.693	15.398	18.597	0.914	20.562	MC0Q	MC1H	Suburb0Q	Suburb0H
34.602	11.661	14.083	0.692	15.571	MC1Q	MC1H	Suburb1Q	Suburb1H
65.821	22.182	26.789	1.316	29.619	MC0Q	MC0H	Suburb0Q	Suburb0H
38.157	12.859	15.530	0.763	17.171	MC1Q	MC1H	Suburb1Q	Suburb1H
39.446	13.293	16.055	0.789	17.751	MC0Q	MC1H	Suburb0Q	Suburb0H
27.766	9.357	11.301	0.555	12.495	MC1Q	MC1H	Suburb1Q	Suburb1H
30.537	10.291	12.428	0.611	13.742	MC0Q	MC0H	Suburb0Q	Suburb0H
17.426	5.872	7.092	0.349	7.842	MC0Q	MC0H	Suburb0Q	Suburb0H
33.385	11.251	13.588	0.668	15.023	MC0Q	MC0H	Suburb0Q	Suburb0H
22.672	7.641	9.228	0.453	10.203	MC0Q	MC0H	Suburb0Q	Suburb0H
32.400	10.919	13.187	0.648	14.580	MC0Q	MC0H	Suburb0Q	Suburb0H
21.255	7.163	8.651	0.425	9.565	MC0Q	MC1H	Suburb0Q	Suburb0H
18.638	6.281	7.585	0.373	8.387	MC1Q	MC1H	Suburb1Q	Suburb1H
59.433	20.029	24.189	1.189	26.745	MC0Q	MC1H	Suburb0Q	Suburb0H
30.099	10.144	12.250	0.602	13.545	MC0Q	MC1H	Suburb0Q	Suburb0H
27.850	9.385	11.335	0.557	12.533	MC0Q	MC1H	Suburb0Q	Suburb0H
41.803	14.088	17.014	0.836	18.811	MC1Q	MC1H	Suburb1Q	Suburb1H
27.300	9.200	11.111	0.546	12.285	MC0Q	MC0H	Suburb0Q	Suburb0H
21.818	7.353	8.880	0.436	9.818	MC1Q	MC1H	Suburb1Q	Suburb1H
27.865	9.391	11.341	0.557	12.539	MC0Q	MC0H	Suburb0Q	Suburb0H
30.887	10.409	12.571	0.618	13.899	MC0Q	MC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
16.072	5.416	6.541	0.321	7.233	MC0Q	MC0H	Suburb0Q	Suburb0H
16.067	5.414	6.539	0.321	7.230	MC0Q	MC0H	Suburb0Q	Suburb0H
33.777	11.383	13.747	0.676	15.199	MC0Q	MC0H	Suburb0Q	Suburb0H
58.099	19.579	23.646	1.162	26.145	MC0Q	MC0H	Suburb0Q	Suburb0H
35.100	11.829	14.286	0.702	15.795	MC0Q	MC0H	Suburb0Q	Suburb0H
61.448	20.708	25.009	1.229	27.651	MC0Q	MC0H	Suburb0Q	Suburb0H
102.193	34.439	41.592	2.044	45.987	MC0Q	MC0H	Suburb0Q	Suburb0H
42.328	14.264	17.227	0.847	19.048	MC0Q	MC0H	Suburb0Q	Suburb0H
35.492	11.961	14.445	0.710	15.971	MC0Q	MC0H	Suburb0Q	Suburb0H
73.514	24.774	29.920	1.470	33.081	MC0Q	MC0H	Suburb0Q	Suburb0H
100.500	33.868	40.903	2.010	45.225	MC0Q	MC0H	Suburb0Q	Suburb0H
23.828	8.030	9.698	0.477	10.723	MC0Q	MC0H	Suburb0Q	Suburb0H
17.508	5.900	7.126	0.350	7.879	MC0Q	MC0H	Suburb0Q	Suburb0H
60.759	20.476	24.729	1.215	27.342	MC0Q	MC0H	Suburb0Q	Suburb0H
87.700	29.555	35.694	1.754	39.465	MC0Q	MC0H	Suburb0Q	Suburb0H
46.639	15.717	18.982	0.933	20.988	MC0Q	MC0H	Suburb0Q	Suburb0H
46.000	15.502	18.722	0.920	20.700	MC0Q	MC0H	Suburb0Q	Suburb0H
4.800	1.618	1.954	0.096	2.160	MC0Q	MC0H	Suburb0Q	Suburb0H
50.661	17.073	20.619	1.013	22.797	MC0Q	MC0H	Suburb0Q	Suburb0H
45.041	15.179	18.332	0.901	20.269	MC0Q	MC0H	Suburb0Q	Suburb0H
41.750	14.070	16.992	0.835	18.788	MC0Q	MC0H	Suburb0Q	Suburb0H
69.983	23.584	28.483	1.400	31.492	MC0Q	MC0H	Suburb0Q	Suburb0H
88.418	29.797	35.986	1.768	39.788	MC0Q	MC0H	Suburb0Q	Suburb0H
48.516	16.350	19.746	0.970	21.832	MC0Q	MC1H	Suburb0Q	Suburb0H
7.700	2.595	3.134	0.154	3.465	MC0Q	MC0H	Suburb0Q	Suburb0H
46.156	15.555	18.785	0.923	20.770	MC0Q	MC0H	Suburb0Q	Suburb0H
36.197	12.198	14.732	0.724	16.289	MC0Q	MC1H	Suburb0Q	Suburb0H
37.077	12.495	15.090	0.742	16.684	MC0Q	MC0H	Suburb0Q	Suburb0H
9.338	3.147	3.801	0.187	4.202	MC1Q	MC1H	Suburb1Q	Suburb1H
9.550	3.218	3.887	0.191	4.297	MC1Q	MC1H	Suburb1Q	Suburb1H
55.156	18.588	22.449	1.103	24.820	MC0Q	MC1H	Suburb0Q	Suburb0H
57.900	19.512	23.565	1.158	26.055	MC1Q	MC1H	Suburb1Q	Suburb1H
68.791	23.183	27.998	1.376	30.956	MC0Q	MC1H	Suburb0Q	Suburb0H
68.769	23.175	27.989	1.375	30.946	MC0Q	MC0H	Suburb0Q	Suburb0H
45.216	15.238	18.403	0.904	20.347	MC0Q	MC1H	Suburb0Q	Suburb0H
43.841	14.775	17.843	0.877	19.729	MC0Q	MC1H	Suburb0Q	Suburb0H
40.019	13.487	16.288	0.800	18.009	MC0Q	MC0H	Suburb0Q	Suburb0H
43.254	14.577	17.604	0.865	19.464	MC0Q	MC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
22.810	7.687	9.284	0.456	10.265	MC0Q	MC0H	Suburb0Q	Suburb0H
54.182	18.259	22.052	1.084	24.382	MC0Q	MC0H	Suburb0Q	Suburb0H
35.000	11.795	14.245	0.700	15.750	MC0Q	MC0H	Suburb0Q	Suburb0H
61.220	20.631	24.916	1.224	27.549	MC0Q	MC0H	Suburb0Q	Suburb0H
24.448	8.239	9.950	0.489	11.002	MC0Q	MC0H	Suburb0Q	Suburb0H
44.738	15.077	18.208	0.895	20.132	MC0Q	MC0H	Suburb0Q	Suburb0H
38.986	13.138	15.867	0.780	17.544	MC0Q	MC0H	Suburb0Q	Suburb0H
62.291	20.992	25.353	1.246	28.031	MC0Q	MC0H	Suburb0Q	Suburb0H
66.196	22.308	26.942	1.324	29.788	MC0Q	MC0H	Suburb0Q	Suburb0H
90.383	30.459	36.786	1.808	40.672	MC0Q	MC0H	Suburb0Q	Suburb0H
43.410	14.629	17.668	0.868	19.535	MC0Q	MC0H	Suburb0Q	Suburb0H
111.700	37.643	45.462	2.234	50.265	MC0Q	MC0H	Suburb0Q	Suburb0H
56.591	19.071	23.032	1.132	25.466	MC0Q	MC0H	Suburb0Q	Suburb0H
76.923	25.923	31.308	1.538	34.615	MC0Q	MC0H	Suburb0Q	Suburb0H
56.400	19.007	22.955	1.128	25.380	MC0Q	MC0H	Suburb0Q	Suburb0H
47.000	15.839	19.129	0.940	21.150	MC0Q	MC0H	Suburb0Q	Suburb0H
57.900	19.512	23.565	1.158	26.055	MC0Q	MC0H	Suburb0Q	Suburb0H
79.362	26.745	32.300	1.587	35.713	MC0Q	MC0H	Suburb0Q	Suburb0H
65.453	22.058	26.639	1.309	29.454	MC0Q	MC0H	Suburb0Q	Suburb0H
74.182	24.999	30.192	1.484	33.382	MC0Q	MC0H	Suburb0Q	Suburb0H
58.547	19.730	23.829	1.171	26.346	MC0Q	MC0H	Suburb0Q	Suburb0H
4.000	1.348	1.628	0.080	1.800	MC0Q	MC0H	Suburb0Q	Suburb0H
22.600	7.616	9.198	0.452	10.170	MC0Q	MC0H	Suburb0Q	Suburb0H
87.932	29.633	35.788	1.759	39.569	MC0Q	MC0H	Suburb0Q	Suburb0H
43.400	14.626	17.664	0.868	19.530	MC0Q	MC0H	Suburb0Q	Suburb0H
23.700	7.987	9.646	0.474	10.665	MC0Q	MC0H	Suburb0Q	Suburb0H
7.554	2.546	3.075	0.151	3.399	MC0Q	MC0H	Suburb0Q	Suburb0H
35.342	11.910	14.384	0.707	15.904	MC0Q	MC0H	Suburb0Q	Suburb0H
42.802	14.424	17.420	0.856	19.261	MC0Q	MC0H	Suburb0Q	Suburb0H
41.560	14.006	16.915	0.831	18.702	MC0Q	MC0H	Suburb0Q	Suburb0H
38.442	12.955	15.646	0.769	17.299	MC0Q	MC0H	Suburb0Q	Suburb0H
38.527	12.983	15.680	0.771	17.337	MC0Q	MC0H	Suburb0Q	Suburb0H
65.294	22.004	26.575	1.306	29.382	MC0Q	MC0H	Suburb0Q	Suburb0H
56.981	19.203	23.191	1.140	25.642	MC0Q	MC0H	Suburb0Q	Suburb0H
27.878	9.395	11.346	0.558	12.545	MC0Q	MC0H	Suburb0Q	Suburb0H
38.370	12.931	15.617	0.767	17.267	MC0Q	MC0H	Suburb0Q	Suburb0H
43.119	14.531	17.549	0.862	19.404	MC0Q	MC0H	Suburb0Q	Suburb0H
31.733	10.694	12.915	0.635	14.280	MC0Q	MC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
25.382	8.554	10.330	0.508	11.422	MC0Q	MC0H	Suburb0Q	Suburb0H
19.856	6.692	8.081	0.397	8.935	MC0Q	MC0H	Suburb0Q	Suburb0H
39.511	13.315	16.081	0.790	17.780	MC0Q	MC0H	Suburb0Q	Suburb0H
51.290	17.285	20.875	1.026	23.080	MC0Q	MC0H	Suburb0Q	Suburb0H
67.545	22.763	27.491	1.351	30.395	MC0Q	MC0H	Suburb0Q	Suburb0H
47.895	16.141	19.493	0.958	21.553	MC0Q	MC0H	Suburb0Q	Suburb0H
13.877	4.677	5.648	0.278	6.245	MC0Q	MC0H	Suburb0Q	Suburb0H
42.200	14.221	17.175	0.844	18.990	MC0Q	MC0H	Suburb0Q	Suburb0H
42.081	14.181	17.127	0.842	18.936	MC0Q	MC0H	Suburb0Q	Suburb0H
31.964	10.772	13.010	0.639	14.384	MC0Q	MC0H	Suburb0Q	Suburb0H
38.504	12.976	15.671	0.770	17.327	MC0Q	MC0H	Suburb0Q	Suburb0H
58.279	19.640	23.720	1.166	26.225	MC0Q	MC0H	Suburb0Q	Suburb0H
74.352	25.057	30.261	1.487	33.458	MC0Q	MC0H	Suburb0Q	Suburb0H
27.248	9.182	11.090	0.545	12.261	MC0Q	MC0H	Suburb0Q	Suburb0H
58.233	19.624	23.701	1.165	26.205	MC0Q	MC0H	Suburb0Q	Suburb0H
6.800	2.292	2.768	0.136	3.060	MC0Q	MC0H	Suburb0Q	Suburb0H
3.182	1.072	1.295	0.064	1.432	MC0Q	MC0H	Suburb0Q	Suburb0H
88.970	29.983	36.211	1.779	40.036	MC0Q	MC0H	Suburb0Q	Suburb0H
64.215	21.640	26.136	1.284	28.897	MC0Q	MC0H	Suburb0Q	Suburb0H
35.400	11.930	14.408	0.708	15.930	MC0Q	MC0H	Suburb0Q	Suburb0H
52.206	17.593	21.248	1.044	23.493	MC0Q	MC0H	Suburb0Q	Suburb0H
56.771	19.132	23.106	1.135	25.547	MC0Q	MC0H	Suburb0Q	Suburb0H
62.348	21.011	25.376	1.247	28.057	MC0Q	MC0H	Suburb0Q	Suburb0H
62.572	21.087	25.467	1.251	28.158	MC0Q	MC0H	Suburb0Q	Suburb0H
50.800	17.120	20.676	1.016	22.860	MC0Q	MC0H	Suburb0Q	Suburb0H
89.495	30.160	36.424	1.790	40.273	MC0Q	MC0H	Suburb0Q	Suburb0H
58.318	19.653	23.736	1.166	26.243	MC0Q	MC0H	Suburb0Q	Suburb0H
29.840	10.056	12.145	0.597	13.428	MC0Q	MC0H	Suburb0Q	Suburb0H
80.598	27.162	32.803	1.612	36.269	MC0Q	MC0H	Suburb0Q	Suburb0H
51.674	17.414	21.031	1.033	23.253	MC0Q	MC0H	Suburb0Q	Suburb0H
66.259	22.329	26.968	1.325	29.817	MC0Q	MC0H	Suburb0Q	Suburb0H
61.558	20.745	25.054	1.231	27.701	MC0Q	MC0H	Suburb0Q	Suburb0H
53.200	17.928	21.652	1.064	23.940	MC0Q	MC0H	Suburb0Q	Suburb0H
9.200	3.100	3.744	0.184	4.140	MC0Q	MC0H	Suburb0Q	Suburb0H
29.200	9.840	11.884	0.584	13.140	MC0Q	MC0H	Suburb0Q	Suburb0H
59.500	20.051	24.216	1.190	26.775	MC0Q	MC0H	Suburb0Q	Suburb0H
60.767	20.478	24.732	1.215	27.345	MC0Q	MC0H	Suburb0Q	Suburb0H
296.036	99.764	120.487	5.921	133.216	MC0Q	MC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
326.000	109.862	132.682	6.520	146.700	MC0Q	MC0H	Suburb0Q	Suburb0H
69.200	23.320	28.164	1.384	31.140	MC0Q	MC0H	Suburb0Q	Suburb0H
66.390	22.373	27.021	1.328	29.875	MC0Q	MC0H	Suburb0Q	Suburb0H
155.300	52.336	63.207	3.106	69.885	MC0Q	MC0H	Suburb0Q	Suburb0H
89.104	30.028	36.265	1.782	40.097	MC0Q	MC0H	Suburb0Q	Suburb0H
57.890	19.509	23.561	1.158	26.051	MC0Q	MC0H	Suburb0Q	Suburb0H
57.467	19.366	23.389	1.149	25.860	MC0Q	MC0H	Suburb0Q	Suburb0H
80.501	27.129	32.764	1.610	36.226	MC0Q	MC0H	Suburb0Q	Suburb0H
54.107	18.234	22.022	1.082	24.348	MC0Q	MC0H	Suburb0Q	Suburb0H
70.104	23.625	28.532	1.402	31.547	MC0Q	MC0H	Suburb0Q	Suburb0H
77.980	26.279	31.738	1.560	35.091	MC0Q	MC0H	Suburb0Q	Suburb0H
50.993	17.185	20.754	1.020	22.947	MC0Q	MC0H	Suburb0Q	Suburb0H
34.267	11.548	13.947	0.685	15.420	MC0Q	MC0H	Suburb0Q	Suburb0H
143.612	48.397	58.450	2.872	64.625	OC0Q	OC0H	Other	Other
87.550	29.504	35.633	1.751	39.398	OC0Q	OC0H	Other	Other
128.483	43.299	52.293	2.570	57.817	OC0Q	OC0H	Other	Other
75.520	25.450	30.737	1.510	33.984	OC0Q	OC0H	Other	Other
52.173	17.582	21.234	1.043	23.478	OC0Q	OC0H	Other	Other
84.641	28.524	34.449	1.693	38.089	OC0Q	OC0H	Other	Other
102.634	34.588	41.772	2.053	46.185	OC0Q	OC0H	Other	Other
74.348	25.055	30.260	1.487	33.457	OC0Q	OC0H	Other	Other
149.605	50.417	60.889	2.992	67.322	OC0Q	OC0H	Other	Other
54.136	18.244	22.033	1.083	24.361	OC0Q	OC0H	Other	Other
98.479	33.187	40.081	1.970	44.316	OC0Q	OC0H	Other	Other
78.696	26.520	32.029	1.574	35.413	OC0Q	OC0H	Other	Other
61.833	20.838	25.166	1.237	27.825	OC0Q	OC0H	Other	Other
60.562	20.410	24.649	1.211	27.253	OC0Q	OC0H	Other	Other
73.890	24.901	30.073	1.478	33.250	OC0Q	OC0H	Other	Other
91.282	30.762	37.152	1.826	41.077	OC0Q	OC0H	Other	Other
61.487	20.721	25.025	1.230	27.669	OC0Q	OC0H	Other	Other
87.875	29.614	35.765	1.758	39.544	OC0Q	OC0H	Other	Other
88.218	29.729	35.905	1.764	39.698	OC0Q	OC0H	Other	Other
124.963	42.112	50.860	2.499	56.233	OC0Q	OC0H	Other	Other
55.923	18.846	22.761	1.118	25.165	OC0Q	OC0H	Other	Other
60.871	20.514	24.775	1.217	27.392	OC0Q	OC0H	Other	Other
136.318	45.939	55.482	2.726	61.343	OC0Q	OC0H	Other	Other
171.075	57.652	69.627	3.421	76.984	OC0Q	OC0H	Other	Other
185.142	62.393	75.353	3.703	83.314	OC0Q	OC0H	Other	Other

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
77.874	26.244	31.695	1.557	35.043	OC0Q	OC0H	Other	Other
138.133	46.551	56.220	2.763	62.160	OC0Q	OC0H	Other	Other
124.681	42.017	50.745	2.494	56.106	OC0Q	OC0H	Other	Other
147.156	49.592	59.893	2.943	66.220	OC0Q	OC0H	Other	Other
12.700	4.280	5.169	0.254	5.715	OC0Q	OC0H	Other	Other
59.173	19.941	24.084	1.183	26.628	OC0Q	OC0H	Other	Other
91.078	30.693	37.069	1.822	40.985	OC0Q	OC0H	Other	Other
175.907	59.281	71.594	3.518	79.158	OC0Q	OC0H	Other	Other
73.737	24.849	30.011	1.475	33.182	OC0Q	OC0H	Other	Other
55.034	18.546	22.399	1.101	24.765	OC0Q	OC0H	Other	Other
117.729	39.675	47.916	2.355	52.978	OC0Q	OC0H	Other	Other
114.898	38.721	46.764	2.298	51.704	OC0Q	OC0H	Other	Other
104.095	35.080	42.367	2.082	46.843	OC0Q	OC0H	Other	Other
81.464	27.453	33.156	1.629	36.659	OC0Q	OC0H	Other	Other
50.258	16.937	20.455	1.005	22.616	OC0Q	OC0H	Other	Other
50.669	17.076	20.622	1.013	22.801	OC0Q	OC0H	Other	Other
61.128	20.600	24.879	1.223	27.508	OC0Q	OC0H	Other	Other
112.654	37.965	45.850	2.253	50.694	OC0Q	OC0H	Other	Other
94.029	31.688	38.270	1.881	42.313	OC0Q	OC0H	Other	Other
83.716	28.212	34.073	1.674	37.672	OC0Q	OC0H	Other	Other
61.257	20.643	24.931	1.225	27.565	OC0Q	OC0H	Other	Other
58.909	19.852	23.976	1.178	26.509	OC0Q	OC0H	Other	Other
66.816	22.517	27.194	1.336	30.067	OC0Q	OC0H	Other	Other
53.955	18.183	21.960	1.079	24.280	OC0Q	OC0H	Other	Other
36.968	12.458	15.046	0.739	16.636	OC0Q	OC0H	Other	Other
68.886	23.215	28.037	1.378	30.999	OC0Q	OC0H	Other	Other
55.567	18.726	22.616	1.111	25.005	OC0Q	OC0H	Other	Other
155.611	52.441	63.334	3.112	70.025	OC0Q	OC0H	Other	Other
123.900	41.754	50.427	2.478	55.755	OC0Q	OC0H	Other	Other
105.089	35.415	42.771	2.102	47.290	OC0Q	OC0H	Other	Other
140.154	47.232	57.043	2.803	63.069	OC0Q	OC0H	Other	Other
116.388	39.223	47.370	2.328	52.374	OC0Q	OC0H	Other	Other
69.000	23.253	28.083	1.380	31.050	OC0Q	OC0H	Other	Other
172.042	57.978	70.021	3.441	77.419	OC0Q	OC0H	Other	Other
61.000	20.557	24.827	1.220	27.450	OC0Q	OC0H	Other	Other
116.545	39.276	47.434	2.331	52.445	OC0Q	OC0H	Other	Other
242.135	81.599	98.549	4.843	108.961	OC0Q	OC0H	Other	Other
52.782	17.787	21.482	1.056	23.752	OC0Q	OC0H	Other	Other

