Comparison of Measured and Modeled Vehicle Emissions for Advance Prediction of Air Quality and NO_X Exposure Levels

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***Abstract*— According to the World Health Organization, air pollution is responsible for the deaths of 4.6 million people each year. Of those 4.6 million victims, 70,000 (1.5%) deaths occur in the United States, 300,000 (6.5%) deaths occur in Europe, and 750,000 (16.3%) deaths occur in China [1]. The World Health Organization submits that air pollution is a significant public health concern attributable to its direct relationship to cardio-pulmonary disease and various forms of terminal cancer. Air pollution increases mortality in the United States and across the globe significantly. Other negative effects attributable to air pollution include climate change, decrease in visibility, and severe ecological damage. To fully understand the role that vehicle emissions play in neighborhood-scale air pollution related health effects, it is necessary to develop an accurate picture of the contribution of these emissions on a rural scale. Using correlations of real-time measured data from the Virginia Tech Flux Lab for Atmospheric Measurement of Emissions (FLAME) and VISSIM rural area traffic flow models, we developed a model capable of predicting neighborhood-scale emissions and consequently air pollution exposure levels to within approximately 4.5%. VISSIM is a microscopic traffic analysis software program capable of modeling traffic emissions within various transportation related scenarios. Utilizing real-time measured emissions (FLAME) and traffic flow data from the Virginia Department of Transportation (VDOT) for an intersection in the Virginia Beach, Virginia area (I-64 and Indian River Road); we calibrated the VISSIM model in order to evaluate its effectiveness not only as a traffic modeling software, but also examine its capabilities for providing reliable traffic related emissions data within urban and industrial settings, and ultimately provide a clear picture of neighborhood air pollution exposure levels.**

Keywords—Environmental justice, air pollution, ambient air quality, NO_x emissions, $PM_{2.5}$ emissions, socioeconomic air quality factors, adverse air quality exposure

I. INTRODUCTION

1.1 Real-Time Air Quality and Emissions Measurement

Many studies have been conducted that involve modeling of emissions from localized traffic data/patterns [2-6]. Also, much research has focused on real time ground level measurements of vehicular emissions. However, very little research has focused on the correlation of real time emissions data with that of modeled emissions data using eddy covariance measurement techniques. The eddy covariance technique is the most widely used, accurate, and direct method presently available for quantifying exchanges of carbon dioxide, water vapor, methane, various other gases, and energy between earth's surface and the atmosphere [7, 8]. Eddy covariance provides an accurate way to measure surface-to-atmosphere fluxes, gas exchange budgets, and emissions from a variety of ecosystems, including agricultural and urban plots, landfills, and various water surfaces [7, 8]. Emissions and fluxes can be measured by instrumentation on a stationary or mobile tower, floating vessel (such as a ship or buoy), van, or aircraft [7, 8]. Even less data is available on the direct health comparison of these measured emissions. Our research focuses on the correlation of modeled emissions with directly measured emissions in an effort to evaluate the effectiveness of using VISSIM traffic emissions modeling software as a tool for predicting air pollution exposure at the neighborhood scale level. Consequently, this model will also provide insight into the localized air pollution related health effects within various neighborhoods as well.

1.2 Adverse Effects of Vehicle Pollution and Air Pollution

More than half of all Americans live in areas with unhealthy levels of air pollution. 18.5 million Americans live in counties where outdoor air failed the *State of the Air* report standards [11]. Vehicle air pollution is responsible for 1.4% of total deaths annually worldwide each year [7]. The major pollutants resulting from automobile emissions are carbon dioxide (CO_2), carbon monoxide (CO), nitrous oxides (NO_x), sulfuric oxides (SO_x), and particulate material ($PM_{2.5}$). On-road vehicles account for 34% of total NO_x emissions in the United States [12]. NO_x, in particular, produces numerous short and long term health effects [1].

NO_x is one of the preeminent pollutants present in ambient air [9]. NO_x is a dangerous gaseous substance largely produced by the combustion of fossil fuels such as coal, natural gas, and oil [9]. NO_x is a reddish brown, highly reactive gas. Long term exposure to NO_x can result in abnormal effects in the lungs, spleen, liver, and blood, while the short term effects include defective pulmonary function, with asthmatics being the most vulnerable [9].

The adverse effects of NO_x exposure can also result in severe changes in cell type in tracheobronchial pulmonary regions, lung structure, metabolism and defense against bacterial and viral infection, as well as emphysema-like symptoms [9]. Not only does NO_x adversely affect human health, but it also results in notable environmental destruction [10]. NO_x contributes to the formation of smog, acid rain, water quality deterioration, global warming and visibility impairment [9].