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
55.939	18.851	22.767	1.119	25.173	OC0Q	OC0H	Other	Other
103.971	35.038	42.316	2.079	46.787	OC0Q	OC0H	Other	Other
94.217	31.751	38.346	1.884	42.398	OC0Q	OC0H	Other	Other
113.379	38.209	46.145	2.268	51.020	OC0Q	OC0H	Other	Other
49.800	16.782	20.268	0.996	22.410	OC0Q	OC0H	Other	Other
59.458	20.037	24.199	1.189	26.756	OC0Q	OC0H	Other	Other
21.208	7.147	8.632	0.424	9.543	OC0Q	OC0H	Other	Other
57.007	19.211	23.202	1.140	25.653	OC0Q	OC0H	Other	Other
111.011	37.411	45.182	2.220	49.955	OC0Q	OC0H	Other	Other
80.804	27.231	32.887	1.616	36.362	OC0Q	OC0H	Other	Other
92.889	31.304	37.806	1.858	41.800	OC0Q	OC0H	Other	Other
89.326	30.103	36.356	1.787	40.197	OC0Q	OC0H	Other	Other
20.967	7.066	8.533	0.419	9.435	OC0Q	OC0H	Other	Other
106.422	35.864	43.314	2.128	47.890	OC0Q	OC0H	Other	Other
127.919	43.109	52.063	2.558	57.563	OC0Q	OC0H	Other	Other
47.231	15.917	19.223	0.945	21.254	OC0Q	OC0H	Other	Other
220.000	74.140	89.540	4.400	99.000	OC0Q	OC0H	Other	Other
81.997	27.633	33.373	1.640	36.899	OC0Q	OC0H	Other	Other
102.478	34.535	41.708	2.050	46.115	OC0Q	OC0H	Other	Other
75.431	25.420	30.700	1.509	33.944	OC0Q	OC0H	Other	Other
78.938	26.602	32.128	1.579	35.522	OC0Q	OC0H	Other	Other
87.468	29.477	35.600	1.749	39.361	OC0Q	OC0H	Other	Other
66.800	22.512	27.188	1.336	30.060	OC0Q	OC0H	Other	Other
101.215	34.109	41.194	2.024	45.547	OC0Q	OC0H	Other	Other
39.197	13.209	15.953	0.784	17.639	OC0Q	OC0H	Other	Other
42.747	14.406	17.398	0.855	19.236	OC0Q	OC0H	Other	Other
44.535	15.008	18.126	0.891	20.041	OC0Q	OC0H	Other	Other
84.231	28.386	34.282	1.685	37.904	OC0Q	OC0H	Other	Other
75.722	25.518	30.819	1.514	34.075	OC0Q	OC0H	Other	Other
72.507	24.435	29.510	1.450	32.628	OC0Q	OC0H	Other	Other
40.452	13.632	16.464	0.809	18.203	OC0Q	OC0H	Other	Other
62.003	20.895	25.235	1.240	27.901	OC0Q	OC0H	Other	Other
78.013	26.290	31.751	1.560	35.106	OC0Q	OC0H	Other	Other
72.438	24.412	29.482	1.449	32.597	PGC0Q	PGC0H	Suburb0Q	Suburb0H
37.044	12.484	15.077	0.741	16.670	PGC0Q	PGC0H	Suburb0Q	Suburb0H
85.110	28.682	34.640	1.702	38.299	PGC0Q	PGC0H	Suburb0Q	Suburb0H
37.373	12.595	15.211	0.747	16.818	PGC0Q	PGC0H	Suburb0Q	Suburb0H
55.500	18.703	22.588	1.110	24.975	PGC0Q	PGC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
158.800	53.516	64.632	3.176	71.460	PGC0Q	PGC0H	Suburb0Q	Suburb0H
13.104	4.416	5.333	0.262	5.897	PGC0Q	PGC0H	Suburb0Q	Suburb0H
13.600	4.583	5.535	0.272	6.120	PGC0Q	PGC0H	Suburb0Q	Suburb0H
16.831	5.672	6.850	0.337	7.574	PGC0Q	PGC0H	Suburb0Q	Suburb0H
29.189	9.837	11.880	0.584	13.135	PGC0Q	PGC0H	Suburb0Q	Suburb0H
37.948	12.788	15.445	0.759	17.077	PGC0Q	PGC0H	Suburb0Q	Suburb0H
15.042	5.069	6.122	0.301	6.769	PGC0Q	PGC1H	Suburb0Q	Suburb0H
15.700	5.291	6.390	0.314	7.065	PGC0Q	PGC1H	Suburb0Q	Suburb0H
36.498	12.300	14.855	0.730	16.424	PGC0Q	PGC0H	Suburb0Q	Suburb0H
16.314	5.498	6.640	0.326	7.341	PGC0Q	PGC0H	Suburb0Q	Suburb0H
29.506	9.944	12.009	0.590	13.278	PGC0Q	PGC0H	Suburb0Q	Suburb0H
41.071	13.841	16.716	0.821	18.482	PGC0Q	PGC0H	Suburb0Q	Suburb0H
6.291	2.120	2.560	0.126	2.831	PGC0Q	PGC1H	Suburb0Q	Suburb0H
7.200	2.426	2.930	0.144	3.240	PGC1Q	PGC1H	Suburb1Q	Suburb1H
32.077	10.810	13.055	0.642	14.434	PGC0Q	PGC1H	Suburb0Q	Suburb0H
21.558	7.265	8.774	0.431	9.701	PGC0Q	PGC0H	Suburb0Q	Suburb0H
30.713	10.350	12.500	0.614	13.821	PGC0Q	PGC0H	Suburb0Q	Suburb0H
20.816	7.015	8.472	0.416	9.367	PGC0Q	PGC0H	Suburb0Q	Suburb0H
56.913	19.180	23.164	1.138	25.611	PGC0Q	PGC0H	Suburb0Q	Suburb0H
18.433	6.212	7.502	0.369	8.295	PGC0Q	PGC1H	Suburb0Q	Suburb0H
26.006	8.764	10.584	0.520	11.703	PGC1Q	PGC1H	Suburb1Q	Suburb1H
11.708	3.946	4.765	0.234	5.269	PGC1Q	PGC1H	Suburb1Q	Suburb1H
83.101	28.005	33.822	1.662	37.396	PGC0Q	PGC0H	Suburb0Q	Suburb0H
35.043	11.810	14.263	0.701	15.770	PGC0Q	PGC0H	Suburb0Q	Suburb0H
69.400	23.388	28.246	1.388	31.230	PGC0Q	PGC1H	Suburb0Q	Suburb0H
102.975	34.703	41.911	2.060	46.339	PGC1Q	PGC1H	Suburb1Q	Suburb1H
25.025	8.433	10.185	0.500	11.261	PGC1Q	PGC1H	Suburb1Q	Suburb1H
48.465	16.333	19.725	0.969	21.809	PGC0Q	PGC0H	Suburb0Q	Suburb0H
43.129	14.534	17.553	0.863	19.408	PGC0Q	PGC0H	Suburb0Q	Suburb0H
43.490	14.656	17.700	0.870	19.570	PGC0Q	PGC0H	Suburb0Q	Suburb0H
37.099	12.502	15.099	0.742	16.694	PGC0Q	PGC0H	Suburb0Q	Suburb0H
52.063	17.545	21.189	1.041	23.428	PGC1Q	PGC1H	Suburb1Q	Suburb1H
32.638	10.999	13.284	0.653	14.687	PGC0Q	PGC1H	Suburb0Q	Suburb0H
12.498	4.212	5.087	0.250	5.624	PGC0Q	PGC1H	Suburb0Q	Suburb0H
43.746	14.742	17.805	0.875	19.686	PGC0Q	PGC0H	Suburb0Q	Suburb0H
11.800	3.977	4.803	0.236	5.310	PGC0Q	PGC0H	Suburb0Q	Suburb0H
67.605	22.783	27.515	1.352	30.422	PGC0Q	PGC0H	Suburb0Q	Suburb0H
3.200	1.078	1.302	0.064	1.440	PGC0Q	PGC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
22.547	7.598	9.177	0.451	10.146	PGC0Q	PGC0H	Suburb0Q	Suburb0H
30.999	10.447	12.617	0.620	13.950	PGC0Q	PGC0H	Suburb0Q	Suburb0H
49.914	16.821	20.315	0.998	22.461	PGC0Q	PGC0H	Suburb0Q	Suburb0H
14.750	4.971	6.003	0.295	6.638	PGC1Q	PGC1H	Suburb1Q	Suburb1H
61.884	20.855	25.187	1.238	27.848	PGC0Q	PGC0H	Suburb0Q	Suburb0H
38.876	13.101	15.823	0.778	17.494	PGC0Q	PGC0H	Suburb0Q	Suburb0H
44.379	14.956	18.062	0.888	19.971	PGC0Q	PGC0H	Suburb0Q	Suburb0H
22.985	7.746	9.355	0.460	10.343	PGC0Q	PGC1H	Suburb0Q	Suburb0H
88.917	29.965	36.189	1.778	40.013	PGC0Q	PGC0H	Suburb0Q	Suburb0H
61.757	20.812	25.135	1.235	27.790	PGC0Q	PGC0H	Suburb0Q	Suburb0H
41.135	13.862	16.742	0.823	18.511	PGC1Q	PGC1H	Suburb1Q	Suburb1H
24.885	8.386	10.128	0.498	11.198	PGC0Q	PGC0H	Suburb0Q	Suburb0H
52.742	17.774	21.466	1.055	23.734	PGC1Q	PGC1H	Suburb1Q	Suburb1H
68.400	23.051	27.839	1.368	30.780	PGC1Q	PGC1H	Suburb1Q	Suburb1H
16.033	5.403	6.526	0.321	7.215	PGC1Q	PGC1H	Suburb1Q	Suburb1H
152.800	51.494	62.190	3.056	68.760	PGC0Q	PGC1H	Suburb0Q	Suburb0H
22.377	7.541	9.107	0.448	10.070	PGC0Q	PGC0H	Suburb0Q	Suburb0H
175.572	59.168	71.458	3.511	79.007	PGC0Q	PGC1H	Suburb0Q	Suburb0H
31.702	10.683	12.903	0.634	14.266	PGC0Q	PGC0H	Suburb0Q	Suburb0H
34.400	11.593	14.001	0.688	15.480	PGC1Q	PGC1H	Suburb1Q	Suburb1H
36.653	12.352	14.918	0.733	16.494	PGC1Q	PGC1H	Suburb1Q	Suburb1H
73.998	24.937	30.117	1.480	33.299	PGC0Q	PGC1H	Suburb0Q	Suburb0H
50.572	17.043	20.583	1.011	22.757	PGC1Q	PGC1H	Suburb1Q	Suburb1H
57.837	19.491	23.540	1.157	26.027	PGC0Q	PGC0H	Suburb0Q	Suburb0H
26.136	8.808	10.638	0.523	11.761	PGC0Q	PGC0H	Suburb0Q	Suburb0H
51.851	17.474	21.103	1.037	23.333	PGC0Q	PGC1H	Suburb0Q	Suburb0H
52.000	17.524	21.164	1.040	23.400	PGC1Q	PGC1H	Suburb1Q	Suburb1H
23.100	7.785	9.402	0.462	10.395	PGC0Q	PGC1H	Suburb0Q	Suburb0H
40.317	13.587	16.409	0.806	18.143	PGC0Q	PGC0H	Suburb0Q	Suburb0H
34.905	11.763	14.206	0.698	15.707	PGC0Q	PGC0H	Suburb0Q	Suburb0H
20.200	6.807	8.221	0.404	9.090	PGC0Q	PGC0H	Suburb0Q	Suburb0H
39.686	13.374	16.152	0.794	17.859	PGC0Q	PGC0H	Suburb0Q	Suburb0H
13.367	4.505	5.440	0.267	6.015	PGC0Q	PGC1H	Suburb0Q	Suburb0H
76.545	25.796	31.154	1.531	34.445	PGC0Q	PGC1H	Suburb0Q	Suburb0H
52.380	17.652	21.319	1.048	23.571	PGC0Q	PGC0H	Suburb0Q	Suburb0H
22.707	7.652	9.242	0.454	10.218	PGC1Q	PGC1H	Suburb1Q	Suburb1H
32.405	10.920	13.189	0.648	14.582	PGC0Q	PGC0H	Suburb0Q	Suburb0H
41.734	14.064	16.986	0.835	18.780	PGC0Q	PGC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
34.760	11.714	14.148	0.695	15.642	PGC0Q	PGC0H	Suburb0Q	Suburb0H
51.710	17.426	21.046	1.034	23.269	PGC0Q	PGC0H	Suburb0Q	Suburb0H
30.946	10.429	12.595	0.619	13.926	PGC0Q	PGC0H	Suburb0Q	Suburb0H
31.998	10.783	13.023	0.640	14.399	PGC0Q	PGC1H	Suburb0Q	Suburb0H
35.254	11.881	14.349	0.705	15.864	PGC0Q	PGC0H	Suburb0Q	Suburb0H
75.461	25.430	30.713	1.509	33.958	PGC1Q	PGC1H	Suburb1Q	Suburb1H
20.380	6.868	8.294	0.408	9.171	PGC0Q	PGC0H	Suburb0Q	Suburb0H
18.792	6.333	7.648	0.376	8.456	PGC0Q	PGC0H	Suburb0Q	Suburb0H
38.005	12.808	15.468	0.760	17.102	PGC0Q	PGC0H	Suburb0Q	Suburb0H
15.713	5.295	6.395	0.314	7.071	PGC1Q	PGC1H	Suburb1Q	Suburb1H
52.046	17.540	21.183	1.041	23.421	PGC1Q	PGC1H	Suburb1Q	Suburb1H
12.275	4.137	4.996	0.246	5.524	PGC0Q	PGC0H	Suburb0Q	Suburb0H
41.062	13.838	16.712	0.821	18.478	PGC1Q	PGC1H	Suburb1Q	Suburb1H
75.602	25.478	30.770	1.512	34.021	PGC1Q	PGC1H	Suburb1Q	Suburb1H
55.400	18.670	22.548	1.108	24.930	PGC1Q	PGC1H	Suburb1Q	Suburb1H
107.015	36.064	43.555	2.140	48.157	PGC0Q	PGC0H	Suburb0Q	Suburb0H
34.504	11.628	14.043	0.690	15.527	PGC0Q	PGC0H	Suburb0Q	Suburb0H
20.450	6.892	8.323	0.409	9.203	PGC0Q	PGC0H	Suburb0Q	Suburb0H
35.716	12.036	14.536	0.714	16.072	PGC0Q	PGC0H	Suburb0Q	Suburb0H
31.358	10.568	12.763	0.627	14.111	PGC0Q	PGC0H	Suburb0Q	Suburb0H
55.864	18.826	22.737	1.117	25.139	PGC0Q	PGC0H	Suburb0Q	Suburb0H
78.254	26.372	31.849	1.565	35.214	PGC0Q	PGC0H	Suburb0Q	Suburb0H
38.449	12.957	15.649	0.769	17.302	PGC0Q	PGC1H	Suburb0Q	Suburb0H
43.600	14.693	17.745	0.872	19.620	PGC1Q	PGC1H	Suburb1Q	Suburb1H
37.195	12.535	15.138	0.744	16.738	PGC1Q	PGC1H	Suburb1Q	Suburb1H
18.200	6.133	7.407	0.364	8.190	PGC0Q	PGC0H	Suburb0Q	Suburb0H
49.648	16.731	20.207	0.993	22.342	PGC0Q	PGC0H	Suburb0Q	Suburb0H
38.015	12.811	15.472	0.760	17.107	PGC0Q	PGC0H	Suburb0Q	Suburb0H
35.072	11.819	14.274	0.701	15.782	PGC0Q	PGC0H	Suburb0Q	Suburb0H
40.339	13.594	16.418	0.807	18.153	PGC0Q	PGC0H	Suburb0Q	Suburb0H
35.092	11.826	14.282	0.702	15.791	PGC0Q	PGC0H	Suburb0Q	Suburb0H
146.772	49.462	59.736	2.935	66.047	PGC0Q	PGC0H	Suburb0Q	Suburb0H
55.116	18.574	22.432	1.102	24.802	PGC0Q	PGC0H	Suburb0Q	Suburb0H
47.282	15.934	19.244	0.946	21.277	PGC0Q	PGC0H	Suburb0Q	Suburb0H
60.260	20.307	24.526	1.205	27.117	PGC0Q	PGC0H	Suburb0Q	Suburb0H
29.960	10.097	12.194	0.599	13.482	PGC0Q	PGC0H	Suburb0Q	Suburb0H
41.846	14.102	17.031	0.837	18.831	PGC0Q	PGC0H	Suburb0Q	Suburb0H
46.016	15.507	18.728	0.920	20.707	PGC0Q	PGC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

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VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
12.700	4.280	5.169	0.254	5.715	PGC0Q	PGC1H	Suburb0Q	Suburb0H
19.980	6.733	8.132	0.400	8.991	PGC0Q	PGC0H	Suburb0Q	Suburb0H
49.103	16.548	19.985	0.982	22.096	PGC0Q	PGC0H	Suburb0Q	Suburb0H
70.685	23.821	28.769	1.414	31.808	PGC0Q	PGC0H	Suburb0Q	Suburb0H
52.394	17.657	21.324	1.048	23.577	PGC0Q	PGC0H	Suburb0Q	Suburb0H
116.335	39.205	47.348	2.327	52.351	PGC0Q	PGC0H	Suburb0Q	Suburb0H
50.996	17.186	20.755	1.020	22.948	PGC0Q	PGC0H	Suburb0Q	Suburb0H
23.700	7.987	9.646	0.474	10.665	PGC0Q	PGC0H	Suburb0Q	Suburb0H
74.340	25.052	30.256	1.487	33.453	PGC0Q	PGC0H	Suburb0Q	Suburb0H
23.800	8.021	9.687	0.476	10.710	PGC0Q	PGC0H	Suburb0Q	Suburb0H
63.600	21.433	25.885	1.272	28.620	PGC0Q	PGC0H	Suburb0Q	Suburb0H
68.592	23.116	27.917	1.372	30.867	PGC0Q	PGC0H	Suburb0Q	Suburb0H
99.688	33.595	40.573	1.994	44.860	PGC0Q	PGC0H	Suburb0Q	Suburb0H
36.293	12.231	14.771	0.726	16.332	PGC0Q	PGC0H	Suburb0Q	Suburb0H
8.900	2.999	3.622	0.178	4.005	PGC0Q	PGC0H	Suburb0Q	Suburb0H
54.969	18.525	22.372	1.099	24.736	PGC0Q	PGC0H	Suburb0Q	Suburb0H
46.286	15.598	18.838	0.926	20.829	PGC0Q	PGC0H	Suburb0Q	Suburb0H
33.532	11.300	13.648	0.671	15.089	PGC1Q	PGC1H	Suburb1Q	Suburb1H
56.647	19.090	23.055	1.133	25.491	PGC0Q	PGC0H	Suburb0Q	Suburb0H
94.000	31.678	38.258	1.880	42.300	PGC0Q	PGC0H	Suburb0Q	Suburb0H
18.935	6.381	7.707	0.379	8.521	PGC0Q	PGC0H	Suburb0Q	Suburb0H
51.717	17.429	21.049	1.034	23.273	PGC0Q	PGC0H	Suburb0Q	Suburb0H
11.600	3.909	4.721	0.232	5.220	PGC0Q	PGC0H	Suburb0Q	Suburb0H
36.754	12.386	14.959	0.735	16.539	PGC0Q	PGC0H	Suburb0Q	Suburb0H
40.801	13.750	16.606	0.816	18.361	PGC0Q	PGC1H	Suburb0Q	Suburb0H
21.148	7.127	8.607	0.423	9.517	PGC0Q	PGC0H	Suburb0Q	Suburb0H
78.300	26.387	31.868	1.566	35.235	PGC0Q	PGC0H	Suburb0Q	Suburb0H
22.400	7.549	9.117	0.448	10.080	PGC0Q	PGC0H	Suburb0Q	Suburb0H
78.800	26.556	32.072	1.576	35.460	PGC0Q	PGC0H	Suburb0Q	Suburb0H
108.190	36.460	44.033	2.164	48.685	PGC0Q	PGC0H	Suburb0Q	Suburb0H
40.609	13.685	16.528	0.812	18.274	PGC0Q	PGC0H	Suburb0Q	Suburb0H
220.800	74.410	89.866	4.416	99.360	PGC0Q	PGC0H	Suburb0Q	Suburb0H
77.318	26.056	31.468	1.546	34.793	PGC0Q	PGC0H	Suburb0Q	Suburb0H
64.034	21.579	26.062	1.281	28.815	PGC0Q	PGC0H	Suburb0Q	Suburb0H
44.200	14.895	17.989	0.884	19.890	PGC0Q	PGC0H	Suburb0Q	Suburb0H
29.000	9.773	11.803	0.580	13.050	PGC0Q	PGC0H	Suburb0Q	Suburb0H
61.379	20.685	24.981	1.228	27.621	PGC0Q	PGC0H	Suburb0Q	Suburb0H
33.323	11.230	13.562	0.666	14.995	PGC0Q	PGC0H	Suburb0Q	Suburb0H

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Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
15.568	5.246	6.336	0.311	7.006	PGC0Q	PGC0H	Suburb0Q	Suburb0H
39.208	13.213	15.958	0.784	17.644	PGC0Q	PGC0H	Suburb0Q	Suburb0H
50.700	17.086	20.635	1.014	22.815	PGC0Q	PGC0H	Suburb0Q	Suburb0H
28.062	9.457	11.421	0.561	12.628	PGC0Q	PGC0H	Suburb0Q	Suburb0H
48.473	16.335	19.728	0.969	21.813	PGC0Q	PGC0H	Suburb0Q	Suburb0H
11.000	3.707	4.477	0.220	4.950	PGC0Q	PGC0H	Suburb0Q	Suburb0H
46.977	15.831	19.120	0.940	21.140	PGC0Q	PGC0H	Suburb0Q	Suburb0H
82.193	27.699	33.452	1.644	36.987	PGC0Q	PGC0H	Suburb0Q	Suburb0H
49.282	16.608	20.058	0.986	22.177	PGC0Q	PGC0H	Suburb0Q	Suburb0H
53.777	18.123	21.887	1.076	24.200	PGC0Q	PGC0H	Suburb0Q	Suburb0H
50.783	17.114	20.669	1.016	22.852	PGC0Q	PGC0H	Suburb0Q	Suburb0H
76.975	25.941	31.329	1.539	34.639	PGC0Q	PGC0H	Suburb0Q	Suburb0H
43.681	14.720	17.778	0.874	19.656	PGC0Q	PGC0H	Suburb0Q	Suburb0H
77.699	26.184	31.623	1.554	34.964	PGC0Q	PGC0H	Suburb0Q	Suburb0H
43.496	14.658	17.703	0.870	19.573	PGC0Q	PGC0H	Suburb0Q	Suburb0H
39.544	13.326	16.094	0.791	17.795	PGC0Q	PGC0H	Suburb0Q	Suburb0H
72.136	24.310	29.359	1.443	32.461	PGC0Q	PGC0H	Suburb0Q	Suburb0H
96.900	32.655	39.438	1.938	43.605	PGC0Q	PGC0H	Suburb0Q	Suburb0H
97.677	32.917	39.755	1.954	43.955	PGC0Q	PGC0H	Suburb0Q	Suburb0H
39.900	13.446	16.239	0.798	17.955	PGC0Q	PGC0H	Suburb0Q	Suburb0H
52.786	17.789	21.484	1.056	23.754	PGC0Q	PGC0H	Suburb0Q	Suburb0H
51.786	17.452	21.077	1.036	23.304	PGC0Q	PGC0H	Suburb0Q	Suburb0H
22.607	7.619	9.201	0.452	10.173	PGC0Q	PGC0H	Suburb0Q	Suburb0H
55.300	18.636	22.507	1.106	24.885	PGC0Q	PGC0H	Suburb0Q	Suburb0H
25.000	8.425	10.175	0.500	11.250	PGC0Q	PGC0H	Suburb0Q	Suburb0H
97.415	32.829	39.648	1.948	43.837	PGC0Q	PGC0H	Suburb0Q	Suburb0H
53.489	18.026	21.770	1.070	24.070	PGC0Q	PGC0H	Suburb0Q	Suburb0H
34.616	11.666	14.089	0.692	15.577	PGC0Q	PGC0H	Suburb0Q	Suburb0H
66.217	22.315	26.950	1.324	29.797	PGC0Q	PGC0H	Suburb0Q	Suburb0H
37.237	12.549	15.155	0.745	16.756	PGC0Q	PGC0H	Suburb0Q	Suburb0H
55.765	18.793	22.696	1.115	25.094	PGC0Q	PGC0H	Suburb0Q	Suburb0H
60.651	20.439	24.685	1.213	27.293	PGC0Q	PGC0H	Suburb0Q	Suburb0H
58.294	19.645	23.726	1.166	26.232	PGC0Q	PGC0H	Suburb0Q	Suburb0H
55.462	18.691	22.573	1.109	24.958	PGC0Q	PGC0H	Suburb0Q	Suburb0H
38.091	12.837	15.503	0.762	17.141	PGC0Q	PGC0H	Suburb0Q	Suburb0H
48.791	16.442	19.858	0.976	21.956	PGC0Q	PGC0H	Suburb0Q	Suburb0H
24.200	8.155	9.849	0.484	10.890	PGC0Q	PGC0H	Suburb0Q	Suburb0H
60.318	20.327	24.549	1.206	27.143	PGC0Q	PGC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
63.264	21.320	25.749	1.265	28.469	PGC0Q	PGC0H	Suburb0Q	Suburb0H
49.827	16.792	20.279	0.997	22.422	PGC0Q	PGC0H	Suburb0Q	Suburb0H
47.733	16.086	19.427	0.955	21.480	PGC0Q	PGC0H	Suburb0Q	Suburb0H
78.569	26.478	31.978	1.571	35.356	PGC0Q	PGC0H	Suburb0Q	Suburb0H
84.045	28.323	34.206	1.681	37.820	PGC0Q	PGC0H	Suburb0Q	Suburb0H
105.900	35.688	43.101	2.118	47.655	PGC0Q	PGC0H	Suburb0Q	Suburb0H
36.066	12.154	14.679	0.721	16.230	PGC0Q	PGC0H	Suburb0Q	Suburb0H
68.903	23.220	28.044	1.378	31.006	PGC0Q	PGC0H	Suburb0Q	Suburb0H
93.436	31.488	38.029	1.869	42.046	PGC0Q	PGC0H	Suburb0Q	Suburb0H
80.071	26.984	32.589	1.601	36.032	PGC0Q	PGC0H	Suburb0Q	Suburb0H
44.975	15.157	18.305	0.900	20.239	PGC0Q	PGC0H	Suburb0Q	Suburb0H
21.693	7.311	8.829	0.434	9.762	PGC0Q	PGC0H	Suburb0Q	Suburb0H
94.400	31.813	38.421	1.888	42.480	PGC0Q	PGC0H	Suburb0Q	Suburb0H
44.800	15.098	18.234	0.896	20.160	PGC0Q	PGC0H	Suburb0Q	Suburb0H
64.965	21.893	26.441	1.299	29.234	PGC0Q	PGC0H	Suburb0Q	Suburb0H
20.600	6.942	8.384	0.412	9.270	PGC0Q	PGC0H	Suburb0Q	Suburb0H
130.839	44.093	53.252	2.617	58.878	PGC0Q	PGC0H	Suburb0Q	Suburb0H
25.667	8.650	10.446	0.513	11.550	PGC0Q	PGC0H	Suburb0Q	Suburb0H
104.822	35.325	42.663	2.096	47.170	PGC0Q	PGC0H	Suburb0Q	Suburb0H
21.700	7.313	8.832	0.434	9.765	PGC0Q	PGC0H	Suburb0Q	Suburb0H
74.036	24.950	30.133	1.481	33.316	PGC0Q	PGC0H	Suburb0Q	Suburb0H
141.488	47.682	57.586	2.830	63.670	PGC0Q	PGC0H	Suburb0Q	Suburb0H
34.100	11.492	13.879	0.682	15.345	PGC0Q	PGC0H	Suburb0Q	Suburb0H
15.000	5.055	6.105	0.300	6.750	PGC0Q	PGC0H	Suburb0Q	Suburb0H
84.819	28.584	34.522	1.696	38.169	PGC0Q	PGC0H	Suburb0Q	Suburb0H
76.576	25.806	31.166	1.532	34.459	PGC0Q	PGC0H	Suburb0Q	Suburb0H
39.048	13.159	15.893	0.781	17.572	PGC0Q	PGC0H	Suburb0Q	Suburb0H
125.118	42.165	50.923	2.502	56.303	PGC0Q	PGC0H	Suburb0Q	Suburb0H
57.343	19.325	23.339	1.147	25.805	PGC0Q	PGC0H	Suburb0Q	Suburb0H
46.286	15.598	18.838	0.926	20.829	PGC0Q	PGC0H	Suburb0Q	Suburb0H
47.683	16.069	19.407	0.954	21.458	PGC0Q	PGC0H	Suburb0Q	Suburb0H
79.401	26.758	32.316	1.588	35.730	PGC0Q	PGC0H	Suburb0Q	Suburb0H
58.180	19.607	23.679	1.164	26.181	PGC0Q	PGC0H	Suburb0Q	Suburb0H
40.800	13.750	16.606	0.816	18.360	PGC0Q	PGC0H	Suburb0Q	Suburb0H
53.190	17.925	21.648	1.064	23.935	PGC0Q	PGC0H	Suburb0Q	Suburb0H
36.002	12.133	14.653	0.720	16.201	PGC0Q	PGC0H	Suburb0Q	Suburb0H
55.850	18.821	22.731	1.117	25.132	PGC0Q	PGC0H	Suburb0Q	Suburb0H
93.867	31.633	38.204	1.877	42.240	PGC0Q	PGC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
100.310	33.804	40.826	2.006	45.139	PGC0Q	PGC0H	Suburb0Q	Suburb0H
44.650	15.047	18.173	0.893	20.092	PGC0Q	PGC0H	Suburb0Q	Suburb0H
77.049	25.965	31.359	1.541	34.672	PGC0Q	PGC0H	Suburb0Q	Suburb0H
14.551	4.904	5.922	0.291	6.548	PGC0Q	PGC0H	Suburb0Q	Suburb0H
56.131	18.916	22.845	1.123	25.259	PGC0Q	PGC0H	Suburb0Q	Suburb0H
24.439	8.236	9.947	0.489	10.998	PGC0Q	PGC0H	Suburb0Q	Suburb0H
98.210	33.097	39.971	1.964	44.194	PGC0Q	PGC0H	Suburb0Q	Suburb0H
63.825	21.509	25.977	1.276	28.721	PGC0Q	PGC0H	Suburb0Q	Suburb0H
171.106	57.663	69.640	3.422	76.998	PGC0Q	PGC0H	Suburb0Q	Suburb0H
110.050	37.087	44.790	2.201	49.523	PGC0Q	PGC0H	Suburb0Q	Suburb0H
87.886	29.617	35.769	1.758	39.548	PGC0Q	PGC0H	Suburb0Q	Suburb0H
44.600	15.030	18.152	0.892	20.070	PGC0Q	PGC0H	Suburb0Q	Suburb0H
80.300	27.061	32.682	1.606	36.135	PGC0Q	PGC0H	Suburb0Q	Suburb0H
140.400	47.315	57.143	2.808	63.180	PGC0Q	PGC0H	Suburb0Q	Suburb0H
52.700	17.760	21.449	1.054	23.715	PGC0Q	PGC0H	Suburb0Q	Suburb0H
85.797	28.913	34.919	1.716	38.608	PGC0Q	PGC0H	Suburb0Q	Suburb0H
105.600	35.587	42.979	2.112	47.520	PGC0Q	PGC0H	Suburb0Q	Suburb0H
72.930	24.577	29.682	1.459	32.818	PGC0Q	PGC0H	Suburb0Q	Suburb0H
158.580	53.441	64.542	3.172	71.361	PGC0Q	PGC0H	Suburb0Q	Suburb0H
5.419	1.826	2.205	0.108	2.438	PGC0Q	PGC0H	Suburb0Q	Suburb0H
1.600	0.539	0.651	0.032	0.720	PGC0Q	PGC0H	Suburb0Q	Suburb0H
26.652	8.982	10.847	0.533	11.994	PGC0Q	PGC0H	Suburb0Q	Suburb0H
13.000	4.381	5.291	0.260	5.850	PGC0Q	PGC0H	Suburb0Q	Suburb0H
131.200	44.214	53.398	2.624	59.040	PGC0Q	PGC0H	Suburb0Q	Suburb0H
58.400	19.681	23.769	1.168	26.280	PGC0Q	PGC0H	Suburb0Q	Suburb0H
59.900	20.186	24.379	1.198	26.955	PGC0Q	PGC0H	Suburb0Q	Suburb0H
74.683	25.168	30.396	1.494	33.607	PWC0Q	PWC0H	Suburb0Q	Suburb0H
73.850	24.887	30.057	1.477	33.232	PWC0Q	PWC0H	Suburb0Q	Suburb0H
82.800	27.904	33.700	1.656	37.260	PWC0Q	PWC0H	Suburb0Q	Suburb0H
51.398	17.321	20.919	1.028	23.129	PWC0Q	PWC0H	Suburb0Q	Suburb0H
53.760	18.117	21.880	1.075	24.192	PWC0Q	PWC0H	Suburb0Q	Suburb0H
54.222	18.273	22.068	1.084	24.400	PWC0Q	PWC0H	Suburb0Q	Suburb0H
84.214	28.380	34.275	1.684	37.896	PWC0Q	PWC0H	Suburb0Q	Suburb0H
52.678	17.753	21.440	1.054	23.705	PWC0Q	PWC0H	Suburb0Q	Suburb0H
127.156	42.852	51.752	2.543	57.220	PWC0Q	PWC0H	Suburb0Q	Suburb0H
24.512	8.261	9.976	0.490	11.030	PWC0Q	PWC0H	Suburb0Q	Suburb0H
66.936	22.557	27.243	1.339	30.121	PWC0Q	PWC0H	Suburb0Q	Suburb0H
65.830	22.185	26.793	1.317	29.623	PWC0Q	PWC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
69.815	23.528	28.415	1.396	31.417	PWC0Q	PWC0H	Suburb0Q	Suburb0H
40.583	13.677	16.517	0.812	18.262	PWC0Q	PWC0H	Suburb0Q	Suburb0H
76.000	25.612	30.932	1.520	34.200	PWC0Q	PWC0H	Suburb0Q	Suburb0H
74.074	24.963	30.148	1.481	33.333	PWC0Q	PWC0H	Suburb0Q	Suburb0H
70.961	23.914	28.881	1.419	31.933	PWC0Q	PWC0H	Suburb0Q	Suburb0H
59.023	19.891	24.022	1.180	26.560	PWC0Q	PWC0H	Suburb0Q	Suburb0H
77.608	26.154	31.586	1.552	34.923	PWC0Q	PWC0H	Suburb0Q	Suburb0H
19.600	6.605	7.977	0.392	8.820	PWC0Q	PWC0H	Suburb0Q	Suburb0H
49.800	16.783	20.269	0.996	22.410	PWC0Q	PWC0H	Suburb0Q	Suburb0H
22.512	7.586	9.162	0.450	10.130	PWC0Q	PWC0H	Suburb0Q	Suburb0H
94.558	31.866	38.485	1.891	42.551	PWC0Q	PWC0H	Suburb0Q	Suburb0H
90.867	30.622	36.983	1.817	40.890	PWC0Q	PWC0H	Suburb0Q	Suburb0H
53.100	17.895	21.612	1.062	23.895	PWC0Q	PWC0H	Suburb0Q	Suburb0H
93.999	31.678	38.258	1.880	42.300	PWC0Q	PWC0H	Suburb0Q	Suburb0H
104.656	35.269	42.595	2.093	47.095	PWC0Q	PWC0H	Suburb0Q	Suburb0H
50.800	17.120	20.676	1.016	22.860	PWC0Q	PWC0H	Suburb0Q	Suburb0H
33.038	11.134	13.447	0.661	14.867	PWC0Q	PWC0H	Suburb0Q	Suburb0H
108.688	36.628	44.236	2.174	48.910	PWC0Q	PWC0H	Suburb0Q	Suburb0H
66.450	22.394	27.045	1.329	29.903	PWC0Q	PWC0H	Suburb0Q	Suburb0H
159.200	53.650	64.794	3.184	71.640	PWC0Q	PWC0H	Suburb0Q	Suburb0H
70.582	23.786	28.727	1.412	31.762	PWC0Q	PWC0H	Suburb0Q	Suburb0H
59.657	20.104	24.280	1.193	26.846	PWC0Q	PWC0H	Suburb0Q	Suburb0H
34.750	11.711	14.143	0.695	15.638	PWC0Q	PWC0H	Suburb0Q	Suburb0H
55.592	18.734	22.626	1.112	25.016	PWC0Q	PWC0H	Suburb0Q	Suburb0H
66.397	22.376	27.024	1.328	29.879	PWC0Q	PWC0H	Suburb0Q	Suburb0H
51.597	17.388	21.000	1.032	23.219	PWC0Q	PWC0H	Suburb0Q	Suburb0H
37.881	12.766	15.417	0.758	17.046	PWC0Q	PWC0H	Suburb0Q	Suburb0H
59.481	20.045	24.209	1.190	26.767	PWC0Q	PWC0H	Suburb0Q	Suburb0H
34.066	11.480	13.865	0.681	15.330	PWC0Q	PWC0H	Suburb0Q	Suburb0H
22.321	7.522	9.085	0.446	10.044	PWC0Q	PWC0H	Suburb0Q	Suburb0H
63.700	21.467	25.926	1.274	28.665	PWC0Q	PWC0H	Suburb0Q	Suburb0H
87.308	29.423	35.534	1.746	39.288	PWC0Q	PWC0H	Suburb0Q	Suburb0H
43.293	14.590	17.620	0.866	19.482	PWC0Q	PWC0H	Suburb0Q	Suburb0H
19.400	6.538	7.896	0.388	8.730	PWC0Q	PWC0H	Suburb0Q	Suburb0H
38.457	12.960	15.652	0.769	17.306	PWC0Q	PWC0H	Suburb0Q	Suburb0H
109.580	36.929	44.599	2.192	49.311	PWC0Q	PWC0H	Suburb0Q	Suburb0H
32.509	10.956	13.231	0.650	14.629	PWC0Q	PWC0H	Suburb0Q	Suburb0H
10.000	3.370	4.070	0.200	4.500	PWC0Q	PWC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
10.600	3.572	4.314	0.212	4.770	PWC0Q	PWC0H	Suburb0Q	Suburb0H
22.400	7.549	9.117	0.448	10.080	PWC0Q	PWC0H	Suburb0Q	Suburb0H
91.157	30.720	37.101	1.823	41.021	PWC0Q	PWC0H	Suburb0Q	Suburb0H
100.244	33.782	40.799	2.005	45.110	PWC0Q	PWC0H	Suburb0Q	Suburb0H
84.527	28.486	34.403	1.691	38.037	PWC0Q	PWC0H	Suburb0Q	Suburb0H
51.157	17.240	20.821	1.023	23.021	PWC0Q	PWC0H	Suburb0Q	Suburb0H
25.590	8.624	10.415	0.512	11.516	PWC0Q	PWC0H	Suburb0Q	Suburb0H
132.078	44.510	53.756	2.642	59.435	PWC0Q	PWC0H	Suburb0Q	Suburb0H
74.464	25.094	30.307	1.489	33.509	PWC0Q	PWC0H	Suburb0Q	Suburb0H
59.531	20.062	24.229	1.191	26.789	PWC0Q	PWC0H	Suburb0Q	Suburb0H
77.424	26.092	31.512	1.548	34.841	PWC0Q	PWC0H	Suburb0Q	Suburb0H
70.018	23.596	28.497	1.400	31.508	PWC0Q	PWC0H	Suburb0Q	Suburb0H
86.900	29.285	35.368	1.738	39.105	PWC0Q	PWC0H	Suburb0Q	Suburb0H
95.923	32.326	39.041	1.918	43.165	PWC0Q	PWC0H	Suburb0Q	Suburb0H
98.500	33.195	40.090	1.970	44.325	PWC0Q	PWC0H	Suburb0Q	Suburb0H
80.300	27.061	32.682	1.606	36.135	PWC0Q	PWC0H	Suburb0Q	Suburb0H
56.365	18.995	22.941	1.127	25.364	PWC0Q	PWC0H	Suburb0Q	Suburb0H
65.500	22.073	26.658	1.310	29.475	PWC0Q	PWC0H	Suburb0Q	Suburb0H
19.500	6.571	7.936	0.390	8.775	PWC0Q	PWC0H	Suburb0Q	Suburb0H
7.200	2.426	2.930	0.144	3.240	PWC0Q	PWC0H	Suburb0Q	Suburb0H
84.200	28.375	34.269	1.684	37.890	PWC0Q	PWC0H	Suburb0Q	Suburb0H
20.000	6.740	8.140	0.400	9.000	PWC0Q	PWC0H	Suburb0Q	Suburb0H
66.900	22.545	27.228	1.338	30.105	PWC0Q	PWC0H	Suburb0Q	Suburb0H
80.000	26.960	32.560	1.600	36.000	PWC0Q	PWC0H	Suburb0Q	Suburb0H
76.029	25.622	30.944	1.521	34.213	PWC0Q	PWC0H	Suburb0Q	Suburb0H
52.874	17.819	21.520	1.057	23.793	PWC0Q	PWC0H	Suburb0Q	Suburb0H
150.372	50.675	61.201	3.007	67.667	PWC0Q	PWC0H	Suburb0Q	Suburb0H
70.300	23.691	28.612	1.406	31.635	PWC0Q	PWC0H	Suburb0Q	Suburb0H
81.800	27.567	33.293	1.636	36.810	PWC0Q	PWC0H	Suburb0Q	Suburb0H
140.130	47.224	57.033	2.803	63.058	PWC0Q	PWC0H	Suburb0Q	Suburb0H
63.956	21.553	26.030	1.279	28.780	PWC0Q	PWC0H	Suburb0Q	Suburb0H
190.301	64.131	77.452	3.806	85.635	PWC0Q	PWC0H	Suburb0Q	Suburb0H
80.400	27.095	32.723	1.608	36.180	PWC0Q	PWC0H	Suburb0Q	Suburb0H
55.888	18.834	22.747	1.118	25.150	PWC0Q	PWC0H	Suburb0Q	Suburb0H
153.700	51.797	62.556	3.074	69.165	PWC0Q	PWC0H	Suburb0Q	Suburb0H
117.811	39.702	47.949	2.356	53.015	PWC0Q	PWC0H	Suburb0Q	Suburb0H
29.163	9.828	11.869	0.583	13.123	PWC0Q	PWC0H	Suburb0Q	Suburb0H
52.881	17.821	21.523	1.058	23.797	PWC0Q	PWC0H	Suburb0Q	Suburb0H