The effects of air and vehicle pollution are clearly visible across the globe, especially in Asia and Europe [1, 6, 11]. During the late 20th century, Europe was facing drastic levels of eutrophication (damage and changes in ecosystems due to the availability of excessive amounts of nutrients) as a consequence of NO_x and SO_x emissions from automobiles. Investigations revealed that devastating ecological damage was a direct consequence of acidification of soil and water due to atmospheric depositions of NO_x and SO_x [12]. Due to the high levels of foreign pollutant emissions, countries across Europe and the United States now limit the amount of greenhouse gases and pollutants emitted in order to reduce and prevent further drastic increases in air pollution.

1.3 NO_x and Vehicle Pollution in Urban Cities

In recent years, urban air pollution has emerged as one of the most acute problems, because of its negative effects on health and deterioration in living conditions [5, 10, 11, 13]. Automobiles and other road vehicles have constantly been acknowledged as chief contributors to the metropolitan air and vehicle pollution burden on society. Traffic-related air pollution is most severe in municipal areas and particularly city centers, where large, thick traffic volumes and congestion give rise to degradation of the air quality in these areas. The dilemma is compounded by the fact that these are also centers of human activity [10].

Virginia Beach, located in the Hampton Roads area of Virginia, is responsible for 2.1% of total NO_x emissions in the Virginia Commonwealth in 2008. The primary source of NO_x in Virginia Beach is attributed to the vast number of automobiles on the roads. Since 87.1% of the total NO_x emissions come from automobiles, the emissions from automobiles have a severe and direct impact on the environment.

For this research, the intersection of I-64 and Indian River Road, a heavily traveled intersection, was chosen as the automobile emissions modeling site. According to the model created this section of Indian River road produces 411.7 kg or 905.8 lbs of NO_x each year. The 2008 measured concentration for the area was 22 ± 7 ppb, approximately 58% less than the EPA National Ambient Air Quality Standard (NAAQS) of 53 ppb. Even though this location is considered safe by the EPA NAAQS, there are multiple areas in Virginia Beach that report concentrations more than 53 ppb. Approximately 25% of locations measured during a 2008 FLAME measurement campaign revealed concentrations above primary and secondary NAAQS standards. 37.5% of tested locations were within the standard deviation of exceeding the National Ambient Air Quality Standards.

II. METHODS

2.1 VISSIM Software and Calibration

VISSIM is a traffic flow and operations modeling program used to model traffic and, indirectly, automobile emissions in urban locations. Because of its multimodal (i.e. cars, trucks, buses, heavy rail and light rail vehicles) traffic modeling capability, VISSIM is utilized by transportation engineers to simulate various traffic scenarios before and after transportation developments. It allows transportation engineers to estimate automobile traffic emissions, cost, traffic flow and transportation quality. Outputs from VISSIM can also be used in EPA approved vehicle emissions models which are widely used throughout the United States. The intersection modeled in this research was I-64 and Indian River Road.

VISSIM software can be used to determine the environmental impact on a specific area and to model and estimate total air pollutant emissions [7]. By making adjustments to the model specifications and given program restraints, researchers varied the built in model parameters to develop an accurate emissions profile for comparison to real-time measured emissions for the purpose of model validation. Real time data collected using the FLAME, provided valuable information for validation of the VISSIM model and produced an accurate determination of localized NO_x emissions and NO_x exposure levels. Below are the equations used in this research to predict the amount of emissions produced from the I-64/Indian River Road VISSIM traffic model:

$$K_1 = 0.075283 - 0.0015892 \times S + 0.000015066 \times S^2 \qquad (1)$$

$$K_2 = .7329 \qquad (2)$$

$$K_3 = 0.0000061411 \times S^2 \qquad (3)$$

$$Fuel\ Consumption = DT_T \times K_1 + SD_T \times K_2 + N_S \times K_3 \qquad (4)$$

$$NO_x\ emissions = 13.6 \times Fuel\ Consumption \qquad (5)$$

The equations above are intrinsic within the node analysis feature in the VISSIM program, and are specific to signalized intersections. Where speed (S) is equivalent to the cruise speed (mph), total distance traveled (DT_T) is equal to the total number of vehicle miles traveled (mi), total stop delay (SD_T) is the total signal delay (hr) and number of stops (N_S) is equal to the total number of stops (vehicles per hour, vph).

It is important to calibrate and validate the VISSIM software by modifying the model's parameters. The parameters, previously mentioned in the above equations, were used to ensure the model is representative of field-like conditions. When modeling automobile emissions at intersections there are many variables that can affect output such as: vehicle type, speed, acceleration, starting acceleration speed, idling time, amount of time of acceleration until the automobile reaches constant speed, number of vehicles, quantity of fuel types burned, quantity of fuel consumed, combustion temperatures, and the age of the vehicle.

For this research, 35 VISSIM runs were conducted to get a model that can accurately estimate emissions along Indian River Road by the I-64 exit. The average speed, total distance traveled, total stop delay, and number of stops were used in the formulas for all three time frames: morning, lunch and afternoon hour periods. Results from these runs provided the normal average NO_x emissions that would be expected in a typical day at the location. The calibrated model for this research is displayed later in the paper.

2.2 Traffic Modeling Parameters

Some vehicles operating within the confines of an urbanized area will be old, some will be new, some will be for passengers and some will be for transporting goods. The quantity of vehicle types is vital. The size of the automobile has direct correlation with the amount of Carbon Dioxide (CO_2) that is produced. Vehicle efficiency can be increased by improving the efficiency of the engine or reducing the loads on the vehicle. The size of the vehicle is important because of the effects of aerodynamics. Aerodynamic losses are imposed by expending energy to push air aside as the vehicle moves. Accessory loads like air conditioning and vehicle lights are also factors that play into increasing the load on the automobile. Vehicle mass also affects tire rolling resistance losses. By increasing the mass and load on the automobile, the engine is forced to operate at a high level. By operating at a higher level, emissions and other pollutant are increased. Thus, mass and size has a direct and strong relationship with vehicle efficiency, as shown in the graphs below.

One major parameter in estimating automobile emissions for an intersection is the starting emissions. In order to make a vehicle start easier, more fuel is normally supplied to the engine. This causes the air/fuel mixture to become richer which makes the vehicle start easier, especially in cold weather. However, this procedure also increases the emissions from the vehicle until the air/fuel ratio is returned to the normal rate. Vehicles manufactured in the United States before 1960 often had a manual adjustment for the air/fuel mixture called a “choke”, which would richen the mixture when pulled and then was manually shut off once the vehicle was warmed up. Modern vehicles handle this adjustment automatically so that the driver is normally unaware that such an adjustment is taking place. These extra emissions that occur as the vehicle is started and warmed up are referred to as start emissions. With the addition of catalysts to vehicles, the emissions associated with a vehicle start compared to normal operations increased further since the catalyst is ineffective until it is warmed up. Thus, an important emissions concern with respect to vehicles is the start emissions associated with the vehicle. Catalyst controlled vehicles tend to have relatively larger start emissions compared to non-catalyst controlled vehicles.

Start emissions are defined as the emissions in excess of normal warm vehicle emissions that occur during the first few minutes of vehicle operation. A vehicle that has been operated so that the engine and catalyst are at least somewhat warm will have less start emissions than a vehicle that has sat for a long time and the engine and catalyst are at ambient temperatures. Thus, there are different start emissions associated with a vehicle that has stopped for only a few minutes and then re-started compared to a vehicle that has not operated for 12 or more hours. The time that a vehicle is not operated is referred to as the “soak” period. The start emissions then vary with the soak period from almost zero with a soak period of less than 15 minutes to the maximum amount after about twelve hours of non-operation soak.

Another important parameter in automobile emissions modeling is the type of fuel being burned and consumed. There are two major fuel types for vehicles: gasoline and diesel. The volatility of the fuel impacts the amount of gasoline that evaporates into the air. The higher the volatility, the more evaporative emissions produced. The amount of sulfur in the gasoline is a key factor in this fuel. The percentage of sulfur in the fuel is released to the atmosphere contributing to acid rain and $PM_{2.5}$. Sulfur degrades the catalyst performance and thus increases vehicle emissions. Octane does not cause emissions itself but degrades the catalyst performance, resulting in increased emissions emitted. The second fuel type is diesel. The hydrocarbon makeup of diesel can impact emissions. A value called the cetane number is measured for the fuel and indicates the combustion of the fuel. Normally, a higher cetane number results in fewer emissions. Sulfur like gasoline degrades the catalyst performance and thus increases vehicle emissions.

A major contributing factor towards the automobile emissions is idling time. Idling time is where are a car is stopped with the engine continuing to run. Due to the engine of the car running, emissions are stilled being emitted. Automobile companies like Ford, General Motors, Toyota, Honda, and Chrysler have utilized new modern technologies to decrease the amount of $PM_{2.5}$, NO_x, and SO_x; however, the car manufacturers have not been able to decrease the amount of CO_2 emissions with engines. Since Carbon dioxide is the principle greenhouse gas, idling time has a major impact on automobile emissions at intersections. Each gallon of gasoline that is consumed emits 20 lbs of CO_2.

The temperature outside is also a major parameter towards automobile emissions. The colder the temperature is outside the harder the engine has to work to circulate the cold oil. The hard the engine has to work is directly related to the amount of emissions produced. Many parts of the vehicle including wheel bearings, tires, and the suspension system will warm up only when the car is in motion. Contrary to common belief, you only need to idle for a maximum of thirty seconds to get the oil circulating through the engine. In the winter time, the emissions from a car are significantly larger due to engine trying to run off of cold gasoline. Fuel combustion is much less efficient in a cold engine, resulting in increased pollutants. Until the converter reaches its peak operating temperature (between 400ºC and 800ºC), all of the engine's emissions pass through the exhaust untreated.