A.1: Input Data for Student t-test and Tukey Range Test

Table A.1: Input Data for Student t-test and Tukey Range Test

VMT	O3VOC	O3NOx	PM2.5	PrecNOx	CtyQmile	CtyHmile	UrbClassQ	UrbClassH
75.240	25.356	30.623	1.505	33.858	PWC0Q	PWC0H	Suburb0Q	Suburb0H
64.100	21.602	26.089	1.282	28.845	PWC0Q	PWC0H	Suburb0Q	Suburb0H
64.700	21.804	26.333	1.294	29.115	PWC0Q	PWC0H	Suburb0Q	Suburb0H
36.000	12.132	14.652	0.720	16.200	PWC0Q	PWC0H	Suburb0Q	Suburb0H
101.191	34.101	41.185	2.024	45.536	SC0Q	SC0H	Exurb	Exurb
68.198	22.983	27.757	1.364	30.689	SC0Q	SC0H	Exurb	Exurb
39.825	13.421	16.209	0.796	17.921	SC0Q	SC0H	Exurb	Exurb
103.404	34.847	42.086	2.068	46.532	SC0Q	SC0H	Exurb	Exurb
70.255	23.676	28.594	1.405	31.615	SC0Q	SC0H	Exurb	Exurb
52.387	17.654	21.321	1.048	23.574	SC0Q	SC0H	Exurb	Exurb
116.964	39.417	47.604	2.339	52.634	SC0Q	SC0H	Exurb	Exurb
68.670	23.142	27.949	1.373	30.902	SC0Q	SC0H	Exurb	Exurb
73.810	24.874	30.041	1.476	33.215	SC0Q	SC0H	Exurb	Exurb
4.600	1.550	1.872	0.092	2.070	SC0Q	SC0H	Exurb	Exurb
67.017	22.585	27.276	1.340	30.158	SC0Q	SC0H	Exurb	Exurb
12.200	4.111	4.965	0.244	5.490	SC0Q	SC0H	Exurb	Exurb

A-2: SAS Code for Student t-test Analysis

```
Proc Format;
       Value $f_County_Dist
       "AAC0Q" = "Anne Arundel, Outside 0.25 mi"
       "AAC1Q" = "Anne Arundel, Inside 0.25 mi"
       "AAC0H" = "Anne Arundel, Non-TOD"
       "AAC1H" = "Anne Arundel, TOD"
       "AC0Q" = "Arlington, Outside 0.25 mi"
       "AC1Q" = "Arlington, Inside 0.25 mi"
       "AC0H" = "Arlington, Non-TOD"
       "AC1H" = "Arlington, TOD"
       "CC0Q" = "Charles, Outside 0.25 mi"
       "CC1Q" = "Charles, Inside 0.25 mi"
       "CC0H" = "Charles, Non-TOD"
       "CC1H" = "Charles, TOD"
       "CA0Q" = "City of Alexandria, Outside 0.25 mi"
       "CA1Q" = "City of Alexandria, Inside 0.25 mi"
       "CA0H" = "City of Alexandria, Non-TOD"
       "CA1H" = "City of Alexandria, TOD"
       "DC0Q" = "District of Columbia, Outside 0.25 mi"
       "DC1Q" = "District of Columbia, Inside 0.25 mi"
       "DC0H" = "District of Columbia, Non-TOD"
       "DC1H" = "District of Columbia, TOD"
       "FFC0Q" = "Fairfax County, Outside 0.25 mi"
       "FFC1Q" = "Fairfax County, Inside 0.25 mi"
       "FFC0H" = "Fairfax County, Non-TOD"
       "FFC1H" = "Fairfax County, TOD"
       "FqC0Q" = "Fauquier, Outside 0.25 mi"
       "FqC1Q" = "Fauquier, Inside 0.25 mi"
       "FqC0H" = "Fauquier, Non-TOD"
       "FqC1H" = "Fauquier, TOD"
       "HC0Q" = "Howard, Outside 0.25 mi"
       "HC1Q" = "Howard, Inside 0.25 mi"
       "HC0H" = "Howard, Non-TOD"
       "HC1H" = "Howard, TOD"
       "LC0Q" = "Loudoun, Outside 0.25 mi"
       "LC1Q" = "Loudoun, Inside 0.25 mi"
       "LC0H" = "Loudoun, Non-TOD"
       "LC1H" = "Loudoun, TOD"
       "MC0Q" = "Montgomery, Outside 0.25 mi"
       "MC1Q" = "Montgomery, Inside 0.25 mi"
       "MC0H" = "Montgomery, Non-TOD"
       "MC1H" = "Montgomery, TOD"
       "OC0H" = "Other Counties, Non-TOD"
       "OC1H" = "Other Counties, TOD"
       "PGC0Q" = "Prince Georges, Outside 0.25 mi"
       "PGC1Q" = "Prince Georges, Inside 0.25 mi"
       "PGC0H" = "Prince Georges, Non-TOD"
       "PGC1H" = "Prince Georges, TOD"
       "PWC0Q" = "Prince Williams, Outside 0.25 mi"
       "PWC1Q" = "Prince Williams, Inside 0.25 mi"
       "PWC0H" = "Prince Williams, Non-TOD"
       "PWC1H" = "Prince Williams, TOD"
       "SC0Q" = "Stafford, Outside 0.25 mi"
       "SC1Q" = "Stafford, Inside 0.25 mi"
       "SC0H" = "Stafford, Non-TOD"
       "SC1H" = "Stafford, TOD"
       "Urban0Q" = "Urban, Outside 0.25 mi"
       "Suburb0Q" = "Suburban, Outside 0.25 mi"
```

```
        "Urban1Q" = "Urban, Inside 0.25 mi"
        "Suburb1Q" = "Suburban, Inside 0.25 mi"
        "Urban0H" = "Urban, Non-TOD"
        "Suburb0H" = "Suburban, Non-TOD"
        "Exurb" = "Exurban, No Metro"
        "Urban1H" = "Urban, TOD"
        "Suburb1H" = "Suburban, TOD"
        ;
Run;
Data EmissionFootprints;
        Infile '("C:\\Users\mvenigal\\Ch4 Sas Input Data.txt")';
        Input HHAutoVMT O3VOC O3NOx PM25Direct PrecNOx CtyQm $ CtyHm $ UCatQm $
UCatHm $ @@;
        format CtyQm f_County_Dist. CtyHm f_County_Dist. UCatQm f_County_Dist.
UCatHm f_County_Dist.;
        label HHAutoVMT = 'Auto Trip VMT/hh'
                 O3VOC = 'Ozone VOC (gm/hh)'
                 O3NOx = 'Ozone NOx (gm/hh)'
                 PM25Direct = 'PM 2.5 (gm/hh)'
                 PrecNOx = 'Precursor NOx (gm/hh)'
                 CtyQm = 'County and TAZs' TOD Status'
                 CtyHm = 'County and TAZs' TOD Status'
                 UCatQm = 'County-Group and TAZs' TOD Status'
                 UCatHm = 'County-Group and TAZs' TOD Status';
Run;
title1 'Ozone VOC Emissions Comparison: Arlington County: Non-TOD vs. TOD';
title2 '-----------------------------------------------------------------';
proc ttest;
         where CtyHm in ('AC0H','AC1H');
         class CtyHm;
         var O3VOC;
         run;
title1 'Ozone VOC Emissions Comparison: City of Alexandria: Non-TOD vs. TOD';
title2 '---------------------------------------------------------------------';
proc ttest;
         where CtyHm in ('CA0H','CA1H');
         class CtyHm;
         var O3VOC;
         run;
title1 'Ozone VOC Emissions Comparison: District of Columbia: Non-TOD vs. TOD';
title2 '---------------------------------------------------------------------';
proc ttest;
         where CtyHm in ('DC0H','DC1H');
         class CtyHm;
         var O3VOC;
         run;
title1 'Ozone VOC Emissions Comparison: Fairfax County: Non-TOD TOD';
title2 '-------------------------------------------------------------';
proc ttest;
         where CtyHm in ('FFC0H','FFC1H');
         class CtyHm;
         var O3VOC;
         run;
title1 'Ozone VOC Emissions Comparison: Montgomery County: Non-TOD vs. TOD';
title2 '--------------------------------------------------------------------';
proc ttest;
         where CtyHm in ('MC0H','MC1H');
         class CtyHm;
         var O3VOC;
         run;
title1 'Ozone VOC Emissions Comparison: Prince Georges County: Non-TOD vs. TOD';
```

```
title2 '-------------------------------------------------------------------';
proc ttest;
         where CtyHm in ('PGC0H','PGC1H');
         class CtyHm;
         var O3VOC;
         run;
```

A-3: SAS Code for Tukey's Range Test Analysis

```
Proc Format;
       Value $f_County_Dist
       "AAC0Q" = "Anne Arundel, Outside 0.25 mi"
       "AAC1Q" = "Anne Arundel, Inside 0.25 mi"
       "AAC0H" = "Anne Arundel, Non-TOD"
       "AAC1H" = "Anne Arundel, TOD"
       "AC0Q" = "Arlington, Outside 0.25 mi"
       "AC1Q" = "Arlington, Inside 0.25 mi"
       "AC0H" = "Arlington, Non-TOD"
       "AC1H" = "Arlington, TOD"
       "CC0Q" = "Charles, Outside 0.25 mi"
       "CC1Q" = "Charles, Inside 0.25 mi"
       "CC0H" = "Charles, Non-TOD"
       "CC1H" = "Charles, TOD"
       "CA0Q" = "City of Alexandria, Outside 0.25 mi"
       "CA1Q" = "City of Alexandria, Inside 0.25 mi"
       "CA0H" = "City of Alexandria, Non-TOD"
       "CA1H" = "City of Alexandria, TOD"
       "DC0Q" = "District of Columbia, Outside 0.25 mi"
       "DC1Q" = "District of Columbia, Inside 0.25 mi"
       "DC0H" = "District of Columbia, Non-TOD"
       "DC1H" = "District of Columbia, TOD"
       "FFC0Q" = "Fairfax County, Outside 0.25 mi"
       "FFC1Q" = "Fairfax County, Inside 0.25 mi"
       "FFC0H" = "Fairfax County, Non-TOD"
       "FFC1H" = "Fairfax County, TOD"
       "FqC0Q" = "Fauquier, Outside 0.25 mi"
       "FqC1Q" = "Fauquier, Inside 0.25 mi"
       "FqC0H" = "Fauquier, Non-TOD"
       "FqC1H" = "Fauquier, TOD"
       "HC0Q" = "Howard, Outside 0.25 mi"
       "HC1Q" = "Howard, Inside 0.25 mi"
       "HC0H" = "Howard, Non-TOD"
       "HC1H" = "Howard, TOD"
       "LC0Q" = "Loudoun, Outside 0.25 mi"
       "LC1Q" = "Loudoun, Inside 0.25 mi"
       "LC0H" = "Loudoun, Non-TOD"
       "LC1H" = "Loudoun, TOD"
       "MC0Q" = "Montgomery, Outside 0.25 mi"
       "MC1Q" = "Montgomery, Inside 0.25 mi"
       "MC0H" = "Montgomery, Non-TOD"
       "MC1H" = "Montgomery, TOD"
       "OC0H" = "Other Counties, Non-TOD"
       "OC1H" = "Other Counties, TOD"
       "PGC0Q" = "Prince Georges, Outside 0.25 mi"
       "PGC1Q" = "Prince Georges, Inside 0.25 mi"
       "PGC0H" = "Prince Georges, Non-TOD"
       "PGC1H" = "Prince Georges, TOD"
       "PWC0Q" = "Prince Williams, Outside 0.25 mi"
       "PWC1Q" = "Prince Williams, Inside 0.25 mi"
       "PWC0H" = "Prince Williams, Non-TOD"
       "PWC1H" = "Prince Williams, TOD"
       "SC0Q" = "Stafford, Outside 0.25 mi"
       "SC1Q" = "Stafford, Inside 0.25 mi"
       "SC0H" = "Stafford, Non-TOD"
       "SC1H" = "Stafford, TOD"
       "Urban0Q" = "Urban, Outside 0.25 mi"
       "Suburb0Q" = "Suburban, Outside 0.25 mi"
```

```
        "Urban1Q" = "Urban, Inside 0.25 mi"
        "Suburb1Q" = "Suburban, Inside 0.25 mi"
        "Urban0H" = "Urban, Non-TOD"
        "Suburb0H" = "Suburban, Non-TOD"
        "Exurb" = "Exurban, No Metro"
        "Urban1H" = "Urban, TOD"
        "Suburb1H" = "Suburban, TOD"
        ;
Run;
Data EmissionFootprints;
        Infile '("C:\\Users\mvenigal\\Ch4 Sas Input Data.txt")';
        Input HHAutoVMT O3VOC O3NOx PM25Direct PrecNOx CtyQm $ CtyHm $ UCatQm $ 
UCatHm $ @@;
        format CtyQm f_County_Dist. CtyHm f_County_Dist. UCatQm f_County_Dist. 
UCatHm f_County_Dist.;
        label HHAutoVMT = 'Auto Trip VMT/hh'
                 O3VOC = 'Ozone VOC (gm/hh)'
                 O3NOx = 'Ozone NOx (gm/hh)'
                 PM25Direct = 'PM 2.5 (gm/hh)'
                 PrecNOx = 'Precursor NOx (gm/hh)'
                 CtyQm = 'County and TOD Status'
                 CtyHm = 'County and TOD Status'
                 UCatQm = 'County-Group and TOD Status'
                 UCatHm = 'County-Group and TOD Status';
Run;
title1 'Pairwise Comparison of Ozone VOC Footprints  by Urban Class';
title2 '------------------------------------------------------------';
Proc GLM;
        class UCatHm;
        model O3VOC = UCatHm;
        means UCatHm / tukey;
run;
title1 'Pairwise Comparison of Ozone NOx Footprints by Urban Class';
title2 '-----------------------------------------------------------';
Proc GLM;
        class UCatHm;
        model O3NOx = UCatHm;
        means UCatHm / tukey;
run;
title1 'Pairwise Comparison of PM 2.5 Footprints by Urban Class';
title2 '--------------------------------------------------------';
Proc GLM;
        class UCatHm;
        model PM25Direct = UCatHm;
        means UCatHm / tukey;
run;
title1 'Pairwise Comparison of Precursor NOx Footprints by Urban Class';
title2 '---------------------------------------------------------------';
Proc GLM;
        class UCatHM;
        model PrecNOx = UCatHm;
        means UCatHm / tukey;
run;
title1 'Pairwise Comparison of Ozone VOC Footprints by County';
title2 '------------------------------------------------------';
Proc GLM;
        class CtyHm;
        model O3VOC = CtyHm;
        means CtyHm / tukey;
run;
title1 'Pairwise Comparison of Ozone NOx Footprints by County';
```

```
title2 '------------------------------------------------------';
Proc GLM;
       class CtyHm;
       model O3NOx = CtyHm;
       means CtyHm / tukey;
run;
title1 'Pairwise Comparison of PM2.5 Direct Footprints by County';
title2 '--------------------------------------------------------';
Proc GLM;
       class CtyHm;
       model PM25Direct = CtyHm;
       means CtyHm / tukey;
run;
title1 'Pairwise Comparison of Precursor NOx Footprints by County';
title2 '----------------------------------------------------------';
Proc GLM;
       class CtyHm;
       model PrecNOx = CtyHm;
       means CtyHm / tukey;
run;
```

A-4: Selected Pages of SAS Output for Student t-test Analysis:

The SAS System

The TTEST Procedure

Variable: O3VOC (Ozone VOC (gm/hh))

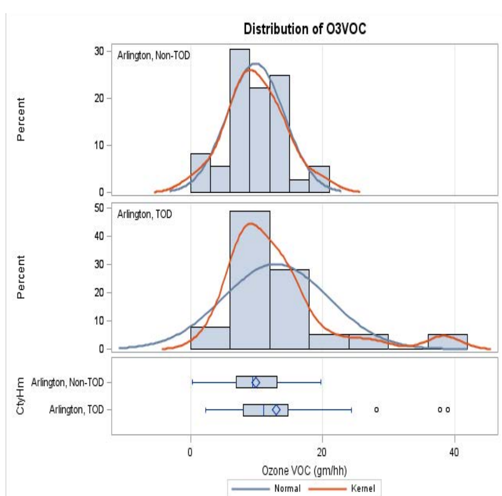
CtyHm	N	Mean	Std Dev	Std Err	Minimum	Maximum
Arlington, Non-TOD	36	9.8538	4.3462	0.7244	0.3370	19.7270
Arlington, TOD	39	12.9457	7.9458	1.2723	2.2670	38.9230
Diff (1-2)		-3.0920	6.4747	1.4965		

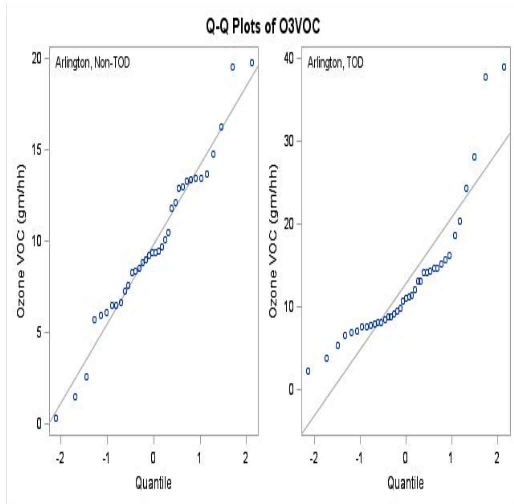
CtyHm	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
Arlington, Non-TOD		9.8538	8.3832	11.3243	4.3462	3.5251	5.6693
Arlington, TOD		12.9457	10.3700	15.5215	7.9458	6.4937	10.2404
Diff (1-2)	Pooled	-3.0920	-6.0744	-0.1095	6.4747	5.5735	7.7263
Diff (1-2)	Satterthwaite	-3.0920	-6.0208	-0.1631			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	73	-2.07	0.0424
Satterthwaite	Unequal	59.804	-2.11	0.0389

Equality of Variances

Method	Num DF	Den DF	F Value	Pr > F
Folded F	38	35	3.34	0.0005





Ozone VOC Emissions Comparison: City of Alexandria: Non-TOD vs. TOD

The TTEST Procedure

Variable: O3VOC (Ozone VOC (gm/hh))

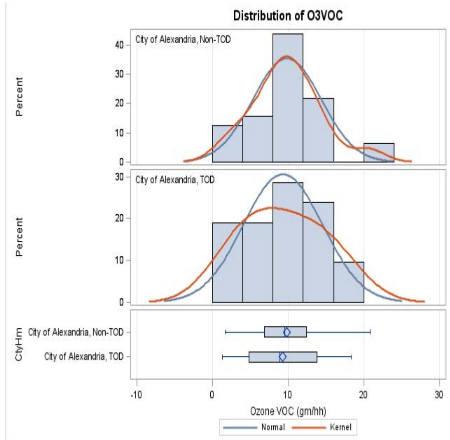
CtyHm	N	Mean	Std Dev	Std Err	Minimum	Maximum
City of Alexandria, Non-TOD	32	9.8514	4.5051	0.7964	1.6540	20.7980
City of Alexandria, TOD	21	9.3166	5.2183	1.1387	1.2810	18.3340
Diff (1-2)		0.5348	4.7975	1.3473		

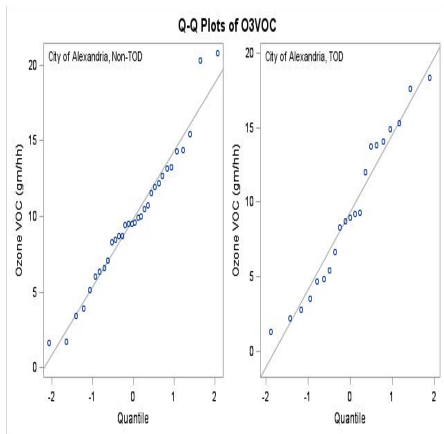
CtyHm	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
City of Alexandria, Non-TOD		9.8514	8.2272	11.4757	4.5051	3.6118	5.9895
City of Alexandria, TOD		9.3166	6.9413	11.6920	5.2183	3.9923	7.5356
Diff (1-2)	Pooled	0.5348	-2.1700	3.2396	4.7975	4.0205	5.9495
Diff (1-2)	Satterthwaite	0.5348	-2.2772	3.3469			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	51	0.40	0.6931
Satterthwaite	Unequal	38.42	0.38	0.7025

Equality of Variances

Method	Num DF	Den DF	F Value	Pr > F
Folded F	20	31	1.34	0.4514





Ozone VOC Emissions Comparison: District of Columbia: Non-TOD vs. TOD

The TTEST Procedure

Variable: O3VOC (Ozone VOC (gm/hh))

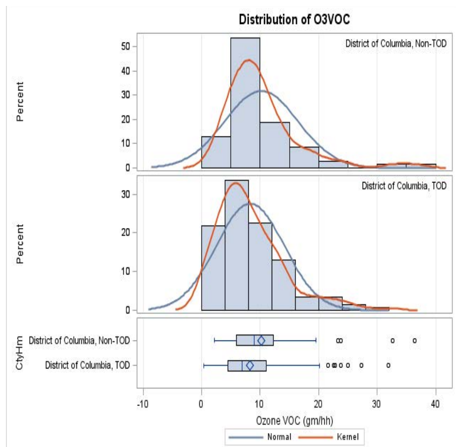
CtyHm	N	Mean	Std Dev	Std Err	Minimum	Maximum
District of Columbia, Non-TOD	69	10.1989	6.2861	0.7568	2.2190	36.4000
District of Columbia, TOD	146	8.2809	5.7959	0.4797	0.4040	31.9480
Diff (1-2)		1.9180	5.9568	0.8702		

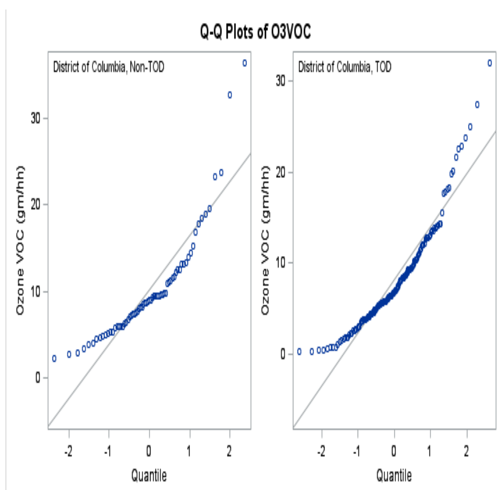
CtyHm	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
District of Columbia, Non-TOD		10.1989	8.6888	11.7090	6.2861	5.3843	7.5538
District of Columbia, TOD		8.2809	7.3329	9.2290	5.7959	5.1986	6.5494
Diff (1-2)	Pooled	1.9180	0.2026	3.6333	5.9568	5.4408	6.5817
Diff (1-2)	Satterthwaite	1.9180	0.1446	3.6913			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	213	2.20	0.0286
Satterthwaite	Unequal	124.21	2.14	0.0343

Equality of Variances

Method	Num DF	Den DF	F Value	Pr > F
Folded F	68	145	1.18	0.4169





Ozone VOC Emissions Comparison: Fairfax County: Non-TOD TOD

The TTEST Procedure

Variable: O3VOC (Ozone VOC (gm/hh))

CtyHm	N	Mean	Std Dev	Std Err	Minimum	Maximum
Fairfax County, Non-TOD	255	16.7622	9.6021	0.6013	1.1120	76.9030

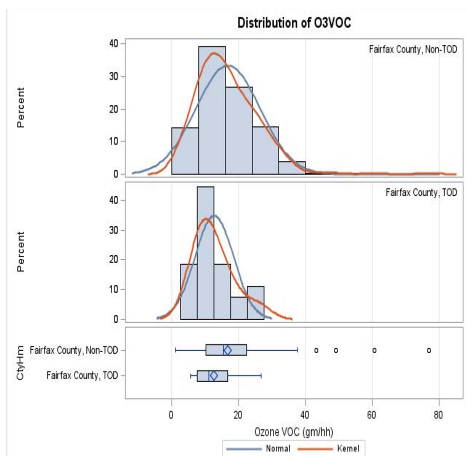
CtyHm	N	Mean	Std Dev	Std Err	Minimum	Maximum
Fairfax County, TOD	27	12.6470	5.7414	1.1049	5.5270	26.6900
Diff (1-2)		4.1152	9.3113	1.8844		

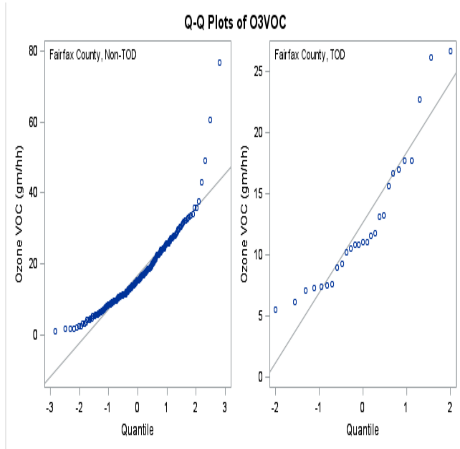
CtyHm	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
Fairfax County, Non-TOD		16.7622	15.5780	17.9464	9.6021	8.8348	10.5166
Fairfax County, TOD		12.6470	10.3758	14.9182	5.7414	4.5214	7.8682
Diff (1-2)	Pooled	4.1152	0.4057	7.8247	9.3113	8.5998	10.1521
Diff (1-2)	Satterthwaite	4.1152	1.5788	6.6516			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	280	2.18	0.0298
Satterthwaite	Unequal	43.292	3.27	0.0021

Equality of Variances

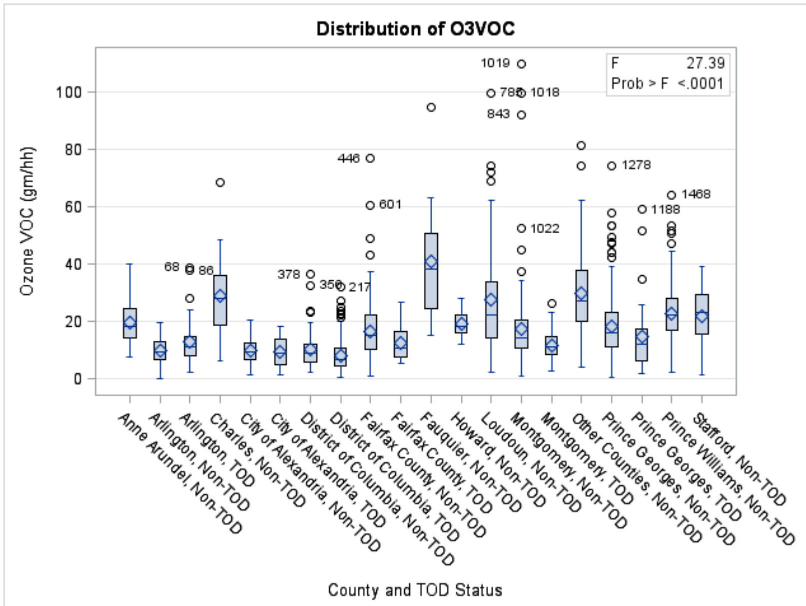
Method	Num DF	Den DF	F Value	Pr > F
Folded F	254	26	2.80	0.0027

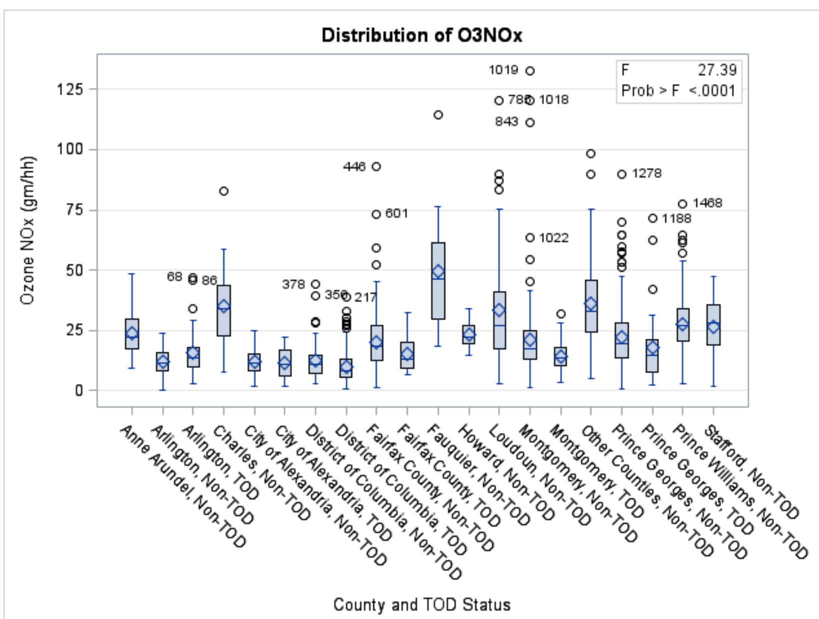


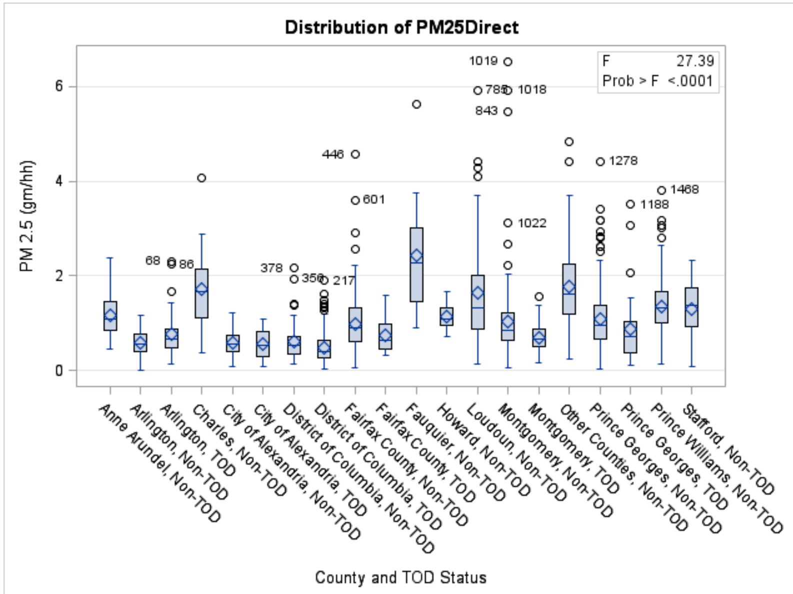


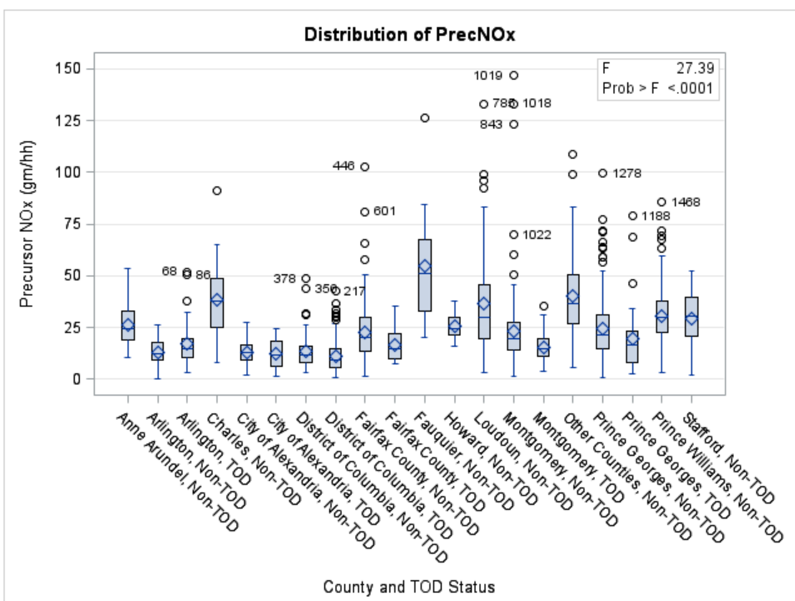
Q-Q Plots of O3VOC
Fairfax County, Non-TOD
Fairfax County, TOD
Ozone VOC (gm/hh)
Quantile

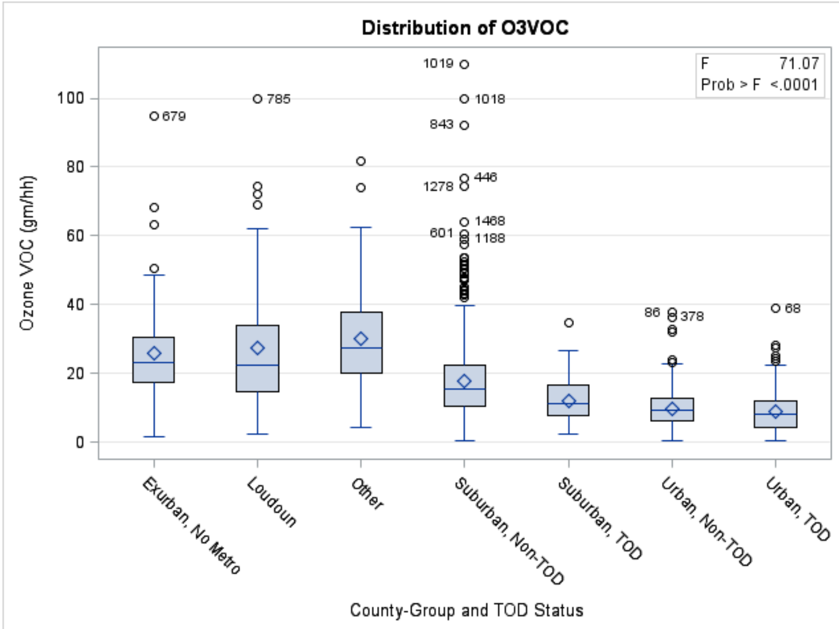
A-5: Selected Pages of SAS Output for Tukey’s Range Test Analysis:

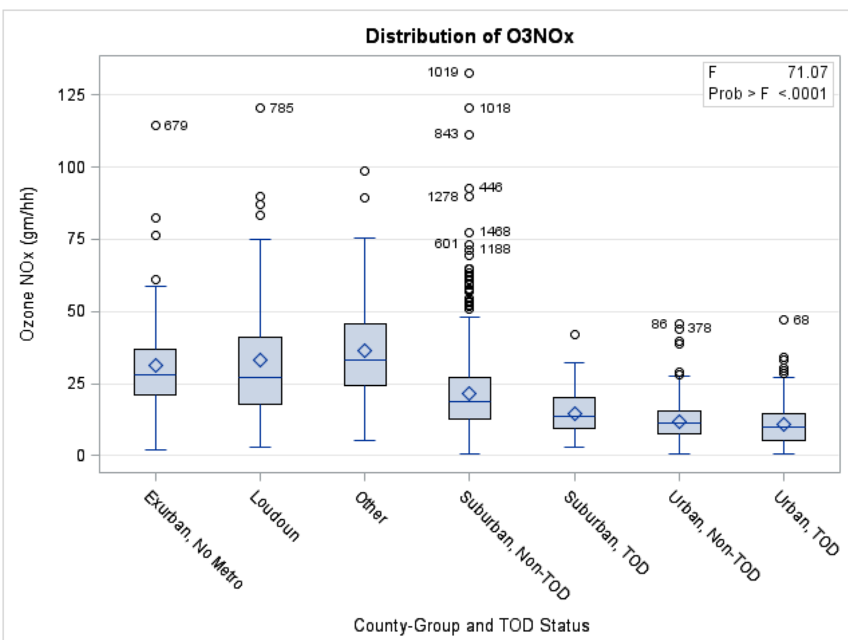


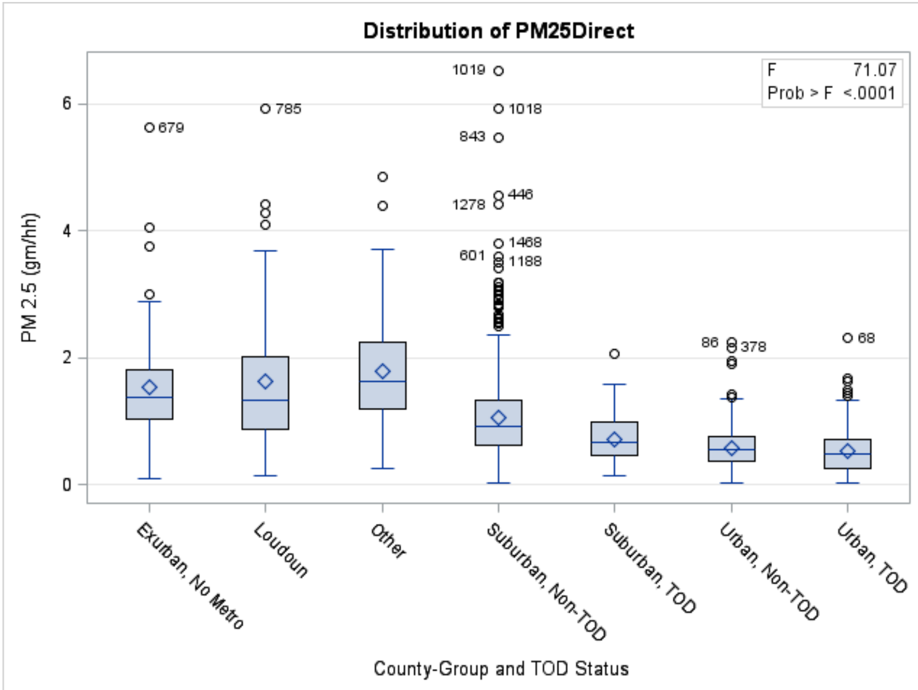


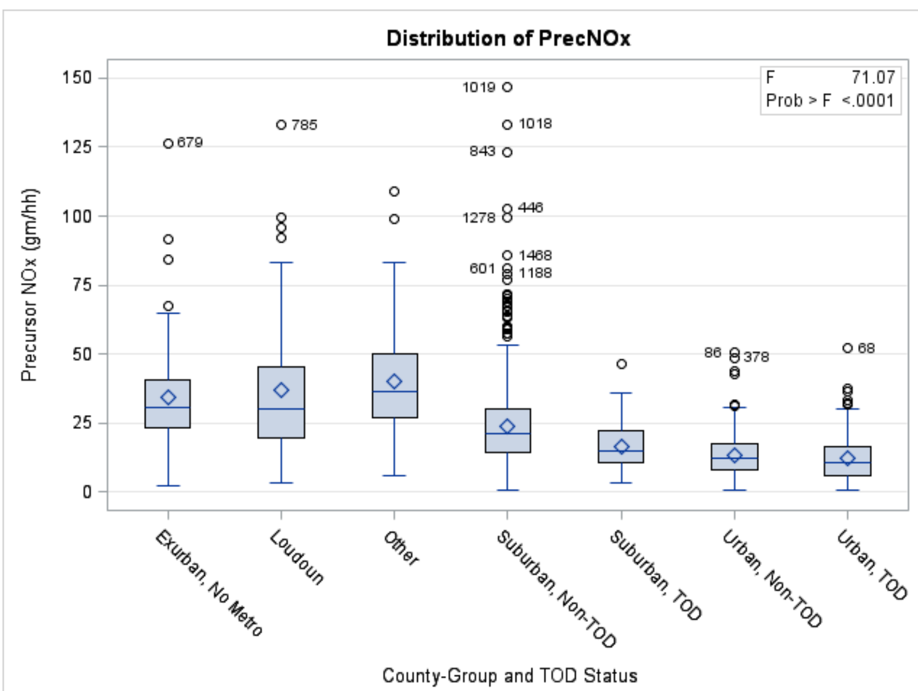

Distribution of PM25Direct
F 27.39
Prob > F <.0001
PM 2.5 (gm/hh)
County and TOD Status
Anne Arundel, Non-TOD
Arlington, Non-TOD
Arlington, TOD
Charles, Non-TOD
City of Alexandria, Non-TOD
City of Alexandria, TOD
District of Columbia, Non-TOD
District of Columbia, TOD
Fairfax County, Non-TOD
Fairfax County, TOD
Fauquier, Non-TOD
Howard, Non-TOD
Loudoun, Non-TOD
Montgomery, Non-TOD
Montgomery, TOD
Other Counties, Non-TOD
Prince Georges, Non-TOD
Prince Georges, TOD
Prince Williams, Non-TOD
Stafford, Non-TOD


Distribution of PrecNOx
F 27.39
Prob > F <.0001
Precursor NOx (gm/hh)
County and TOD Status
Anne Arundel, Non-TOD
Arlington, Non-TOD
Arlington, TOD
Charles, Non-TOD
City of Alexandria, Non-TOD
City of Alexandria, TOD
District of Columbia, Non-TOD
District of Columbia, TOD
Fairfax County, Non-TOD
Fairfax County, TOD
Fauquier, Non-TOD
Howard, Non-TOD
Loudoun, Non-TOD
Montgomery, Non-TOD
Montgomery, TOD
Other Counties, Non-TOD
Prince Georges, Non-TOD
Prince Georges, TOD
Prince Williams, Non-TOD
Stafford, Non-TOD


Distribution of O3VOC
F 71.07
Prob > F <.0001
Ozone VOC (gm/hh)
1019
1018
785
679
843
1278
446
1468
601
1188
86
378
68
Exurban, No Metro
Loudoun
Other
Suburban, Non-TOD
Suburban, TOD
Urban, Non-TOD
Urban, TOD
County-Group and TOD Status


Distribution of O3NOx
F 71.07
Prob > F <.0001
Ozone NOx (gm/hh)
1019
1018
785
679
843
1278
446
1468
601
1188
86
378
68
Exurban, No Metro
Loudoun
Other
Suburban, Non-TOD
Suburban, TOD
Urban, Non-TOD
Urban, TOD
County-Group and TOD Status


Distribution of PM25Direct
F 71.07
Prob > F <.0001
PM 2.5 (gm/hh)
0
2
4
6
1019
1018
843
446
1278
1468
601
1188
679
785
86
378
68
Exurban, No Metro
Loudoun
Other
Suburban, Non-TOD
Suburban, TOD
Urban, Non-TOD
Urban, TOD
County-Group and TOD Status


Distribution of PrecNOx
F 71.07
Prob > F <.0001
Precursor NOx (gm/hh)
0
25
50
75
100
125
150
1019
1018
843
446
1278
1468
601
1188
679
785
86
378
68
Exurban, No Metro
Loudoun
Other
Suburban, Non-TOD
Suburban, TOD
Urban, Non-TOD
Urban, TOD
County-Group and TOD Status

The SAS System

The GLM Procedure

Class Level Information

Class	Levels	Values
UCatHm	7	Exurban, No Metro Loudoun Other Suburban, Non-TOD Suburban, TOD Urban, Non-TOD Urban, TOD

Number of Observations Read	1490
Number of Observations Used	1490

The GLM Procedure

Dependent Variable: O3VOC Ozone VOC (gm/hh)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	51842.0435	8640.3406	71.07	<.0001
Error	1483	180298.9997	121.5772		
Corrected Total	1489	232141.0433			

R-Square	Coeff Var	Root MSE	O3VOC Mean
0.223321	63.75900	11.02621	17.29357

Source	DF	Type I SS	Mean Square	F Value	Pr > F
UCatHm	6	51842.04354	8640.34059	71.07	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
UCatHm	6	51842.04354	8640.34059	71.07	<.0001

The GLM Procedure

Tukey's Studentized Range (HSD) Test for O3VOC

Note: This test controls the Type I experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	1483
Error Mean Square	121.5772
Critical Value of Studentized Range	4.17530

Comparisons significant at the 0.05 level are indicated by ***.

UCatHm Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
Other - Loudoun	2.4907	-2.5076	7.4890	
Other - Exurban, No Metro	4.1721	-0.8262	9.1703	
Other - Suburban, Non-TOD	12.2851	8.7742	15.7961	***
Other - Suburban, TOD	17.8416	12.8433	22.8398	***
Other - Urban, Non-TOD	20.1260	16.1000	24.1519	***
Other - Urban, TOD	20.9784	16.6520	25.3049	***
Loudoun - Other	-2.4907	-7.4890	2.5076	
Loudoun - Exurban, No Metro	1.6814	-3.5995	6.9623	
Loudoun - Suburban, Non-TOD	9.7944	5.8917	13.6972	***
Loudoun - Suburban, TOD	15.3509	10.0700	20.6318	***
Loudoun - Urban, Non-TOD	17.6353	13.2634	22.0072	***
Loudoun - Urban, TOD	18.4877	13.8376	23.1378	***
Exurban, No Metro - Other	-4.1721	-9.1703	0.8262	
Exurban, No Metro - Loudoun	-1.6814	-6.9623	3.5995	
Exurban, No Metro - Suburban, Non-TOD	8.1131	4.2103	12.0158	***
Exurban, No Metro - Suburban, TOD	13.6695	8.3886	18.9504	***
Exurban, No Metro - Urban, Non-TOD	15.9539	11.5820	20.3258	***
Exurban, No Metro - Urban, TOD	16.8063	12.1563	21.4564	***
Suburban, Non-TOD - Other	-12.2851	-15.7961	-8.7742	***
Suburban, Non-TOD - Loudoun	-9.7944	-13.6972	-5.8917	***
Suburban, Non-TOD - Exurban, No Metro	-8.1131	-12.0158	-4.2103	***
Suburban, Non-TOD - Suburban, TOD	5.5564	1.6537	9.4592	***
Suburban, Non-TOD - Urban, Non-TOD	7.8408	5.2998	10.3819	***
Suburban, Non-TOD - Urban, TOD	8.6933	5.6988	11.6878	***
Suburban, TOD - Other	-17.8416	-22.8398	-12.8433	***
Suburban, TOD - Loudoun	-15.3509	-20.6318	-10.0700	***
Suburban, TOD - Exurban, No Metro	-13.6695	-18.9504	-8.3886	***
Suburban, TOD - Suburban, Non-TOD	-5.5564	-9.4592	-1.6537	***

Comparisons significant at the 0.05 level are indicated by ***.

UCatHm Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
Suburban, TOD - Urban, Non-TOD	2.2844	-2.0875	6.6563	
Suburban, TOD - Urban, TOD	3.1368	-1.5132	7.7869	
Urban, Non-TOD - Other	-20.1260	-24.1519	-16.1000	***
Urban, Non-TOD - Loudoun	-17.6353	-22.0072	-13.2634	***
Urban, Non-TOD - Exurban, No Metro	-15.9539	-20.3258	-11.5820	***
Urban, Non-TOD - Suburban, Non-TOD	-7.8408	-10.3819	-5.2998	***
Urban, Non-TOD - Suburban, TOD	-2.2844	-6.6563	2.0875	
Urban, Non-TOD - Urban, TOD	0.8524	-2.7321	4.4369	
Urban, TOD - Other	-20.9784	-25.3049	-16.6520	***
Urban, TOD - Loudoun	-18.4877	-23.1378	-13.8376	***
Urban, TOD - Exurban, No Metro	-16.8063	-21.4564	-12.1563	***
Urban, TOD - Suburban, Non-TOD	-8.6933	-11.6878	-5.6988	***
Urban, TOD - Suburban, TOD	-3.1368	-7.7869	1.5132	
Urban, TOD - Urban, Non-TOD	-0.8524	-4.4369	2.7321	

Precursor NOx Emissions Comparison by County Groups

The GLM Procedure

Class Level Information

Class	**Levels**	**Values**
CtyHm	20	Anne Arundel, Non-TOD Arlington, Non-TOD Arlington, TOD Charles, Non-TOD City of Alexandria, Non-TOD City of Alexandria, TOD District of Columbia, Non-TOD District of Columbia, TOD Fairfax County, Non-TOD Fairfax County, TOD Fauquier, Non-TOD Howard, Non-TOD Loudoun, Non-TOD Montgomery, Non-TOD Montgomery, TOD Other Counties, Non-TOD Prince Georges, Non-TOD Prince Georges, TOD Prince Williams, Non-TOD Stafford, Non-TOD

Number of Observations Read	1490
Number of Observations Used	1490

The GLM Procedure

Dependent Variable: O3VOC Ozone VOC (gm/hh)

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	19	60690.4790	3194.2357	27.39	<.0001
Error	1470	171450.5643	116.6330		
Corrected Total	1489	232141.0433			

R-Square	Coeff Var	Root MSE	O3VOC Mean
0.261438	62.44911	10.79968	17.29357

Source	DF	Type I SS	Mean Square	F Value	Pr > F
CtyHm	19	60690.47900	3194.23574	27.39	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
CtyHm	19	60690.47900	3194.23574	27.39	<.0001

Precursor NOx Emissions Comparison by County Groups

The GLM Procedure

Tukey's Studentized Range (HSD) Test for O3VOC

Note: This test controls the Type I experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	1470
Error Mean Square	116.633
Critical Value of Studentized Range	5.02098

Comparisons significant at the 0.05 level are indicated by ***.

CtyHm Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
Fauquier, Non-TOD - Other Counties, Non-TOD	10.8032	-1.4020	23.0084	
Fauquier, Non-TOD - Charles, Non-TOD	11.9289	-2.1272	25.9849	
Fauquier, Non-TOD - Loudoun, Non-TOD	13.2939	0.9247	25.6630	***
Fauquier, Non-TOD - Prince Williams, Non-TOD	17.9866	5.7542	30.2190	***
Fauquier, Non-TOD - Stafford, Non-TOD	18.9809	2.9756	34.9861	***
Fauquier, Non-TOD - Anne Arundel, Non-TOD	21.1994	7.6843	34.7145	***
Fauquier, Non-TOD - Howard, Non-TOD	21.4235	7.0304	35.8166	***
Fauquier, Non-TOD - Prince Georges, Non-TOD	22.5818	10.7276	34.4360	***
Fauquier, Non-TOD - Montgomery, Non-TOD	23.5207	11.6021	35.4393	***
Fauquier, Non-TOD - Fairfax County, Non-TOD	24.0821	12.2746	35.8896	***
Fauquier, Non-TOD - Prince Georges,	26.1643	13.2677	39.0610	***

Comparisons significant at the 0.05 level are indicated by ***.

CtyHm Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
TOD				
Fauquier, Non-TOD - Arlington, TOD	27.8985	14.8085	40.9886	***
Fauquier, Non-TOD - Fairfax County, TOD	28.1973	14.4822	41.9123	***
Fauquier, Non-TOD - Montgomery, TOD	29.1149	16.6908	41.5390	***
Fauquier, Non-TOD - District of Columbia, Non-TOD	30.6454	18.1971	43.0936	***
Fauquier, Non-TOD - Arlington, Non-TOD	30.9905	17.7810	44.2000	***
Fauquier, Non-TOD - City of Alexandria, Non-TOD	30.9928	17.5915	44.3941	***
Fauquier, Non-TOD - City of Alexandria, TOD	31.5277	17.2567	45.7986	***
Fauquier, Non-TOD - District of Columbia, TOD	32.5633	20.5749	44.5518	***
Other Counties, Non-TOD - Fauquier, Non-TOD	-10.8032	-23.0084	1.4020	
Other Counties, Non-TOD - Charles, Non-TOD	1.1257	-7.7757	10.0271	
Other Counties, Non-TOD - Loudoun, Non-TOD	2.4907	-3.3965	8.3778	
Other Counties, Non-TOD - Prince Williams, Non-TOD	7.1835	1.5893	12.7776	***
Other Counties, Non-TOD - Stafford, Non-TOD	8.1777	-3.5624	19.9177	
Other Counties, Non-TOD - Anne Arundel, Non-TOD	10.3962	2.3763	18.4162	***
Other Counties, Non-TOD - Howard, Non-TOD	10.6204	1.1958	20.0449	***
Other Counties, Non-TOD - Prince Georges, Non-TOD	11.7786	7.0686	16.4886	***
Other Counties, Non-TOD - Montgomery, Non-TOD	12.7175	7.8477	17.5873	***
Other Counties, Non-TOD - Fairfax County, Non-TOD	13.2789	8.6876	17.8702	***
Other Counties, Non-TOD - Prince Georges, TOD	15.3612	8.4341	22.2883	***
Other Counties, Non-TOD - Arlington, TOD	17.0954	9.8145	24.3762	***
Other Counties, Non-TOD - Fairfax County, TOD	17.3941	9.0415	25.7467	***
Other Counties, Non-TOD - Montgomery,	18.3118	12.3100	24.3135	***

Comparisons significant at the 0.05 level are indicated by ***.

CtyHm Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
TOD				
Other Counties, Non-TOD - District of Columbia, Non-TOD	19.8422	13.7906	25.8937	***
Other Counties, Non-TOD - Arlington, Non-TOD	20.1873	12.6938	27.6808	***
Other Counties, Non-TOD - City of Alexandria, Non-TOD	20.1897	12.3630	28.0164	***
Other Counties, Non-TOD - City of Alexandria, TOD	20.7245	11.4875	29.9615	***
Other Counties, Non-TOD - District of Columbia, TOD	21.7602	16.7219	26.7984	***
Charles, Non-TOD - Fauquier, Non-TOD	-11.9289	-25.9849	2.1272	
Charles, Non-TOD - Other Counties, Non-TOD	-1.1257	-10.0271	7.7757	
Charles, Non-TOD - Loudoun, Non-TOD	1.3650	-7.7600	10.4899	
Charles, Non-TOD - Prince Williams, Non-TOD	6.0577	-2.8810	14.9965	
Charles, Non-TOD - Stafford, Non-TOD	7.0520	-6.6021	20.7061	
Charles, Non-TOD - Anne Arundel, Non-TOD	9.2705	-1.3562	19.8972	
Charles, Non-TOD - Howard, Non-TOD	9.4946	-2.2284	21.2177	
Charles, Non-TOD - Prince Georges, Non-TOD	10.6529	2.2392	19.0666	***
Charles, Non-TOD - Montgomery, Non-TOD	11.5918	3.0876	20.0960	***
Charles, Non-TOD - Fairfax County, Non-TOD	12.1532	3.8054	20.5010	***
Charles, Non-TOD - Prince Georges, TOD	14.2355	4.4074	24.0635	***
Charles, Non-TOD - Arlington, TOD	15.9696	5.8891	26.0502	***
Charles, Non-TOD - Fairfax County, TOD	16.2684	5.3885	27.1483	***
Charles, Non-TOD - Montgomery, TOD	17.1860	7.9867	26.3853	***
Charles, Non-TOD - District of Columbia, Non-TOD	18.7165	9.4846	27.9484	***
Charles, Non-TOD - Arlington, Non-TOD	19.0616	8.8264	29.2968	***
Charles, Non-TOD - City of Alexandria, Non-TOD	19.0640	8.5824	29.5455	***
Charles, Non-TOD - City of Alexandria, TOD	19.5988	8.0260	31.1715	***
Charles, Non-TOD - District of Columbia, TOD	20.6345	12.0327	29.2362	***

Comparisons significant at the 0.05 level are indicated by ***.

CtyHm Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
Loudoun, Non-TOD - Fauquier, Non-TOD	-13.2939	-25.6630	-0.9247	***
Loudoun, Non-TOD - Other Counties, Non-TOD	-2.4907	-8.3778	3.3965	
Loudoun, Non-TOD - Charles, Non-TOD	-1.3650	-10.4899	7.7600	
Loudoun, Non-TOD - Prince Williams, Non-TOD	4.6928	-1.2507	10.6362	
Loudoun, Non-TOD - Stafford, Non-TOD	5.6870	-6.2234	17.5975	
Loudoun, Non-TOD - Anne Arundel, Non-TOD	7.9056	-0.3619	16.1730	
Loudoun, Non-TOD - Howard, Non-TOD	8.1297	-1.5064	17.7657	
Loudoun, Non-TOD - Prince Georges, Non-TOD	9.2879	4.1679	14.4079	***
Loudoun, Non-TOD - Montgomery, Non-TOD	10.2268	4.9594	15.4942	***
Loudoun, Non-TOD - Fairfax County, Non-TOD	10.7882	5.7773	15.7992	***
Loudoun, Non-TOD - Prince Georges, TOD	12.8705	5.6584	20.0826	***
Loudoun, Non-TOD - Arlington, TOD	14.6047	7.0521	22.1572	***
Loudoun, Non-TOD - Fairfax County, TOD	14.9034	6.3130	23.4938	***
Loudoun, Non-TOD - Montgomery, TOD	15.8211	9.4925	22.1497	***
Loudoun, Non-TOD - District of Columbia, Non-TOD	17.3515	10.9757	23.7273	***
Loudoun, Non-TOD - Arlington, Non-TOD	17.6966	9.9389	25.4544	***
Loudoun, Non-TOD - City of Alexandria, Non-TOD	17.6990	9.6189	25.7790	***
Loudoun, Non-TOD - City of Alexandria, TOD	18.2338	8.7811	27.6865	***
Loudoun, Non-TOD - District of Columbia, TOD	19.2695	13.8460	24.6930	***
Prince Williams, Non-TOD - Fauquier, Non-TOD	-17.9866	-30.2190	-5.7542	***
Prince Williams, Non-TOD - Other Counties, Non-TOD	-7.1835	-12.7776	-1.5893	***
Prince Williams, Non-TOD - Charles, Non-TOD	-6.0577	-14.9965	2.8810	
Prince Williams, Non-TOD - Loudoun, Non-TOD	-4.6928	-10.6362	1.2507	
Prince Williams, Non-TOD - Stafford, Non-TOD	0.9942	-10.7741	12.7626	
Prince Williams, Non-TOD - Anne	3.2128	-4.8486	11.2742	

Comparisons significant at the 0.05 level are indicated by ***.

CtyHm Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
Arundel, Non-TOD				
Prince Williams, Non-TOD - Howard, Non-TOD	3.4369	-6.0230	12.8968	
Prince Williams, Non-TOD - Prince Georges, Non-TOD	4.5952	-0.1850	9.3753	
Prince Williams, Non-TOD - Montgomery, Non-TOD	5.5340	0.5963	10.4718	***
Prince Williams, Non-TOD - Fairfax County, Non-TOD	6.0955	1.4322	10.7587	***
Prince Williams, Non-TOD - Prince Georges, TOD	8.1777	1.2027	15.1527	***
Prince Williams, Non-TOD - Arlington, TOD	9.9119	2.5855	17.2384	***
Prince Williams, Non-TOD - Fairfax County, TOD	10.2107	1.8183	18.6030	***
Prince Williams, Non-TOD - Montgomery, TOD	11.1283	5.0713	17.1853	***
Prince Williams, Non-TOD - District of Columbia, Non-TOD	12.6587	6.5524	18.7650	***
Prince Williams, Non-TOD - Arlington, Non-TOD	13.0039	5.4661	20.5417	***
Prince Williams, Non-TOD - City of Alexandria, Non-TOD	13.0062	5.1371	20.8753	***
Prince Williams, Non-TOD - City of Alexandria, TOD	13.5410	4.2680	22.8140	***
Prince Williams, Non-TOD - District of Columbia, TOD	14.5767	9.4728	19.6806	***
Stafford, Non-TOD - Fauquier, Non-TOD	-18.9809	-34.9861	-2.9756	***
Stafford, Non-TOD - Other Counties, Non-TOD	-8.1777	-19.9177	3.5624	
Stafford, Non-TOD - Charles, Non-TOD	-7.0520	-20.7061	6.6021	
Stafford, Non-TOD - Loudoun, Non-TOD	-5.6870	-17.5975	6.2234	
Stafford, Non-TOD - Prince Williams, Non-TOD	-0.9942	-12.7626	10.7741	
Stafford, Non-TOD - Anne Arundel, Non-TOD	2.2186	-10.8780	15.3151	
Stafford, Non-TOD - Howard, Non-TOD	2.4427	-11.5582	16.4435	
Stafford, Non-TOD - Prince Georges, Non-TOD	3.6009	-7.7738	14.9757	
Stafford, Non-TOD - Montgomery, Non-TOD	4.5398	-6.9020	15.9816	

Comparisons significant at the 0.05 level are indicated by ***.

CtyHm Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
Stafford, Non-TOD - Fairfax County, Non-TOD	5.1012	-6.2248	16.4273	
Stafford, Non-TOD - Prince Georges, TOD	7.1835	-5.2738	19.6408	
Stafford, Non-TOD - Arlington, TOD	8.9177	-3.7398	21.5751	
Stafford, Non-TOD - Fairfax County, TOD	9.2164	-4.0864	22.5192	
Stafford, Non-TOD - Montgomery, TOD	10.1341	-1.8334	22.1016	
Stafford, Non-TOD - District of Columbia, Non-TOD	11.6645	-0.3280	23.6571	
Stafford, Non-TOD - Arlington, Non-TOD	12.0096	-0.7713	24.7906	
Stafford, Non-TOD - City of Alexandria, Non-TOD	12.0120	-0.9671	24.9911	
Stafford, Non-TOD - City of Alexandria, TOD	12.5468	-1.3285	26.4221	
Stafford, Non-TOD - District of Columbia, TOD	13.5825	2.0680	25.0970	***
Anne Arundel, Non-TOD - Fauquier, Non-TOD	-21.1994	-34.7145	-7.6843	***
Anne Arundel, Non-TOD - Other Counties, Non-TOD	-10.3962	-18.4162	-2.3763	***
Anne Arundel, Non-TOD - Charles, Non-TOD	-9.2705	-19.8972	1.3562	
Anne Arundel, Non-TOD - Loudoun, Non-TOD	-7.9056	-16.1730	0.3619	
Anne Arundel, Non-TOD - Prince Williams, Non-TOD	-3.2128	-11.2742	4.8486	
Anne Arundel, Non-TOD - Stafford, Non-TOD	-2.2186	-15.3151	10.8780	
Anne Arundel, Non-TOD - Howard, Non-TOD	0.2241	-10.8445	11.2927	
Anne Arundel, Non-TOD - Prince Georges, Non-TOD	1.3824	-6.0926	8.8574	
Anne Arundel, Non-TOD - Montgomery, Non-TOD	2.3212	-5.2555	9.8980	
Anne Arundel, Non-TOD - Fairfax County, Non-TOD	2.8827	-4.5181	10.2834	
Anne Arundel, Non-TOD - Prince Georges, TOD	4.9649	-4.0726	14.0024	
Anne Arundel, Non-TOD - Arlington, TOD	6.6991	-2.6123	16.0105	
Anne Arundel, Non-TOD - Fairfax	6.9979	-3.1735	17.1692	

Comparisons significant at the 0.05 level are indicated by ***.

CtyHm Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
County, TOD				
Anne Arundel, Non-TOD - Montgomery, TOD	7.9155	-0.4339	16.2649	
Anne Arundel, Non-TOD - District of Columbia, Non-TOD	9.4460	1.0607	17.8312	***
Anne Arundel, Non-TOD - Arlington, Non-TOD	9.7911	0.3125	19.2697	***
Anne Arundel, Non-TOD - City of Alexandria, Non-TOD	9.7934	0.0493	19.5376	***
Anne Arundel, Non-TOD - City of Alexandria, TOD	10.3282	-0.5811	21.2376	
Anne Arundel, Non-TOD - District of Columbia, TOD	11.3639	3.6779	19.0500	***
Howard, Non-TOD - Fauquier, Non-TOD	-21.4235	-35.8166	-7.0304	***
Howard, Non-TOD - Other Counties, Non-TOD	-10.6204	-20.0449	-1.1958	***
Howard, Non-TOD - Charles, Non-TOD	-9.4946	-21.2177	2.2284	
Howard, Non-TOD - Loudoun, Non-TOD	-8.1297	-17.7657	1.5064	
Howard, Non-TOD - Prince Williams, Non-TOD	-3.4369	-12.8968	6.0230	
Howard, Non-TOD - Stafford, Non-TOD	-2.4427	-16.4435	11.5582	
Howard, Non-TOD - Anne Arundel, Non-TOD	-0.2241	-11.2927	10.8445	
Howard, Non-TOD - Prince Georges, Non-TOD	1.1583	-7.8072	10.1237	
Howard, Non-TOD - Montgomery, Non-TOD	2.0971	-6.9533	11.1475	
Howard, Non-TOD - Fairfax County, Non-TOD	2.6586	-6.2450	11.5622	
Howard, Non-TOD - Prince Georges, TOD	4.7408	-5.5635	15.0451	
Howard, Non-TOD - Arlington, TOD	6.4750	-4.0704	17.0204	
Howard, Non-TOD - Fairfax County, TOD	6.7737	-4.5382	18.0857	
Howard, Non-TOD - Montgomery, TOD	7.6914	-2.0151	17.3979	
Howard, Non-TOD - District of Columbia, Non-TOD	9.2218	-0.5155	18.9592	
Howard, Non-TOD - Arlington, Non-TOD	9.5670	-1.1263	20.2603	
Howard, Non-TOD - City of Alexandria, Non-TOD	9.5693	-1.3601	20.4987	
Howard, Non-TOD - City of Alexandria, TOD	10.1041	-1.8757	22.0840	

Comparisons significant at the 0.05 level are indicated by ***.

CtyHm Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
Howard, Non-TOD - District of Columbia, TOD	11.1398	1.9977	20.2819	***
Prince Georges, Non-TOD - Fauquier, Non-TOD	-22.5818	-34.4360	-10.7276	***
Prince Georges, Non-TOD - Other Counties, Non-TOD	-11.7786	-16.4886	-7.0686	***
Prince Georges, Non-TOD - Charles, Non-TOD	-10.6529	-19.0666	-2.2392	***
Prince Georges, Non-TOD - Loudoun, Non-TOD	-9.2879	-14.4079	-4.1679	***
Prince Georges, Non-TOD - Prince Williams, Non-TOD	-4.5952	-9.3753	0.1850	
Prince Georges, Non-TOD - Stafford, Non-TOD	-3.6009	-14.9757	7.7738	
Prince Georges, Non-TOD - Anne Arundel, Non-TOD	-1.3824	-8.8574	6.0926	
Prince Georges, Non-TOD - Howard, Non-TOD	-1.1583	-10.1237	7.8072	
Prince Georges, Non-TOD - Montgomery, Non-TOD	0.9389	-2.9689	4.8467	
Prince Georges, Non-TOD - Fairfax County, Non-TOD	1.5003	-2.0543	5.0549	
Prince Georges, Non-TOD - Prince Georges, TOD	3.5826	-2.7056	9.8707	
Prince Georges, Non-TOD - Arlington, TOD	5.3167	-1.3591	11.9926	
Prince Georges, Non-TOD - Fairfax County, TOD	5.6155	-2.2153	13.4462	
Prince Georges, Non-TOD - Montgomery, TOD	6.5331	1.2818	11.7845	***
Prince Georges, Non-TOD - District of Columbia, Non-TOD	8.0636	2.7554	13.3718	***
Prince Georges, Non-TOD - Arlington, Non-TOD	8.4087	1.5016	15.3158	***
Prince Georges, Non-TOD - City of Alexandria, Non-TOD	8.4110	1.1438	15.6783	***
Prince Georges, Non-TOD - City of Alexandria, TOD	8.9459	0.1778	17.7139	***
Prince Georges, Non-TOD - District of Columbia, TOD	9.9816	5.8658	14.0973	***
Montgomery, Non-TOD - Fauquier, Non-TOD	-23.5207	-35.4393	-11.6021	***

Comparisons significant at the 0.05 level are indicated by ***.

CtyHm Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
Montgomery, Non-TOD - Other Counties, Non-TOD	-12.7175	-17.5873	-7.8477	***
Montgomery, Non-TOD - Charles, Non-TOD	-11.5918	-20.0960	-3.0876	***
Montgomery, Non-TOD - Loudoun, Non-TOD	-10.2268	-15.4942	-4.9594	***
Montgomery, Non-TOD - Prince Williams, Non-TOD	-5.5340	-10.4718	-0.5963	***
Montgomery, Non-TOD - Stafford, Non-TOD	-4.5398	-15.9816	6.9020	
Montgomery, Non-TOD - Anne Arundel, Non-TOD	-2.3212	-9.8980	5.2555	
Montgomery, Non-TOD - Howard, Non-TOD	-2.0971	-11.1475	6.9533	
Montgomery, Non-TOD - Prince Georges, Non-TOD	-0.9389	-4.8467	2.9689	
Montgomery, Non-TOD - Fairfax County, Non-TOD	0.5614	-3.2024	4.3253	
Montgomery, Non-TOD - Prince Georges, TOD	2.6437	-3.7650	9.0524	
Montgomery, Non-TOD - Arlington, TOD	4.3779	-2.4117	11.1674	
Montgomery, Non-TOD - Fairfax County, TOD	4.6766	-3.2513	12.6045	
Montgomery, Non-TOD - Montgomery, TOD	5.5943	0.1991	10.9894	***
Montgomery, Non-TOD - District of Columbia, Non-TOD	7.1247	1.6742	12.5752	***
Montgomery, Non-TOD - Arlington, Non-TOD	7.4698	0.4528	14.4869	***
Montgomery, Non-TOD - City of Alexandria, Non-TOD	7.4722	0.1003	14.8440	***
Montgomery, Non-TOD - City of Alexandria, TOD	8.0070	-0.8479	16.8619	
Montgomery, Non-TOD - District of Columbia, TOD	9.0427	4.7449	13.3404	***
Fairfax County, Non-TOD - Fauquier, Non-TOD	-24.0821	-35.8896	-12.2746	***
Fairfax County, Non-TOD - Other Counties, Non-TOD	-13.2789	-17.8702	-8.6876	***
Fairfax County, Non-TOD - Charles, Non-TOD	-12.1532	-20.5010	-3.8054	***
Fairfax County, Non-TOD - Loudoun, Non-TOD	-10.7882	-15.7992	-5.7773	***
Fairfax County, Non-TOD - Prince Williams, Non-TOD	-6.0955	-10.7587	-1.4322	***

Comparisons significant at the 0.05 level are indicated by ***.

CtyHm Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
Fairfax County, Non-TOD - Stafford, Non-TOD	-5.1012	-16.4273	6.2248	
Fairfax County, Non-TOD - Anne Arundel, Non-TOD	-2.8827	-10.2834	4.5181	
Fairfax County, Non-TOD - Howard, Non-TOD	-2.6586	-11.5622	6.2450	
Fairfax County, Non-TOD - Prince Georges, Non-TOD	-1.5003	-5.0549	2.0543	
Fairfax County, Non-TOD - Montgomery, Non-TOD	-0.5614	-4.3253	3.2024	
Fairfax County, Non-TOD - Prince Georges, TOD	2.0823	-4.1174	8.2819	
Fairfax County, Non-TOD - Arlington, TOD	3.8164	-2.7761	10.4090	
Fairfax County, Non-TOD - Fairfax County, TOD	4.1152	-3.6447	11.8751	
Fairfax County, Non-TOD - Montgomery, TOD	5.0328	-0.1123	10.1779	
Fairfax County, Non-TOD - District of Columbia, Non-TOD	6.5633	1.3602	11.7664	***
Fairfax County, Non-TOD - Arlington, Non-TOD	6.9084	0.0817	13.7351	***
Fairfax County, Non-TOD - City of Alexandria, Non-TOD	6.9108	-0.2801	14.1016	
Fairfax County, Non-TOD - City of Alexandria, TOD	7.4456	-1.2592	16.1504	
Fairfax County, Non-TOD - District of Columbia, TOD	8.4813	4.5019	12.4606	***
Prince Georges, TOD - Fauquier, Non-TOD	-26.1643	-39.0610	-13.2677	***
Prince Georges, TOD - Other Counties, Non-TOD	-15.3612	-22.2883	-8.4341	***
Prince Georges, TOD - Charles, Non-TOD	-14.2355	-24.0635	-4.4074	***
Prince Georges, TOD - Loudoun, Non-TOD	-12.8705	-20.0826	-5.6584	***
Prince Georges, TOD - Prince Williams, Non-TOD	-8.1777	-15.1527	-1.2027	***
Prince Georges, TOD - Stafford, Non-TOD	-7.1835	-19.6408	5.2738	
Prince Georges, TOD - Anne Arundel, Non-TOD	-4.9649	-14.0024	4.0726	
Prince Georges, TOD - Howard, Non-TOD	-4.7408	-15.0451	5.5635	

Comparisons significant at the 0.05 level are indicated by ***.

CtyHm Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
Prince Georges, TOD - Prince Georges, Non-TOD	-3.5826	-9.8707	2.7056	
Prince Georges, TOD - Montgomery, Non-TOD	-2.6437	-9.0524	3.7650	
Prince Georges, TOD - Fairfax County, Non-TOD	-2.0823	-8.2819	4.1174	
Prince Georges, TOD - Arlington, TOD	1.7342	-6.6543	10.1227	
Prince Georges, TOD - Fairfax County, TOD	2.0329	-7.3010	11.3668	
Prince Georges, TOD - Montgomery, TOD	2.9506	-4.3554	10.2566	
Prince Georges, TOD - District of Columbia, Non-TOD	4.4810	-2.8659	11.8280	
Prince Georges, TOD - Arlington, Non-TOD	4.8262	-3.7476	13.3999	
Prince Georges, TOD - City of Alexandria, Non-TOD	4.8285	-4.0379	13.6949	
Prince Georges, TOD - City of Alexandria, TOD	5.3633	-4.7697	15.4964	
Prince Georges, TOD - District of Columbia, TOD	6.3990	-0.1386	12.9366	
Arlington, TOD - Fauquier, Non-TOD	-27.8985	-40.9886	-14.8085	***
Arlington, TOD - Other Counties, Non-TOD	-17.0954	-24.3762	-9.8145	***
Arlington, TOD - Charles, Non-TOD	-15.9696	-26.0502	-5.8891	***
Arlington, TOD - Loudoun, Non-TOD	-14.6047	-22.1572	-7.0521	***
Arlington, TOD - Prince Williams, Non-TOD	-9.9119	-17.2384	-2.5855	***
Arlington, TOD - Stafford, Non-TOD	-8.9177	-21.5751	3.7398	
Arlington, TOD - Anne Arundel, Non-TOD	-6.6991	-16.0105	2.6123	
Arlington, TOD - Howard, Non-TOD	-6.4750	-17.0204	4.0704	
Arlington, TOD - Prince Georges, Non-TOD	-5.3167	-11.9926	1.3591	
Arlington, TOD - Montgomery, Non-TOD	-4.3779	-11.1674	2.4117	
Arlington, TOD - Fairfax County, Non-TOD	-3.8164	-10.4090	2.7761	
Arlington, TOD - Prince Georges, TOD	-1.7342	-10.1227	6.6543	
Arlington, TOD - Fairfax County, TOD	0.2987	-9.3006	9.8981	
Arlington, TOD - Montgomery, TOD	1.2164	-6.4258	8.8586	

Comparisons significant at the 0.05 level are indicated by ***.

CtyHm Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
Arlington, TOD - District of Columbia, Non-TOD	2.7468	-4.9346	10.4282	
Arlington, TOD - Arlington, Non-TOD	3.0920	-5.7700	11.9540	
Arlington, TOD - City of Alexandria, Non-TOD	3.0943	-6.0512	12.2398	
Arlington, TOD - City of Alexandria, TOD	3.6291	-6.7490	14.0072	
Arlington, TOD - District of Columbia, TOD	4.6648	-2.2465	11.5761	
Fairfax County, TOD - Fauquier, Non-TOD	-28.1973	-41.9123	-14.4822	***
Fairfax County, TOD - Other Counties, Non-TOD	-17.3941	-25.7467	-9.0415	***
Fairfax County, TOD - Charles, Non-TOD	-16.2684	-27.1483	-5.3885	***
Fairfax County, TOD - Loudoun, Non-TOD	-14.9034	-23.4938	-6.3130	***
Fairfax County, TOD - Prince Williams, Non-TOD	-10.2107	-18.6030	-1.8183	***
Fairfax County, TOD - Stafford, Non-TOD	-9.2164	-22.5192	4.0864	
Fairfax County, TOD - Anne Arundel, Non-TOD	-6.9979	-17.1692	3.1735	
Fairfax County, TOD - Howard, Non-TOD	-6.7737	-18.0857	4.5382	
Fairfax County, TOD - Prince Georges, Non-TOD	-5.6155	-13.4462	2.2153	
Fairfax County, TOD - Montgomery, Non-TOD	-4.6766	-12.6045	3.2513	
Fairfax County, TOD - Fairfax County, Non-TOD	-4.1152	-11.8751	3.6447	
Fairfax County, TOD - Prince Georges, TOD	-2.0329	-11.3668	7.3010	
Fairfax County, TOD - Arlington, TOD	-0.2987	-9.8981	9.3006	
Fairfax County, TOD - Montgomery, TOD	0.9176	-7.7517	9.5870	
Fairfax County, TOD - District of Columbia, Non-TOD	2.4481	-6.2558	11.1520	
Fairfax County, TOD - Arlington, Non-TOD	2.7932	-6.9684	12.5548	
Fairfax County, TOD - City of Alexandria, Non-TOD	2.7956	-7.2241	12.8152	
Fairfax County, TOD - City of Alexandria, TOD	3.3304	-7.8257	14.4865	

Comparisons significant at the 0.05 level are indicated by ***.

CtyHm Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
Fairfax County, TOD - District of Columbia, TOD	4.3661	-3.6664	12.3985	
Montgomery, TOD - Fauquier, Non-TOD	-29.1149	-41.5390	-16.6908	***
Montgomery, TOD - Other Counties, Non-TOD	-18.3118	-24.3135	-12.3100	***
Montgomery, TOD - Charles, Non-TOD	-17.1860	-26.3853	-7.9867	***
Montgomery, TOD - Loudoun, Non-TOD	-15.8211	-22.1497	-9.4925	***
Montgomery, TOD - Prince Williams, Non-TOD	-11.1283	-17.1853	-5.0713	***
Montgomery, TOD - Stafford, Non-TOD	-10.1341	-22.1016	1.8334	
Montgomery, TOD - Anne Arundel, Non-TOD	-7.9155	-16.2649	0.4339	
Montgomery, TOD - Howard, Non-TOD	-7.6914	-17.3979	2.0151	
Montgomery, TOD - Prince Georges, Non-TOD	-6.5331	-11.7845	-1.2818	***
Montgomery, TOD - Montgomery, Non-TOD	-5.5943	-10.9894	-0.1991	***
Montgomery, TOD - Fairfax County, Non-TOD	-5.0328	-10.1779	0.1123	
Montgomery, TOD - Prince Georges, TOD	-2.9506	-10.2566	4.3554	
Montgomery, TOD - Arlington, TOD	-1.2164	-8.8586	6.4258	
Montgomery, TOD - Fairfax County, TOD	-0.9176	-9.5870	7.7517	
Montgomery, TOD - District of Columbia, Non-TOD	1.5304	-4.9513	8.0122	
Montgomery, TOD - Arlington, Non-TOD	1.8756	-5.9695	9.7206	
Montgomery, TOD - City of Alexandria, Non-TOD	1.8779	-6.2860	10.0418	
Montgomery, TOD - City of Alexandria, TOD	2.4127	-7.1117	11.9372	
Montgomery, TOD - District of Columbia, TOD	3.4484	-2.0992	8.9961	
District of Columbia, Non-TOD - Fauquier, Non-TOD	-30.6454	-43.0936	-18.1971	***
District of Columbia, Non-TOD - Other Counties, Non-TOD	-19.8422	-25.8937	-13.7906	***
District of Columbia, Non-TOD - Charles, Non-TOD	-18.7165	-27.9484	-9.4846	***
District of Columbia, Non-TOD - Loudoun, Non-TOD	-17.3515	-23.7273	-10.9757	***
District of Columbia, Non-TOD - Prince	-12.6587	-18.7650	-6.5524	***

Comparisons significant at the 0.05 level are indicated by ***.

CtyHm Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
Williams, Non-TOD				
District of Columbia, Non-TOD - Stafford, Non-TOD	-11.6645	-23.6571	0.3280	
District of Columbia, Non-TOD - Anne Arundel, Non-TOD	-9.4460	-17.8312	-1.0607	***
District of Columbia, Non-TOD - Howard, Non-TOD	-9.2218	-18.9592	0.5155	
District of Columbia, Non-TOD - Prince Georges, Non-TOD	-8.0636	-13.3718	-2.7554	***
District of Columbia, Non-TOD - Montgomery, Non-TOD	-7.1247	-12.5752	-1.6742	***
District of Columbia, Non-TOD - Fairfax County, Non-TOD	-6.5633	-11.7664	-1.3602	***
District of Columbia, Non-TOD - Prince Georges, TOD	-4.4810	-11.8280	2.8659	
District of Columbia, Non-TOD - Arlington, TOD	-2.7468	-10.4282	4.9346	
District of Columbia, Non-TOD - Fairfax County, TOD	-2.4481	-11.1520	6.2558	
District of Columbia, Non-TOD - Montgomery, TOD	-1.5304	-8.0122	4.9513	
District of Columbia, Non-TOD - Arlington, Non-TOD	0.3451	-7.5381	8.2283	
District of Columbia, Non-TOD - City of Alexandria, Non-TOD	0.3475	-7.8531	8.5481	
District of Columbia, Non-TOD - City of Alexandria, TOD	0.8823	-8.6736	10.4382	
District of Columbia, Non-TOD - District of Columbia, TOD	1.9180	-3.6835	7.5195	
Arlington, Non-TOD - Fauquier, Non-TOD	-30.9905	-44.2000	-17.7810	***
Arlington, Non-TOD - Other Counties, Non-TOD	-20.1873	-27.6808	-12.6938	***
Arlington, Non-TOD - Charles, Non-TOD	-19.0616	-29.2968	-8.8264	***
Arlington, Non-TOD - Loudoun, Non-TOD	-17.6966	-25.4544	-9.9389	***
Arlington, Non-TOD - Prince Williams, Non-TOD	-13.0039	-20.5417	-5.4661	***
Arlington, Non-TOD - Stafford, Non-TOD	-12.0096	-24.7906	0.7713	
Arlington, Non-TOD - Anne Arundel, Non-TOD	-9.7911	-19.2697	-0.3125	***
Arlington, Non-TOD - Howard, Non-TOD	-9.5670	-20.2603	1.1263	

Comparisons significant at the 0.05 level are indicated by ***.

CtyHm Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
Arlington, Non-TOD - Prince Georges, Non-TOD	-8.4087	-15.3158	-1.5016	***
Arlington, Non-TOD - Montgomery, Non-TOD	-7.4698	-14.4869	-0.4528	***
Arlington, Non-TOD - Fairfax County, Non-TOD	-6.9084	-13.7351	-0.0817	***
Arlington, Non-TOD - Prince Georges, TOD	-4.8262	-13.3999	3.7476	
Arlington, Non-TOD - Arlington, TOD	-3.0920	-11.9540	5.7700	
Arlington, Non-TOD - Fairfax County, TOD	-2.7932	-12.5548	6.9684	
Arlington, Non-TOD - Montgomery, TOD	-1.8756	-9.7206	5.9695	
Arlington, Non-TOD - District of Columbia, Non-TOD	-0.3451	-8.2283	7.5381	
Arlington, Non-TOD - City of Alexandria, Non-TOD	0.0023	-9.3133	9.3180	
Arlington, Non-TOD - City of Alexandria, TOD	0.5372	-9.9912	11.0655	
Arlington, Non-TOD - District of Columbia, TOD	1.5729	-5.5621	8.7078	
City of Alexandria, Non-TOD - Fauquier, Non-TOD	-30.9928	-44.3941	-17.5915	***
City of Alexandria, Non-TOD - Other Counties, Non-TOD	-20.1897	-28.0164	-12.3630	***
City of Alexandria, Non-TOD - Charles, Non-TOD	-19.0640	-29.5455	-8.5824	***
City of Alexandria, Non-TOD - Loudoun, Non-TOD	-17.6990	-25.7790	-9.6189	***
City of Alexandria, Non-TOD - Prince Williams, Non-TOD	-13.0062	-20.8753	-5.1371	***
City of Alexandria, Non-TOD - Stafford, Non-TOD	-12.0120	-24.9911	0.9671	
City of Alexandria, Non-TOD - Anne Arundel, Non-TOD	-9.7934	-19.5376	-0.0493	***
City of Alexandria, Non-TOD - Howard, Non-TOD	-9.5693	-20.4987	1.3601	
City of Alexandria, Non-TOD - Prince Georges, Non-TOD	-8.4110	-15.6783	-1.1438	***
City of Alexandria, Non-TOD - Montgomery, Non-TOD	-7.4722	-14.8440	-0.1003	***
City of Alexandria, Non-TOD - Fairfax County, Non-TOD	-6.9108	-14.1016	0.2801	

Comparisons significant at the 0.05 level are indicated by ***.

CtyHm Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
City of Alexandria, Non-TOD - Prince Georges, TOD	-4.8285	-13.6949	4.0379	
City of Alexandria, Non-TOD - Arlington, TOD	-3.0943	-12.2398	6.0512	
City of Alexandria, Non-TOD - Fairfax County, TOD	-2.7956	-12.8152	7.2241	
City of Alexandria, Non-TOD - Montgomery, TOD	-1.8779	-10.0418	6.2860	
City of Alexandria, Non-TOD - District of Columbia, Non-TOD	-0.3475	-8.5481	7.8531	
City of Alexandria, Non-TOD - Arlington, Non-TOD	-0.0023	-9.3180	9.3133	
City of Alexandria, Non-TOD - City of Alexandria, TOD	0.5348	-10.2332	11.3029	
City of Alexandria, Non-TOD - District of Columbia, TOD	1.5705	-5.9136	9.0547	
City of Alexandria, TOD - Fauquier, Non-TOD	-31.5277	-45.7986	-17.2567	***
City of Alexandria, TOD - Other Counties, Non-TOD	-20.7245	-29.9615	-11.4875	***
City of Alexandria, TOD - Charles, Non-TOD	-19.5988	-31.1715	-8.0260	***
City of Alexandria, TOD - Loudoun, Non-TOD	-18.2338	-27.6865	-8.7811	***
City of Alexandria, TOD - Prince Williams, Non-TOD	-13.5410	-22.8140	-4.2680	***
City of Alexandria, TOD - Stafford, Non-TOD	-12.5468	-26.4221	1.3285	
City of Alexandria, TOD - Anne Arundel, Non-TOD	-10.3282	-21.2376	0.5811	
City of Alexandria, TOD - Howard, Non-TOD	-10.1041	-22.0840	1.8757	
City of Alexandria, TOD - Prince Georges, Non-TOD	-8.9459	-17.7139	-0.1778	***
City of Alexandria, TOD - Montgomery, Non-TOD	-8.0070	-16.8619	0.8479	
City of Alexandria, TOD - Fairfax County, Non-TOD	-7.4456	-16.1504	1.2592	
City of Alexandria, TOD - Prince Georges, TOD	-5.3633	-15.4964	4.7697	
City of Alexandria, TOD - Arlington, TOD	-3.6291	-14.0072	6.7490	

Comparisons significant at the 0.05 level are indicated by ***.

CtyHm Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
City of Alexandria, TOD - Fairfax County, TOD	-3.3304	-14.4865	7.8257	
City of Alexandria, TOD - Montgomery, TOD	-2.4127	-11.9372	7.1117	
City of Alexandria, TOD - District of Columbia, Non-TOD	-0.8823	-10.4382	8.6736	
City of Alexandria, TOD - Arlington, Non-TOD	-0.5372	-11.0655	9.9912	
City of Alexandria, TOD - City of Alexandria, Non-TOD	-0.5348	-11.3029	10.2332	
City of Alexandria, TOD - District of Columbia, TOD	1.0357	-7.9129	9.9843	
District of Columbia, TOD - Fauquier, Non-TOD	-32.5633	-44.5518	-20.5749	***
District of Columbia, TOD - Other Counties, Non-TOD	-21.7602	-26.7984	-16.7219	***
District of Columbia, TOD - Charles, Non-TOD	-20.6345	-29.2362	-12.0327	***
District of Columbia, TOD - Loudoun, Non-TOD	-19.2695	-24.6930	-13.8460	***
District of Columbia, TOD - Prince Williams, Non-TOD	-14.5767	-19.6806	-9.4728	***
District of Columbia, TOD - Stafford, Non-TOD	-13.5825	-25.0970	-2.0680	***
District of Columbia, TOD - Anne Arundel, Non-TOD	-11.3639	-19.0500	-3.6779	***
District of Columbia, TOD - Howard, Non-TOD	-11.1398	-20.2819	-1.9977	***
District of Columbia, TOD - Prince Georges, Non-TOD	-9.9816	-14.0973	-5.8658	***
District of Columbia, TOD - Montgomery, Non-TOD	-9.0427	-13.3404	-4.7449	***
District of Columbia, TOD - Fairfax County, Non-TOD	-8.4813	-12.4606	-4.5019	***
District of Columbia, TOD - Prince Georges, TOD	-6.3990	-12.9366	0.1386	
District of Columbia, TOD - Arlington, TOD	-4.6648	-11.5761	2.2465	
District of Columbia, TOD - Fairfax County, TOD	-4.3661	-12.3985	3.6664	
District of Columbia, TOD - Montgomery, TOD	-3.4484	-8.9961	2.0992	

Comparisons significant at the 0.05 level are indicated by ***.

CtyHm Comparison	Difference Between Means	Simultaneous 95% Confidence Limits	
District of Columbia, TOD - District of Columbia, Non-TOD	-1.9180	-7.5195	3.6835
District of Columbia, TOD - Arlington, Non-TOD	-1.5729	-8.7078	5.5621
District of Columbia, TOD - City of Alexandria, Non-TOD	-1.5705	-9.0547	5.9136
District of Columbia, TOD - City of Alexandria, TOD	-1.0357	-9.9843	7.9129

APPENDIX B: SCENARIO DATA, MODEL OUTPUT

B-1: Development Square Footage for Various Uses Across Scenarios

TREND SCENARIO	Square Feet		
	Full Build Out Potential	Horizon Year Estimate	Existing Development*
Retail	658985	118685	118685
Office	8613488	2318286	1843586
Data center	3948042	1108336	108336
Industrial	427000	427000	0
Other	235216	235216	52216

TOD SCENARIO	Square Feet		
	Full Build Out Potential	Horizon Year Estimate	Existing Development*
Retail	887864	504164	118685
Office	9615202	3600817	1843586
Data center	2301936	1173436	108336
Industrial	0	0	0
Other	52216	52216	52216

HOUSING SCENARIO	Square Feet		
	Full Build Out Potential	Horizon Year Estimate	Existing Development*
Retail	427464	233564	118685
Office	6221470	2374211	1843586
Data center	1878436	1180236	108336
Industrial	0	0	0
Other	52216	52216	52216

B-2: Build Out Potential for Scenarios at a Regional, Sub-Regional & Policy Level

SCENARIO DEMOGAPHY AT REGIONAL LEVEL					
LU In Silver Line Policy Area		HH	HHPOP	TOTPOP	TOTEMP
Trend Scenario	TR	3366709	8497061	8659205	5558281
Housing Scenario	HS	3373473	8513173	8675317	5558112
Transit Oriented Development Scenario	TOD	3374563	8511725	8673869	5566804
Recommended Scenario	RD	3373337	8509411	8671555	5567110
SCENARIO DEMOGAPHY AT SUB-REGIONAL LEVEL(COUNTY)					
LU In Silver Line Policy Area		HH	HHPOP	TOTPOP	TOTEMP
Trend Scenario	TR	165275	483031	484943	283246
Housing Scenario	HS	172039	499143	501055	283077
Transit Oriented Development Scenario	TOD	173129	497695	499607	291769
SCENARIO DEMOGAPHY AT POLICY LEVEL					
LU In Silver Line Policy Area		HH	HHPOP	TOTPOP	TOTEMP
Trend Scenario	TR	1928	4023	4023	8890
Housing Scenario	HS	8692	20135	20135	8347
Transit Oriented Development Scenario	TOD	9782	18687	18687	16079

B-3: Transit Share Files For HBW Trip Purpose

; Transit Share Table, HBW
; Simulation - Year: 2010 Alternative: Ver2.3.39_2010 Iteration: i4 File: i4_mc_NL_summary.tab
; Purpose: Internal HBW Trips MODE: Transit Percentage

;	DC CR 1	DC NC 2	MTG 3	PG 4	ARLCR 5	ARNCR 6	ALX 7	FFX 8	LDN 9	PW 10	FRD 11	CAR 12	HOW 13	AAR 14	CAL 15	STM 16	CHS 17	FAU 18	STA 19	CL/JF 20	SP/FB 21	KGEO/CAR 22	EXTL 23
1	73.7	89.7	73.2	46.4	91.7	94.1	83.2	44.0	0.1	9.3	0	0	4.0	1.0	0	0	0	0	0	0	0	0	0
2	92.1	84.0	67.2	41.5	84.9	89.7	79.6	35.7	0.1	5.6	0	0	2.7	0.9	0	0	0	0	0	0	0	0	0
3	56.2	30.5	16.6	7.3	51.2	39.5	19.7	4.6	0.0	0.1	0	0	0.3	0.1	0	0	0	0	0	0	0	0	0
4	54.8	31.7	19.5	8.4	53.2	44.1	19.8	6.7	0.0	0.2	0	0	1.5	0.5	0	0	0.0	0	0	0	0	0	0
5	97.5	70.4	48.6	22.5	23.0	68.8	55.0	20.8	0.1	2.1	0	0	0	0.3	0	0	0	0	0	0	0	0	0
6	81.4	49.3	29.3	11.6	47.5	41.5	37.3	12.3	0.1	1.0	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0
7	67.4	38.0	22.2	6.3	47.9	45.3	23.5	9.9	0.0	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0
8	43.9	22.3	10.6	2.3	45.3	36.1	18.6	5.3	0.1	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0
9	20.0	8.0	3.0	0.5	22.0	14.0	4.0	1.0	1.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	33.7	19.3	8.3	1.4	36.4	28.8	14.1	1.9	0.0	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0
11	27.5	8.6	3.4	0.8	16.4	11.4	4.8	0.4	0	0.0	1.1	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	36.2	14.1	4.8	2.4	34.9	25.0	9.8	1.2	0	0.0	0	0	0.7	0.1	0	0	0	0	0	0	0	0	0
14	33.2	11.2	4.5	1.7	27.8	20.8	7.8	1.5	0	0	0	0	0.2	0.1	0	0	0	0	0	0	0	0	0
15	14.5	10.6	4.6	0.9	23.9	17.4	6.1	0.8	0	0	0	0	0	0.1	0.1	0.0	0	0	0	0	0	0	0
16	6.2	3.6	1.8	0.2	8.4	5.7	1.7	0.2	0	0	0	0	0	0	0.0	0.2	0.2	0	0	0	0	0	0
17	23.0	12.9	6.9	1.0	26.2	19.5	6.5	1.3	0	0.0	0	0	0.0	0.0	0	0.1	1.3	0	0	0	0	0	0
18	5.9	4.1	1.2	0.2	8.2	6.6	3.3	0.1	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
19	20.0	11.3	4.5	0.5	23.5	17.8	6.5	0.2	0	0.1	0	0	0	0	0	0	0	0	0.0	0	0	0	0
20	15.0	12.2	3.4	1.2	18.1	11.4	4.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	24.0	15.9	6.5	0.8	29.1	22.7	11.8	0.3	0	0.5	0	0	0	0	0	0	0	0	0.0	0	0.0	0.0	0
22	1.8	1.2	0.7	0.0	3.8	3.4	2.0	0.0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

B-4: Vehicle Trips Across Scenarios at Regional and Sub-Regional Level

	Trips In Region		
Mode Shift	TD	HD	CD
As Is%	21100127	21146523	21149771
5%	21094720	21142524	21143024
10%	21088840	21138184	21140647
15%	21084647	21138184	21131892

	Trips Within County		
	TD	HD	CD
As Is%	1246294	1271518	1286253
5%	1244063	1269353	1283791
10%	1241835	1266858	1281383
15%	1239466	1266858	1278584

B-5: VMT -For Facility & Area Type By Scenario and %Mode Shift

	2-Med-High Mxd Density			3-Med Emp Density			4-Med Pop Den			Total (Including Low Density and Rural Areas)		
Transit Share = As Is	**TR**	**HS**	**CD**	**TR**	**HS**	**CD**	**TR**	**HS**	**CD**	**TR**	**HS**	**CD**
1-Freeway	676,686	705,510	707,055	2,150,359	2,144,964	2,146,331	240,683	241,889	242,447	4,229,356	4,246,009	4,255,624
3-Principal Arterial	0	0	102,251	871,144	881,157	775,891	0	0	0	1,078,043	1,086,264	1,084,860
4-Major Arterial	329,847	422,824	432,101	347,424	285,009	286,223	255,741	260,613	262,993	963,583	1,000,747	1,012,423
5-Minor Arterial	92,140	93,555	92,580	490,844	497,331	495,195	367,705	366,913	369,425	2,422,258	2,428,098	2,427,736
6-Major Collector	328,024	405,378	393,822	954,113	907,250	929,755	560,807	559,976	567,514	3,408,326	3,424,057	3,457,730
7-Minor Collector	123,646	161,848	185,120	273,381	239,901	224,950	173,174	174,265	175,727	728,067	733,576	742,662
8-Local	68,188	68,295	69,582	106,236	107,183	107,004	125,504	125,437	125,070	1,211,407	1,211,163	1,204,342
9-Unpaved	0	0	0	5,672	5,558	6,114	0	0	0	137,961	134,894	138,093
10-High Speed Ramp	74,241	74,815	77,081	106,881	107,299	104,937	5,133	5,123	5,148	245,164	245,707	245,791
11-Low Speed Ramp	70,391	74,073	74,510	113,324	110,476	110,358	19,123	18,930	18,846	235,867	236,877	236,814
Total	1,763,163	2,006,298	2,134,102	5,419,378	5,286,128	5,186,758	1,747,870	1,753,146	1,767,170	14,660,032	14,747,392	14,806,075

	2-Med-High Mxd Density			3-Med Emp Density			4-Med Pop Den			Total		
Transit Share= +5%	**TR**	**HS**	**CD**	**TR**	**HS**	**CD**	**TR**	**HS**	**CD**	**TR**	**HS**	**CD**
1-Freeway	675,391	699,218	703,238	2,146,061	2,132,232	2,136,587	239,668	238,296	241,657	4,225,289	4,216,177	4,241,435
3-Principal Arterial	0	0	101,974	868,049	881,168	772,199	0	0	0	1,074,092	1,085,628	1,078,463
4-Major Arterial	329,317	422,013	430,695	347,951	283,528	285,053	254,443	258,928	262,051	962,397	995,071	1,008,692
5-Minor Arterial	91,549	93,359	92,527	488,091	495,448	493,362	369,795	363,136	366,939	2,416,155	2,407,739	2,419,074
6-Major Collector	324,593	403,654	390,861	950,052	903,610	925,914	557,697	556,761	562,913	3,400,856	3,405,554	3,431,447
7-Minor Collector	123,046	161,094	184,514	271,564	238,376	224,180	172,917	173,504	174,926	726,168	727,728	739,743
8-Local	68,178	68,628	69,425	105,200	106,839	106,683	124,002	124,891	124,354	1,197,996	1,206,524	1,207,530
9-Unpaved	0	0	0	5,521	5,513	6,338	0	0	0	137,138	132,295	136,936
10-High Speed Ramp	73,959	74,876	77,137	106,460	107,086	104,613	5,096	5,086	5,135	244,722	245,538	245,544
11-Low Speed Ramp	70,516	73,925	74,112	112,532	110,463	110,442	18,763	19,044	18,906	234,944	236,568	236,628
Total	1,756,549	1,996,767	2,124,483	5,401,481	5,264,263	5,165,371	1,742,381	1,739,646	1,756,881	14,619,757	14,658,822	14,745,492

B-5: VMT For Facility & Area Type By Scenario and % Transit (Continued)

	2-Med-High Mxd Density			3-Med Emp Density			4-Med Pop Den			Total		
Transit Share = +10%	**TR**	**HS**	**CD**	**TR**	**HS**	**CD**	**TR**	**HS**	**CD**	**TR**	**HS**	**CD**
1-Freeway	671,889	701,257	699,433	2,131,193	2,132,875	2,128,466	237,501	239,823	239,768	4,179,941	4,226,433	4,223,449
3-Principal Arterial	0	0	102,208	865,589	879,381	772,141	0	0	0	1,071,648	1,085,534	1,082,760
4-Major Arterial	329,764	419,738	430,209	347,538	283,302	285,531	255,001	258,174	261,460	963,435	992,448	1,008,751
5-Minor Arterial	90,983	92,878	92,674	484,007	493,292	493,773	362,884	366,134	368,922	2,357,907	2,419,791	2,427,311
6-Major Collector	323,405	403,242	391,218	942,137	901,021	925,854	553,636	556,125	563,152	3,315,521	3,405,424	3,438,658
7-Minor Collector	123,140	160,542	184,476	268,351	238,023	223,827	171,243	172,819	174,738	720,491	727,332	740,680
8-Local	67,618	68,341	69,684	103,720	106,647	107,207	123,971	124,310	124,383	1,142,587	1,202,416	1,200,347
9-Unpaved	0	0	0	5,557	5,701	6,173	0	0	0	130,869	137,981	139,390
10-High Speed Ramp	73,784	75,324	77,320	106,081	107,432	104,485	5,012	5,146	5,128	242,959	245,844	245,242
11-Low Speed Ramp	69,838	73,744	73,741	111,996	110,563	110,622	18,891	18,990	18,941	233,425	236,387	236,079
Total	1,750,421	1,995,066	2,120,963	5,366,169	5,258,237	5,158,079	1,728,139	1,741,521	1,756,492	14,358,783	14,679,590	14,742,667

	2-Med-High Mxd Density			3-Med Emp Density			4-Med Pop Den			Total		
Transit Share = +15%	**TR**	**HS**	**CD**	**TR**	**HS**	**CD**	**TR**	**HS**	**CD**	**TR**	**HS**	**CD**
1-Freeway	669,230	701,257	699,537	2,121,197	2,132,875	2,122,323	236,290	239,823	240,091	4,161,859	4,226,433	4,213,026
3-Principal Arterial	0	0	101,565	864,725	879,381	770,267	0	0	0	1,068,725	1,085,534	1,074,431
4-Major Arterial	327,426	419,738	428,855	344,225	283,302	284,880	252,163	258,174	262,976	953,870	992,448	1,009,019
5-Minor Arterial	90,937	92,878	91,525	483,299	493,292	490,295	362,069	366,134	366,879	2,356,046	2,419,791	2,413,783
6-Major Collector	321,608	403,242	388,409	939,503	901,021	920,415	553,022	556,125	561,525	3,325,079	3,405,424	3,418,688
7-Minor Collector	122,899	160,542	183,031	268,175	238,023	223,959	171,279	172,819	173,533	719,765	727,332	735,688
8-Local	67,483	68,341	69,161	104,067	106,647	106,249	123,339	124,310	123,420	1,145,487	1,202,416	1,195,504
9-Unpaved	0	0	0	5,521	5,701	5,957	0	0	0	128,617	137,981	138,878
10-High Speed Ramp	74,067	75,324	77,183	105,728	107,432	104,135	4,969	5,146	5,057	243,018	245,844	244,697
11-Low Speed Ramp	69,827	73,744	73,448	111,904	110,563	109,949	18,947	18,990	18,975	233,422	236,387	235,433
Total	1,743,477	1,995,066	2,112,714	5,348,344	5,258,237	5,138,429	1,722,078	1,741,521	1,752,456	14,335,888	14,679,590	14,679,147

B-6: VMT – District to District and Outside Of County By % Transit

VEH_Trips_TD_As Is% — Destination District

Origin District			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
	1	Dulles	5445	4019	6809	4078	5004	2046	6503	1462	5194	1412	3193	470	1413	183	77	106	99	565	858	338	745	183	46693	96895
	2	W Strlng	3757	9718	13698	10669	4579	2308	10931	2073	8494	2019	3774	641	1875	207	80	120	99	689	1147	379	876	193	21238	99564
	3	E Strlng	5956	14798	41460	23843	2216	1081	8397	1488	8971	2782	3756	536	1512	200	59	79	89	666	1023	360	815	223	32338	152648
	4	PotFalls	3967	9392	21321	27647	795	338	3548	491	4269	1555	1658	190	586	67	11	31	32	243	365	126	273	92	19369	96366
O	5	S Riding	4059	4836	2189	755	17098	4939	13448	2673	2117	791	881	102	411	202	309	241	61	147	181	54	101	34	20238	75867
r	6	Lenah	1642	2148	1010	323	5005	3260	7573	1756	846	557	406	56	240	77	116	96	21	54	98	20	45	13	11768	37130
i	7	Southbrg	6635	10137	8286	3480	13825	8068	47344	9472	18518	3529	5404	587	2432	387	343	329	133	535	1032	282	641	167	31564	173130
g	8	Oatlands	1525	2048	1470	502	2688	1948	9473	6655	2979	2110	1781	202	1268	137	228	153	42	140	356	60	171	39	8338	44313
i	9	Ashburn	6560	8366	8519	3941	2803	829	19731	3007	34548	6326	9967	734	3266	175	73	108	91	622	1319	304	793	202	20900	133184
n	10	Sycolin	1538	1863	2654	1499	709	544	3634	2006	6024	12848	8632	2191	5811	391	93	137	132	1066	2327	459	1295	287	10028	66168
	11	NE Lsbrg	3872	3472	3491	1531	939	435	5782	1678	9484	8797	22308	1649	8236	326	112	157	126	992	2509	375	1402	432	16583	94688
D	12	NW Lsbrg	585	772	490	175	101	55	673	237	780	1929	1381	1092	2390	75	27	35	14	186	766	60	176	33	2470	14502
i	13	S Leesbg	1788	1791	1349	523	362	249	2766	1200	3315	4121	7235	2394	7099	284	80	124	115	1016	2536	355	1249	264	9310	49525
s	14	GooseCrk	199	225	194	64	181	74	385	126	172	398	308	75	278	653	53	58	22	171	386	93	27	8	1441	5591
t	15	Aldie	79	94	51	12	210	107	297	156	61	87	71	20	53	35	659	438	91	31	35	43	9	2	1788	4429
r	16	Middlbrg	114	122	76	29	174	84	302	120	90	118	105	26	94	58	398	1059	123	61	109	46	12	3	2430	5753
i	17	Uppervil	103	102	86	31	59	21	138	35	87	112	103	20	111	21	96	128	248	96	297	93	15	3	1565	3570
c	18	Airmont	539	662	619	232	121	52	518	127	587	923	768	169	824	165	30	61	89	3984	4972	944	137	22	3457	20002
t	19	Purcelvl	854	1110	912	334	174	92	1001	347	1175	1832	1934	693	2151	352	39	108	251	5180	12120	970	474	58	6239	38400
	20	Lovetsvl	374	424	345	128	44	25	295	67	308	456	395	59	409	49	21	21	47	727	626	2735	1098	33	2791	11477
	21	Waterfrd	867	949	779	272	104	47	698	166	802	1134	1295	179	1212	27	9	14	16	157	555	1138	3787	205	4061	18473
	22	Lucketts	202	203	217	79	30	15	179	39	215	272	378	26	247	9	3	6	2	26	80	36	223	1107	1025	4619
	23	Outside	48572	24458	34142	22856	21596	12289	31929	8374	21926	10243	16546	2483	9143	1440	1802	2441	2296	3850	6777	2831	3858	1030	19562951	19853833
		Total	99232		150167		78817		175545		130962		92279		51061		4718		4239		40474		18222		19838585	21100127
				101709		103003		38906		43755		64351		14594		5520		6050		21204		12101		4633		

VEH_Trips_TD_5% — Destination District

Origin District			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
	1	Dulles	5443	4024	6794	4046	4999	2054	6507	1461	5203	1414	3187	470	1411	178	76	108	101	564	857	334	747	179	46734	96891
	2	W Strlng	3764	9742	13693	10627	4562	2312	10964	2072	8518	2012	3778	641	1876	211	86	108	102	681	1145	374	878	203	21171	99520
	3	E Strlng	5938	14791	41432	23800	2227	1084	8417	1497	8991	2785	3760	534	1495	199	55	83	98	659	1023	356	813	213	32114	152364
	4	PotFalls	3941	9355	21270	27612	793	346	3530	488	4271	1549	1666	181	579	67	17	25	34	240	367	126	279	73	19132	95941
O	5	S Riding	4058	4831	2191	758	17097	4939	13479	2677	2116	799	881	111	408	201	302	255	64	143	186	53	97	29	19987	75662
r	6	Lenah	1650	2147	1022	319	5008	3261	7596	1757	839	571	413	55	238	74	111	100	20	55	100	24	40	14	11589	37003
i	7	Southbrg	6639	10175	8300	3488	13846	8084	47433	9490	18550	3555	5405	563	2446	382	341	326	137	542	1030	280	635	168	31118	172933
g	8	Oatlands	1521	2059	1477	499	2699	1947	9477	6653	2981	2113	1773	209	1278	133	232	155	36	144	353	63	164	38	8212	44216
i	9	Ashburn	6565	8391	8551	3927	2811	833	19767	3015	34573	6353	9943	745	3272	181	85	94	86	635	1302	293	799	212	20507	132940
n	10	Sycolin	1539	1867	2648	1495	715	549	3637	2010	6035	12852	8625	2193	5807	390	92	136	124	1068	2324	453	1305	285	9937	66086
	11	NE Lsbrg	3869	3461	3482	1522	938	440	5785	1695	9473	8790	22300	1645	8237	326	114	150	127	992	2498	387	1397	435	16451	94514
D	12	NW Lsbrg	587	775	489	171	98	53	673	234	778	1928	1376	1098	2392	74	28	32	20	184	765	60	181	27	2438	14461
i	13	S Leesbg	1788	1778	1356	518	366	257	2773	1203	3317	4124	7226	2374	7108	285	85	124	113	1017	2533	358	1253	275	9215	49446
s	14	GooseCrk	199	221	191	65	175	77	391	121	170	399	305	77	281	654	51	63	22	171	389	95	23	6	1427	5573
t	15	Aldie	77	92	54	13	212	107	302	155	62	82	71	20	55	36	664	436	93	32	35	44	6	5	1772	4425
r	16	Middlbrg	108	116	81	26	179	91	308	118	89	122	104	29	94	58	388	1065	124	61	109	47	9	8	2410	5744
i	17	Uppervil	100	101	83	31	59	21	141	37	81	112	112	22	110	23	97	126	249	93	296	94	16	5	1552	3561
c	18	Airmont	539	658	614	230	121	49	505	140	578	925	771	162	817	163	36	59	92	3990	4985	948	143	16	3409	19950
t	19	Purcelvl	843	1115	907	329	176	96	1000	345	1186	1838	1932	689	2146	341	41	103	255	5185	12136	974	477	51	6168	38333
	20	Lovetsvl	370	421	347	125	44	24	302	63	311	450	398	63	409	49	23	19	47	730	629	2747	1099	38	2751	11459
	21	Waterfrd	866	943	777	275	100	48	698	163	810	1128	1286	183	1221	26	7	17	19	158	549	1146	3798	204	4011	18433
	22	Lucketts	203	205	215	80	29	13	176	43	215	277	375	30	247	8	5	3	3	22	83	37	221	1106	1012	4608
	23	Outside	48598	24372	33924	22627	21373	12036	31498	8342	21554	10140	16353	2461	9044	1400	1813	2379	2320	3818	6745	2805	3800	1018	19562237	19850657
		Total	99205		149898		78627		175359		130701		92040		50971		4749		4286		40439		18180		19835354	21094720
				101640		102583		38721		43779		64318		14555		5459		5966		21184		12098		4608		

B-6: VMT – District to District and Outside Of County By % Transit (Continued)

Destination District																												
VEH_Trips_TD_ 10%			|	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	|	Total
	1	Dulles	|	5445	4024	6789	4045	4997	2055	6502	1461	5199	1408	3179	470	1411	181	74	108	99	561	854	330	743	183	46768	|	96886
	2	W Strlng	|	3760	9728	13663	10626	4564	2307	10956	2072	8517	2011	3757	639	1881	206	81	121	98	691	1135	373	867	198	21207	|	99458
	3	E Strlng	|	5934	14759	41410	23788	2210	1082	8416	1486	8993	2785	3755	534	1501	197	62	82	90	661	1034	354	796	218	31910	|	152057
	4	PotFalls	|	3935	9348	21261	27609	789	338	3538	495	4253	1524	1667	188	587	61	18	23	31	240	364	121	280	75	18796	|	95541
O	5	S Riding	|	4053	4821	2185	750	17058	4927	13442	2674	2109	803	851	109	404	203	318	230	64	141	185	48	97	38	19870	|	75380
r	6	Lenah	|	1648	2149	1006	324	4993	3247	7588	1754	829	553	412	51	244	78	116	96	18	57	97	20	41	12	11524	|	36857
i	7	Southbrg	|	6646	10156	8299	3473	13816	8063	47401	9489	18523	3539	5401	585	2414	379	340	326	141	518	1041	280	632	161	31055	|	172678
g	8	Oatlands	|	1523	2044	1482	493	2695	1940	9466	6653	2980	2096	1782	207	1274	135	226	153	46	136	347	67	165	41	8161	|	44112
i	9	Ashburn	|	6558	8393	8527	3923	2797	823	19736	2996	34539	6347	9932	741	3268	178	82	96	81	626	1302	288	788	206	20340	|	132567
n	10	Sycolin	|	1540	1858	2649	1489	703	548	3637	2011	6018	12842	8617	2193	5800	383	93	133	129	1069	2313	457	1292	290	9973	|	66037
	11	NE Lsbrg	|	3859	3448	3489	1513	935	431	5779	1689	9460	8780	22274	1653	8209	319	118	152	125	981	2494	381	1402	431	16404	|	94326
D	12	NW Lsbrg	|	584	766	490	171	96	55	677	240	776	1924	1375	1090	2386	78	24	35	18	186	761	60	182	29	2416	|	14419
i	13	S Leesbg	|	1798	1786	1355	517	359	250	2756	1204	3319	4108	7217	2391	7077	291	81	124	115	1016	2543	367	1252	261	9233	|	49420
s	14	GooseCrk	|	194	223	190	65	176	75	385	130	172	400	301	72	286	649	51	64	19	170	386	94	24	6	1425	|	5557
t	15	Aldie	|	77	91	55	11	211	107	298	159	65	86	66	16	57	37	663	432	95	28	38	48	7	2	1782	|	4431
r	16	Middlbrg	|	114	120	82	23	176	87	298	119	91	106	109	28	98	58	394	1063	120	59	107	51	14	2	2431	|	5750
i	17	Uppervil	|	97	102	81	33	57	20	137	38	86	106	110	23	108	26	101	126	249	93	297	94	15	6	1561	|	3566
c	18	Airmont	|	531	655	613	226	119	51	503	130	587	919	764	157	836	175	34	55	97	3986	4971	944	150	22	3440	|	19965
t	19	Purcelvl	|	850	1109	908	325	167	102	992	338	1162	1841	1920	686	2162	344	42	107	256	5184	12135	974	472	58	6233	|	38367
	20	Lovetsvl	|	368	424	344	129	44	25	294	70	309	441	396	65	413	48	19	25	49	727	627	2740	1105	35	2766	|	11463
	21	Waterfrd	|	862	936	783	272	103	46	695	159	795	1134	1290	183	1218	30	7	18	20	152	551	1150	3787	207	4003	|	18401
	22	Lucketts	|	201	201	214	78	28	12	178	40	212	268	382	28	246	8	3	6	3	27	77	39	223	1101	1022	|	4597
	23	Outside	|	48662	24426	33774	22234	21239	12018	31408	8217	21365	10200	16355	2402	9081	1413	1792	2435	2322	3830	6810	2798	3809	1033	19559382	|	19847005
		Total		99239		149649		78332		175082		130359		91912		50961		4739		4285		40469		18143		19831702	|	21088840
			|		101567		102117		38609		43624		64221		14511		5477		6010		21139		12078		4615		|	

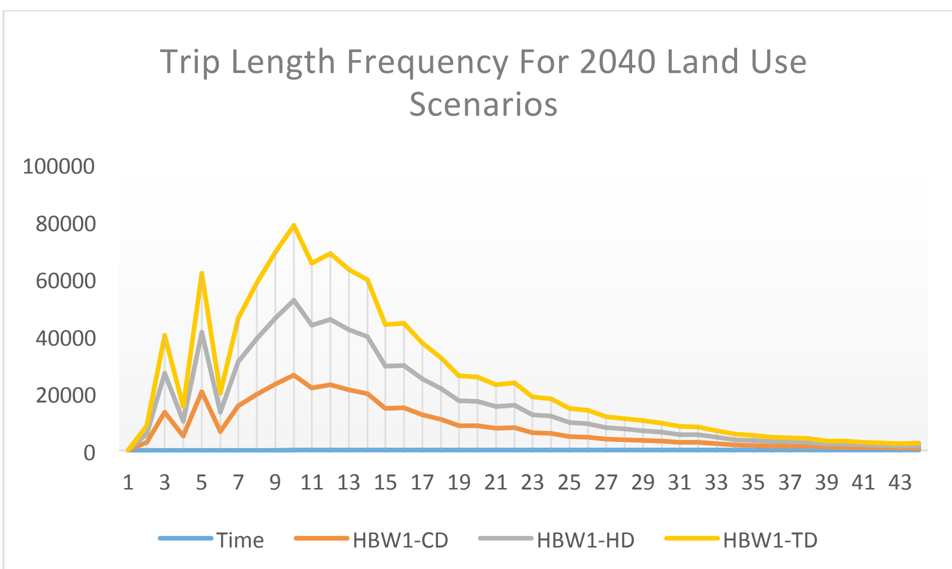
	Destination District																											
			|	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	|	Total
	1	Dulles	|	5443	4023	6783	4036	4998	2050	6498	1456	5192	1406	3182	468	1414	180	79	106	99	566	851	330	747	182	46794	|	96883
	2	W Strlng	|	3762	9731	13681	10601	4553	2302	10954	2070	8514	2008	3763	652	1880	208	88	113	100	700	1125	371	875	208	21152	|	99411
	3	E Strlng	|	5929	14770	41426	23771	2202	1088	8417	1484	8986	2778	3756	539	1508	201	59	83	90	666	1022	359	815	215	31598	|	151762
	4	PotFalls	|	3935	9332	21242	27589	782	341	3531	487	4250	1530	1650	191	575	72	18	32	25	235	364	131	279	82	18426	|	95099
O	5	S Riding	|	4045	4819	2161	763	17098	4933	13462	2674	2114	817	862	102	410	204	306	246	70	149	192	50	100	30	19574	|	75181
r	6	Lenah	|	1644	2139	1016	322	5010	3255	7595	1756	842	560	411	49	241	76	120	95	20	50	104	22	44	14	11338	|	36723
i	7	Southbrg	|	6625	10157	8300	3463	13833	8077	47443	9499	18539	3552	5405	584	2442	372	352	315	148	533	1041	285	643	168	30639	|	172415
g	8	Oatlands	|	1524	2051	1485	497	2696	1941	9477	6654	2980	2097	1777	213	1272	135	229	161	38	140	361	58	163	45	8013	|	44007
i	9	Ashburn	|	6555	8397	8534	3922	2803	838	19746	3006	34546	6340	9940	747	3258	171	79	101	78	630	1296	302	794	209	19936	|	132228
n	10	Sycolin	|	1535	1864	2643	1492	713	548	3649	2007	6025	12857	8619	2189	5812	399	95	137	122	1073	2325	458	1301	289	9809	|	65961
	11	NE Lsbrg	|	3854	3462	3481	1510	940	433	5786	1683	9470	8789	22293	1636	8227	332	124	146	126	980	2502	397	1400	428	16144	|	94143
D	12	NW Lsbrg	|	583	779	491	172	96	56	670	236	780	1922	1381	1097	2384	79	33	28	18	186	762	59	183	29	2357	|	14381
i	13	S Leesbg	|	1783	1789	1365	517	364	252	2773	1206	3323	4106	7234	2388	7092	288	87	126	111	1020	2550	375	1245	268	9092	|	49354
s	14	GooseCrk	|	197	224	191	66	178	77	393	127	167	401	309	75	284	652	48	72	17	174	388	92	21	7	1390	|	5550
t	15	Aldie	|	79	92	51	14	211	105	298	157	64	82	72	18	53	37	663	436	92	33	37	45	9	1	1777	|	4426
r	16	Middlbrg	|	112	123	85	22	178	85	300	118	91	120	105	24	93	63	395	1059	122	64	108	44	12	5	2415	|	5743
i	17	Uppervil	|	105	109	85	32	57	21	133	34	79	124	103	18	113	22	95	124	250	91	297	99	14	6	1548	|	3559
c	18	Airmont	|	538	660	620	222	120	53	522	136	576	924	784	174	833	163	31	64	94	3998	4976	954	139	13	3335	|	19929
t	19	Purcelvl	|	853	1101	911	325	168	96	1003	342	1160	1827	1937	701	2157	343	41	110	253	5198	12137	976	473	59	6135	|	38306
	20	Lovetsvl	|	371	423	350	131	47	20	300	67	297	449	406	66	416	48	19	22	50	728	627	2744	1101	32	2729	|	11443
	21	Waterfrd	|	860	946	778	277	105	49	701	172	804	1143	1290	175	1227	25	7	10	18	158	552	1148	3799	208	3915	|	18367
	22	Lucketts	|	206	203	217	78	30	15	176	41	215	275	378	29	248	7	4	0	5	26	78	37	222	1112	993	|	4595
	23	Outside	|	48669	24334	33430	21940	20963	11839	31073	8021	20922	9992	16040	2333	9004	1377	1795	2405	2308	3758	6704	2768	3700	1009	19560797	|	19845181
		Total		99207		149326		78145		174900		129936		91697		50943		4767		4254		40399		18079		19829906	|	21084647
			|		101528		101762		38474		43433		64099		14468		5454		5991		21156		12104		4619		|	

B-7: Measures Of Effectiveness By Route and Scenario- VMT, VHT, Delay

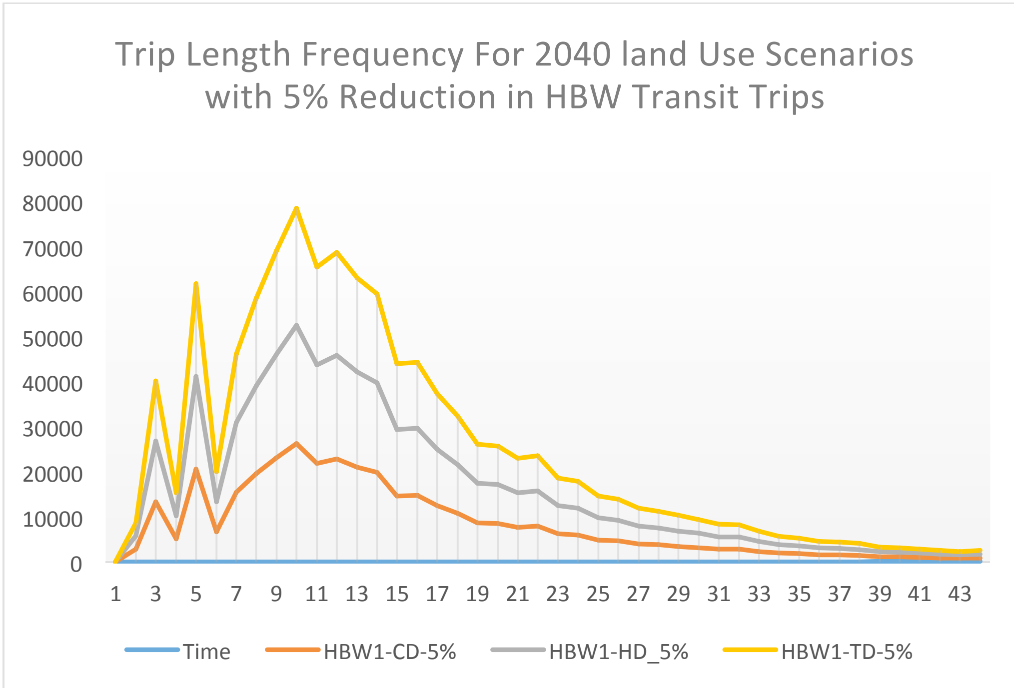
VMT/VHT/Speed Summary	TD	TD5%	TD10%	TD15%	HD	HD5%	HD10%	HD15%	CD	CD5%	CD10%	CD15%
Vehicle-mi-of-travel	14,663,000	14,623,000	14,362,000	14,339,000	14,750,000	14,662,000	14,682,000	14,682,000	14,809,000	14,748,000	14,745,000	14,682,000
Congested veh-hours	524,000	523,000	506,000	507,000	529,000	525,000	526,000	526,000	532,000	529,000	529,000	526,000
Free-flow veh-hours	343,000	342,000	335,000	335,000	345,000	343,000	344,000	344,000	347,000	346,000	346,000	344,000
Delay (aggregate hrs)	181,000	181,000	171,000	172,000	184,000	182,000	182,000	182,000	185,000	183,000	183,000	182,000
Pct Congested Delay	53	53	51	51	53	53	53	53	53	53	53	53
Avg Congested Speed	28	28	28	28	28	28	28	28	28	28	28	28
Daily Vehicle Miles of Travel by Route	TD	TD5%	TD10%	TD15%	HD	HD5%	HD10%	HD15%	CD	CD5%	CD10%	CD15%
Va 7	3,174,000	3,174,000	3,135,000	3,123,000	3,158,000	3,146,000	3,154,000	3,154,000	3,164,000	3,163,000	3,163,000	3,146,000
US 15	818,000	817,000	792,000	790,000	815,000	806,000	815,000	815,000	816,000	816,000	818,000	819,000
Va 28	933,000	929,000	923,000	921,000	944,000	940,000	938,000	938,000	939,000	937,000	935,000	930,000
US 50	591,000	592,000	581,000	579,000	600,000	594,000	597,000	597,000	596,000	594,000	591,000	591,000
Va 267	917,000	915,000	908,000	900,000	937,000	924,000	928,000	928,000	947,000	931,000	919,000	921,000
Rt 606	797,000	792,000	794,000	792,000	806,000	806,000	804,000	804,000	803,000	801,000	801,000	800,000
Rt 659	505,000	507,000	502,000	505,000	506,000	505,000	506,000	506,000	511,000	508,000	510,000	511,000

B-8: Trip Length Frequency Distribution

TLF_PK_2040_CD			TLF_PK_2040_CD_5pct			TLF_PK_2040_HD			TLF_PK_2040_HD_5pct			TLF_PK_2040_TD			TLF_PK_2040_TD_5pct		
Time	HBW1-CD	HBW4-CD	Time	HBW1-CD-5%	HBW4-CD-5%	Time	HBW1-HD	HBW4-HD	Time	HBW1-HD_5%	HBW4-HD_5%	Time	HBW1-TD	HBW4-TD	Time	HBW1-TD-5%	HBW4-TD-5%
2	18	23	2	18	23	2	18	23	2	18	23	2	18	23	2	18	23
4	2891	4081	4	2891	4081	4	2895	4086	4	2895	4086	4	2890	4081	4	2890	4081
6	13397	12745	6	13397	12745	6	13430	12766	6	13430	12766	6	13391	12745	6	13391	12745
8	5087	7163	8	5087	7163	8	5100	7170	8	5100	7170	8	5093	7173	8	5093	7173
10	20558	15729	10	20558	15729	10	20571	15732	10	20571	15732	10	20569	15808	10	20569	15808
12	6706	7878	12	6706	7878	12	6651	7807	12	6651	7807	12	6587	7758	12	6587	7758
14	15455	17710	14	15455	17710	14	15435	17633	14	15435	17633	14	15269	17517	14	15269	17517
16	19510	22057	16	19510	22057	16	19567	22041	16	19567	22041	16	19400	21948	16	19400	21948
18	23066	29096	18	23066	29096	18	23125	29103	18	23125	29103	18	22980	28990	18	22980	28990
20	26233	32353	20	26233	32353	20	26231	32284	20	26231	32284	20	26087	32186	20	26087	32186
22	21820	30303	22	21820	30303	22	21816	30257	22	21816	30257	22	21744	30213	22	21744	30213
24	22888	33587	24	22888	33587	24	22879	33503	24	22879	33503	24	22855	33525	24	22855	33525
26	21037	32751	26	21037	32751	26	21050	32715	26	21050	32715	26	20959	32616	26	20959	32616
28	19824	32792	28	19824	32792	28	19857	32799	28	19857	32799	28	19811	32774	28	19811	32774
30	14641	28042	30	14641	28042	30	14677	28082	30	14677	28082	30	14658	28025	30	14658	28025
32	14775	30359	32	14775	30359	32	14798	30383	32	14798	30383	32	14757	30339	32	14757	30339
34	12471	28055	34	12471	28055	34	12464	28026	34	12464	28026	34	12416	27941	34	12416	27941
36	10794	25746	36	10794	25746	36	10775	25728	36	10775	25728	36	10755	25700	36	10755	25700
38	8690	21863	38	8690	21863	38	8702	21877	38	8702	21877	38	8683	21839	38	8683	21839
40	8547	20583	40	8547	20583	40	8558	20593	40	8558	20593	40	8542	20582	40	8542	20582
42	7658	21543	42	7658	21543	42	7666	21563	42	7666	21563	42	7652	21540	42	7652	21540
44	7859	20794	44	7859	20794	44	7854	20807	44	7854	20807	44	7839	20753	44	7839	20753
46	6208	16895	46	6208	16895	46	6211	16914	46	6211	16914	46	6205	16882	46	6205	16882
48	5960	16601	48	5960	16601	48	5954	16605	48	5954	16605	48	5950	16592	48	5950	16592
50	4849	15319	50	4849	15319	50	4850	15352	50	4850	15352	50	4852	15335	50	4852	15335
52	4625	14707	52	4625	14707	52	4614	14694	52	4614	14694	52	4620	14675	52	4620	14675
54	3934	13119	54	3934	13119	54	3939	13133	54	3939	13133	54	3932	13111	54	3932	13111
56	3720	12023	56	3720	12023	56	3706	12017	56	3706	12017	56	3706	11994	56	3706	11994
58	3423	11474	58	3423	11474	58	3408	11479	58	3408	11479	58	3415	11469	58	3415	11469
60	3138	11068	60	3138	11068	60	3130	11084	60	3130	11084	60	3115	11041	60	3115	11041
62	2769	10979	62	2769	10979	62	2767	11000	62	2767	11000	62	2771	10963	62	2771	10963
64	2711	10507	64	2711	10507	64	2709	10522	64	2709	10522	64	2699	10456	64	2699	10456
66	2239	8968	66	2239	8968	66	2239	8993	66	2239	8993	66	2235	8928	66	2235	8928
68	1888	8007	68	1888	8007	68	1859	7987	68	1859	7987	68	1864	7952	68	1864	7952
70	1720	7501	70	1720	7501	70	1721	7533	70	1721	7533	70	1727	7466	70	1727	7466
72	1503	7267	72	1503	7267	72	1498	7280	72	1498	7280	72	1486	7198	72	1486	7198
74	1452	6640	74	1452	6640	74	1451	6657	74	1451	6657	74	1451	6622	74	1451	6622
76	1350	6044	76	1350	6044	76	1347	6061	76	1347	6061	76	1350	6048	76	1350	6048
78	1085	5371	78	1085	5371	78	1084	5387	78	1084	5387	78	1083	5361	78	1083	5361
80	1029	4819	80	1029	4819	80	1030	4836	80	1030	4836	80	1026	4811	80	1026	4811
82	940	4926	82	940	4926	82	937	4935	82	937	4935	82	934	4918	82	934	4918
84	840	4740	84	840	4740	84	841	4753	84	841	4753	84	846	4750	84	846	4750
86	742	4571	86	742	4571	86	742	4578	86	742	4578	86	742	4574	86	742	4574
88	814	4082	88	814	4082	88	816	4088	88	816	4088	88	817	4090	88	817	4090
90	13764	76599	90	13764	76599	90	13763	76658	90	13763	76658	90	13764	76601	90	13764	76601



B-8: Trip Length Frequency Distribution (Continued)



APPENDIX C: STATISTICAL ANALYSIS OF RESULTS

C-1: O_3 VOC Emission Reduction Comparison Between Scenarios

Transit Share = As Is	All Area Type Totals Comparison			Transit Share = As I	Area Type-2(High Density) Comparison			Transit Share = As I	Area Type-3(Med Emp Density) Comparison			Transit Share = As I	Area Type-4(Med Pop Density) Comparison		
	HS v TR	TOD v TR	TOD v HS		HS v TR	TOD v TR	TOD v HS	Transit Share = As I	HS v TR	TOD v TR	TOD v HS	Transit Share = As I	HS v TR	TOD v TR	TOD v HS
Freeway	-3.6%	-3.9%	0.41%	**Freeway**	0.2%	-0.3%	0.41%	**Freeway**	-4.2%	-4.7%	0.6%	**Freeway**	-3.5%	-3.8%	0.40%
Major Arterial	-1.8%	0.3%	-0.53%	**Major Arterial**	23.1%	25.1%	-1.53%	**Major Arterial**	-8.1%	-21.4%	0.2%	**Major Arterial**	-2.1%	-1.8%	-0.28%
Minor Arterial	-3.7%	-4.3%	0.65%	**Minor Arterial**	-2.5%	-4.1%	1.69%	**Minor Arterial**	-2.7%	-3.7%	1.1%	**Minor Arterial**	-4.1%	-4.1%	-0.05%
Major Collector	-3.5%	-3.2%	-0.35%	**Major Collector**	18.7%	14.6%	3.59%	**Major Collector**	-8.7%	-7.0%	-1.8%	**Major Collector**	-4.1%	-3.4%	-0.70%
Minor Collector	-3.2%	-2.6%	-0.60%	**Minor Collector**	25.7%	42.9%	-12.02%	**Minor Collector**	-15.7%	-21.4%	7.3%	**Minor Collector**	-3.3%	-3.1%	-0.20%
High-speed ramp	-3.7%	-4.3%	0.60%	**High-speed ramp**	-3.2%	-0.9%	-2.32%	**High-speed ramp**	-3.6%	-6.3%	2.9%	**High-speed ramp**	-4.1%	-4.3%	0.14%
Low-speed ramp	-3.5%	-4.2%	0.66%	**Low-speed ramp**	1.1%	1.0%	0.04%	**Low-speed ramp**	-6.3%	-7.0%	0.7%	**Low-speed ramp**	-4.9%	-5.9%	1.08%
Total	-3.4%	-3.6%	0.23%	**Total**	9.3%	15.5%	-5.39%	**Total**	-6.3%	-8.6%	2.6%	**Total**	-3.6%	-3.5%	-0.17%

Transit Share = As Is	All Area Type Totals Comparison			Transit Share = As I	Area Type-2(High Density) Comparison			Transit Share = As Is	Area Type-3(Med Emp Density) Comparison			Transit Share = As Is	Area Type-4(Med Pop Density) Comparison		
	HS v TR	TOD v TR	TOD v HS		HS v TR	TOD v TR	TOD v HS	Transit Share = As Is	HS v TR	TOD v TR	TOD v HS	Transit Share = As Is	HS v TR	TOD v TR	TOD v HS
Freeway	-3.6%	-3.9%	0.41%	**Freeway**	0.2%	-0.3%	0.41%	**Freeway**	-4.2%	-4.7%	0.6%	**Freeway**	-3.5%	-3.8%	0.40%
Major Arterial	-1.8%	0.3%	-0.53%	**Major Arterial**	23.1%	25.1%	-1.53%	**Major Arterial**	-8.1%	-21.4%	0.2%	**Major Arterial**	-2.1%	-1.8%	-0.28%
Minor Arterial	-3.7%	-4.3%	0.65%	**Minor Arterial**	-2.5%	-4.1%	1.69%	**Minor Arterial**	-2.7%	-3.7%	1.1%	**Minor Arterial**	-4.1%	-4.1%	-0.05%
Major Collector	-3.5%	-3.2%	-0.35%	**Major Collector**	18.7%	14.6%	3.59%	**Major Collector**	-8.7%	-7.0%	-1.8%	**Major Collector**	-4.1%	-3.4%	-0.70%
Minor Collector	-3.2%	-2.6%	-0.60%	**Minor Collector**	25.7%	42.9%	-12.02%	**Minor Collector**	-15.7%	-21.4%	7.3%	**Minor Collector**	-3.3%	-3.1%	-0.20%
High-speed ramp	-3.7%	-4.3%	0.60%	**High-speed ramp**	-3.2%	-0.9%	-2.32%	**High-speed ramp**	-3.6%	-6.3%	2.9%	**High-speed ramp**	-4.1%	-4.3%	0.14%
Low-speed ramp	-3.5%	-4.2%	0.66%	**Low-speed ramp**	1.1%	1.0%	0.04%	**Low-speed ramp**	-6.3%	-7.0%	0.7%	**Low-speed ramp**	-4.9%	-5.9%	1.08%
Total	-3.4%	-3.6%	0.23%	**Total**	9.3%	15.5%	-5.39%	**Total**	-6.3%	-8.6%	2.6%	**Total**	-3.6%	-3.5%	-0.17%

Transit Share = +10%	All Area Type Totals Comparison			Transit Share = 10%	Area Type2-High Density Comparison			Transit Share = 10%	Area Type-3(Med Emp Density) Comparison			Transit Share = 10%	Area Type-4(Med Pop Density) Comparison		
	HS v TR	TOD v TR	TOD v HS		HS v TR	TOD v TR	TOD v HS		HS v TR	TOD v TR	TOD v HS		HS v TR	TOD v TR	TOD v HS
Freeway	-2.9%	-3.5%	0.70%	**Freeway**	0%	-1%	0.90%	**Freeway**	-4%	-5%	1%	**Freeway**	-3.0%	-3.6%	0.66%
Major Arterial	-1.9%	0.0%	-0.99%	**Major Arterial**	22%	25%	-1.82%	**Major Arterial**	-8%	-22%	0%	**Major Arterial**	-2.7%	-2.1%	-0.63%
Minor Arterial	-1.4%	-1.7%	0.32%	**Minor Arterial**	-2%	-3%	0.86%	**Minor Arterial**	-2%	-3%	1%	**Minor Arterial**	-3.1%	-2.9%	-0.13%
Major Collector	-1.3%	-1.0%	-0.34%	**Major Collector**	20%	15%	3.73%	**Major Collector**	-8%	-6%	-2%	**Major Collector**	-3.5%	-2.9%	-0.62%
Minor Collector	-3.0%	-1.9%	-1.18%	**Minor Collector**	25%	43%	-12.42%	**Minor Collector**	-15%	-20%	7%	**Minor Collector**	-3.0%	-2.6%	-0.47%
High-speed ramp	-2.8%	-3.6%	0.88%	**High-speed ramp**	-2%	0%	-1.96%	**High-speed ramp**	-3%	-6%	3%	**High-speed ramp**	-1.4%	-2.3%	0.99%
Low-speed ramp	-2.7%	-3.5%	0.76%	**Low-speed ramp**	1%	1%	0.64%	**Low-speed ramp**	-5%	-6%	1%	**Low-speed ramp**	-3.4%	-4.3%	0.89%
Total	-1.8%	-2.0%	0.20%	**Total**	9%	16%	-5.34%	**Total**	-6%	-8%	3%	**Total**	-3.2%	-3.0%	-0.22%

Transit Share = +15%	All Area Type Totals Comparison			Transit Share 15%	Area Type2-High Density Comparison			Transit Share 15%	Area Type-3(Med Emp Density) Comparison			Transit Share 15%	Area Type-4(Med Pop Density) Comparison		
	HS v TR	TOD v TR	TOD v HS		HS v TR	TOD v TR	TOD v HS		HS v TR	TOD v TR	TOD v HS		HS v TR	TOD v TR	TOD v HS
Freeway	-2.4%	-3.4%	0.95%	**Freeway**	1%	0%	0.88%	**Freeway**	-3.4%	-4.5%	1%	**Freeway**	-2.5%	-3.0%	0.52%
Major Arterial	-1.3%	1.0%	-1.02%	**Major Arterial**	23%	25%	-1.51%	**Major Arterial**	-7.6%	-21.0%	0%	**Major Arterial**	-1.6%	-0.4%	-1.20%
Minor Arterial	-1.3%	-2.2%	0.88%	**Minor Arterial**	-2%	-4%	2.12%	**Minor Arterial**	-1.9%	-3.2%	1%	**Minor Arterial**	-2.9%	-3.3%	0.43%
Major Collector	-1.6%	-1.8%	0.24%	**Major Collector**	20%	15%	4.48%	**Major Collector**	-7.9%	-6.5%	-1%	**Major Collector**	-3.4%	-3.1%	-0.33%
Minor Collector	-2.9%	-2.4%	-0.51%	**Minor Collector**	25%	42%	-11.73%	**Minor Collector**	-14.7%	-20.3%	7%	**Minor Collector**	-3.1%	-3.3%	0.22%
High-speed ramp	-2.8%	-3.9%	1.11%	**High-speed ramp**	-2%	-1%	-1.79%	**High-speed ramp**	-2.4%	-6.0%	4%	**High-speed ramp**	-0.5%	-2.8%	2.40%
Low-speed ramp	-2.7%	-3.7%	1.04%	**Low-speed ramp**	1%	0%	1.04%	**Low-speed ramp**	-5.1%	-6.2%	1%	**Low-speed ramp**	-3.7%	-4.4%	0.71%
Total	-1.6%	-2.3%	0.64%	**Total**	10%	16%	-4.97%	**Total**	-5.6%	-8.3%	3%	**Total**	-2.8%	-2.9%	0.01%

C-2: O3 VOC Emissions Comparison Between Scenarios

C-3: SAS Input File for 3-Factor ANOVA of the Emissions

```
title 'Analysis of Unbalanced 3-by-3 Factorial';
   data O3VOC;
      input FT $ AT $ TP $ HSvTR TODvTR @@;
      datalines;
1      2     1      0.08013      -0.10048      1      3      1      -0.41144
       -0.43778     1      4      1      -0.37367      -0.39431      3      5
       1      -0.42283      -0.42980
2      2     1      1.00387      1.04853       2      3      1      -0.57583
       -0.96071     2      4      1      -0.29096      -0.27135      3      5
       1      -0.22193      -0.32299
3      2     1      -0.31475     -0.40681      3      3      1      -0.32778
       -0.38661     3      4      1      -0.40973      -0.40728      3      5
       1      -0.38772      -0.42880
4      2     1      0.89497      0.78449       4      3      1      -0.59705
       -0.53449     4      4      1      -0.40648      -0.37062      3      5
       1      -0.57497      -0.58870
5      2     1      1.06443      1.42884       5      3      1      -0.81473
       -0.96303     5      4      1      -0.36682      -0.35566      3      5
       1      -0.45196      -0.48528
6      2     1      -0.35908     -0.18839      6      3      1      -0.37942
       -0.50630     6      4      1      -0.40874      -0.41566      3      5
       1      -0.41198      -0.44038
7      2     1      0.20952      0.20526       7      3      1      -0.50931
       -0.53690     7      4      1      -0.44647      -0.49153      3      5
       1      -0.38192      -0.45794
1      2     2      -0.14744     -0.15513      1      3      2      -0.42995
       -0.44909     1      4      2      -0.42662      -0.38946      1      5
       2      -0.46615      -0.44473
2      2     2      1.00296      1.04376       2      3      2      -0.57295
       -0.97141     2      4      2      -0.30035      -0.26012      2      5
       2      -0.39205      -0.40081
3      2     2      -0.28609     -0.37729      3      3      2      -0.31651
       -0.37669     3      4      2      -0.48049      -0.46343      3      5
       2      -0.43398      -0.43477
4      2     2      0.91392      0.79408       4      3      2      -0.59626
       -0.53403     4      4      2      -0.40743      -0.38412      4      5
       2      -0.57456      -0.57116
5      2     2      1.06499      1.43342       5      3      2      -0.81406
       -0.95681     5      4      2      -0.38209      -0.37241      5      5
       2      -0.52144      -0.52204
6      2     2      -0.33262     -0.13192      6      3      2      -0.36907
       -0.50299     6      4      2      -0.40881      -0.39269      6      5
       2      -0.47159      -0.50465
7      2     2      0.16904      0.11525       7      3      2      -0.48206
       -0.50781     7      4      2      -0.31711      -0.39285      7      5
       2      -0.40443      -0.44075
1      2     3      0.10348      -0.15802      1      3      3      -0.39529
       -0.43510     1      4      3      -0.34772      -0.38314      1      5
       3      -0.33535      -0.35674
2      2     3      0.98315      1.03657       2      3      3      -0.57079
       -0.96597     2      4      3      -0.33236      -0.29214      2      5
       3      -0.34763      -0.33600
3      2     3      -0.27880     -0.33395      3      3      3      -0.29006
       -0.32455     3      4      3      -0.35232      -0.34511      3      5
       3      -0.29971      -0.31435
```

```
4      2      3      0.92189      0.80877      4      3      3      -0.57808
       -0.50273      4      4      3      -0.37637      -0.34200      4      5
       3      -0.44655      -0.45364
5      2      3      1.05291      1.43061      5      3      3      -0.78947
       -0.93665      5      4      3      -0.35094      -0.32316      5      5
       3      -0.40865      -0.44149
6      2      3      -0.27850      0.03922      6      3      3      -0.33064
       -0.49379      6      4      3      -0.23405      -0.30629      6      5
       3      -0.31310      -0.35778
7      2      3      0.24070      0.17897      7      3      3      -0.45835
       -0.48248      7      4      3      -0.37246      -0.41696      7      5
       3      -0.23162      -0.36752
1      2      4      0.16338      -0.09240      1      3      4      -0.37106
       -0.42683      1      4      4      -0.31726      -0.34822      1      5
       4      -0.29393      -0.35426
2      2      4      1.00399      1.04803      2      3      4      -0.55891
       -0.95193      2      4      4      -0.25696      -0.13320      2      5
       4      -0.20974      0.37751
3      2      4      -0.27518      -0.39857      3      3      4      -0.27986
       -0.35712      3      4      4      -0.33945      -0.36357      3      5
       4      -0.29730      -0.34577
4      2      4      0.93858      0.80355      4      3      4      -0.56858
       -0.51462      4      4      4      -0.37050      -0.35217      4      5
       4      -0.45052      -0.49552
5      2      4      1.05855      1.41359      5      3      4      -0.78789
       -0.93418      5      4      4      -0.35212      -0.36424      5      5
       4      -0.41943      -0.48596
6      2      4      -0.30458      -0.14440      6      3      4      -0.31000
       -0.49387      6      4      4      -0.14290      -0.33901      6      5
       4      -0.36408      -0.35704
7      2      4      0.24203      0.12876      7      3      4      -0.45482
       -0.50347      7      4      4      -0.38784      -0.42244      7      5
       4      -0.28405      -0.34932
;
   proc glm data=O3VOC;
      class FT AT TP;
      model TODvTR = FT AT TP FT*AT FT*TP
                  AT*TP FT*AT*TP ;
   run;
   proc glm data=O3VOC;
      class FT AT TP;
      model HSvTR = FT AT TP FT*AT FT*TP
                  AT*TP FT*AT*TP ;
   run;
```

C-4: SAS Output File for 3-Factor ANOVA of the Emissions

Analysis of Unbalanced 3-by-3 Factorial

The GLM Procedure

Class Level Information		
Class	Levels	Values
FT	7	1 2 3 4 5 6 7
AT	4	2 3 4 5
TP	4	1 2 3 4

Number of Observations Read	112
Number of Observations Used	112

Analysis of Unbalanced 3-by-3 Factorial

The GLM Procedure

Dependent Variable: TODvTR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	105	30.02137538	0.28591786	45.60	<.0001
Error	6	0.03762481	0.00627080		
Corrected Total	111	30.05900019			

R-Square	Coeff Var	Root MSE	TODvTR Mean
0.998748	-32.97380	0.079188	-0.240156

Source	DF	Type I SS	Mean Square	F Value	Pr > F
FT	6	1.98110238	0.33018373	52.65	<.0001
AT	3	16.06803962	5.35601321	854.12	<.0001
TP	3	0.06291637	0.02097212	3.34	0.0971
FT*AT	18	11.46588854	0.63699381	101.58	<.0001

Source	DF	Type I SS	Mean Square	F Value	Pr > F
FT*TP	18	0.13905992	0.00772555	1.23	0.4255
AT*TP	9	0.08198407	0.00910934	1.45	0.3348
FT*AT*TP	48	0.22238448	0.00463301	0.74	0.7474

Source	DF	Type III SS	Mean Square	F Value	Pr > F
FT	6	1.53059534	0.25509922	40.68	0.0001
AT	3	16.08726595	5.36242198	855.14	<.0001
TP	3	0.07627843	0.02542614	4.05	0.0683
FT*AT	18	11.39208567	0.63289365	100.93	<.0001
FT*TP	18	0.13454168	0.00747454	1.19	0.4440
AT*TP	9	0.08198407	0.00910934	1.45	0.3348
FT*AT*TP	48	0.22238448	0.00463301	0.74	0.7474

Analysis of Unbalanced 3-by-3 Factorial

The GLM Procedure

Class Level Information		
Class	Levels	Values
FT	7	1 2 3 4 5 6 7
AT	4	2 3 4 5
TP	4	1 2 3 4

Number of Observations Read	112
Number of Observations Used	112

Analysis of Unbalanced 3-by-3 Factorial

The GLM Procedure

Dependent Variable: HSvTR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	105	23.31081899	0.22200780	20.26	0.0005
Error	6	0.06575969	0.01095995		
Corrected Total	111	23.37657867			

R-Square	Coeff Var	Root MSE	HSvTR Mean
0.997187	-48.48560	0.104690	-0.215919

Source	DF	Type I SS	Mean Square	F Value	Pr > F
FT	6	1.51420826	0.25236804	23.03	0.0007
AT	3	13.12170148	4.37390049	399.08	<.0001
TP	3	0.09655732	0.03218577	2.94	0.1212
FT*AT	18	8.42887211	0.46827067	42.73	<.0001
FT*TP	18	0.05104121	0.00283562	0.26	0.9882
AT*TP	9	0.03002023	0.00333558	0.30	0.9464
FT*AT*TP	48	0.06841839	0.00142538	0.13	1.0000

Source	DF	Type III SS	Mean Square	F Value	Pr > F
FT	6	1.13625502	0.18937584	17.28	0.0015
AT	3	13.14342883	4.38114294	399.74	<.0001
TP	3	0.11187720	0.03729240	3.40	0.0942
FT*AT	18	8.32957700	0.46275428	42.22	<.0001
FT*TP	18	0.04962440	0.00275691	0.25	0.9896
AT*TP	9	0.03002023	0.00333558	0.30	0.9464
FT*AT*TP	48	0.06841839	0.00142538	0.13	1.0000

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BIOGRAPHY

Shweta Dixit, daughter of Anand Kumar Dixit and Nivedita Dixit, grew up in Hyderabad, India. She attended Nagpur University where she received her Bachelors in Civil Engineering in 2005. She worked for Aarvee consultants, an engineering firm in India, as an environmental engineer for major state and national projects before moving to the United States in 2007. She received her Master of Science in Civil, Environmental and Infrastructure Engineering in 2010 from George Mason University. She started her Ph.D. program in 2010 as a recipient of the prestigious Presidential Scholar Award at George Mason University after which she worked for Arlington County on challenging traffic engineering projects for the county. She worked for AECOM, one of the top design and engineering firms with a global presence, managing and working on challenging transportation projects in the tristate area. She was associated with Loudoun County for two years until 2016, as a senior transportation planner where she was majorly engaged in the design and development of the Silver Line metro area. She streamlined her focus towards completion of Ph.D. 2016 at Mason.

Shweta is blessed with a beautiful family- husband, Ravi and their two beautiful daughters, Savitri and Sharada. Shweta has love for music and dance.