Speed and acceleration is another key parameter involved with modeling emissions output. The heuristic is the faster the speed and acceleration the more emission an automobile is going to produce. Studies from Virginia Tech show that the slower and calmer style of driving was found to reduce CO emissions by 17%, VOC emissions by 22%, NO_x emissions by 48%. Multiple studies also prove that the most efficient method of decreasing CO emissions is to drive slowly and calmly. The less strain and work from the engine the less CO is emitted from the exhaust pipes.

2.3 FLAME

The Flux Lab for the Atmospheric Measurement of Emissions (FLAME) is able to capture emissions from ground-based sources, such as motor vehicles, rail and barge traffic, refuse fires and refueling stations, for which no direct measurement method has been available previously [7]. The FLAME allows for the real-time neighborhood-scale measurement of pollutant fluxes. The mobile FLAME is capable of conducting measurements in many different areas and can focus on specific sources by parking downwind of them [7]. The FLAME uses eddy covariance in order to measure the emissions output in a given region. The eddy covariance method relies on the combined high-speed measurements of gas concentrations, temperature, and wind speed, followed by rapid data collection and analysis [7].

In physical terms, "eddy flux" is computed by measuring how many molecules, moles, or milligrams of gas traveled up with upward wind movement at one moment and how many traveled down with downward wind movement in the next moment [8]. In mathematical terms, "eddy flux" is computed as a covariance between the instantaneous deviation in vertical wind speed (w') from the mean value (w) and the instantaneous deviation in gas mixing ratio (s'), from its mean value (s), multiplied by mean air density (ρ_a) [8].

The eddy covariance method is a direct means for measuring turbulent fluxes in the atmospheric boundary layer, near the surface [8]. In a typical setup, sensors are mounted on a tower for measuring fluxes above the atmosphere-vegetation interface and for within-vegetation measurements [8]. The basic instruments include a CO_2/H_2O analyzer (open path and/or closed path), and a sonic anemometer.

Because of the fast vertical movement of the wind and small amounts of gas and water vapor carried by the upward and downward winds, eddy covariance measurements require very sophisticated (fast and precise) instrumentation [7-9].

III. RESULTS AND DISCUSSION

2.4 Real-Time Emissions Load

The FLAME produced measured NO_x pollutant flux values for a footprint surrounding a residential subdivision. Recorded traffic volumes were not available for the subdivision, therefore, we assumed the vast majority of the pollutants detected from the FLAME came from the nearby high traffic road, Indian River Road. This is a reasonable assumption since residential traffic in this particular area is light, producing low idling times, and slower driving speeds. Indian River Road is more congested in the mornings, afternoons, and evenings, has higher speed limits, and results in more stops and idling times. Also, recorded real-time emission concentrations from the FLAME were more consistent with a congested roadway.

The modeled site is located at the University Shoppes center at the intersection of Strickland Boulevard and Indian River Road (Figure 1). Regent University was located 0.25 kilometers southwest and the majority of the area is residential. Within 0.1 kilometers there were several fuel stations, restaurants, and strip malls. Traffic was heavy during rush hours.

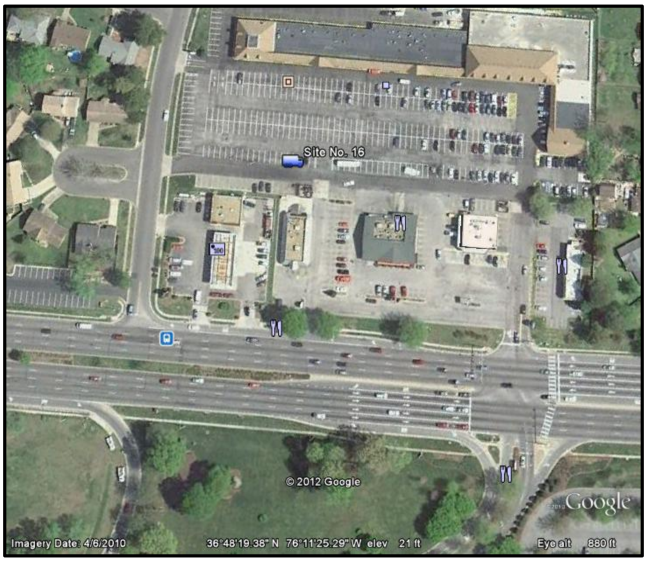

Figure 1. Emissions modeling location - Intersection of I-64 and Indian River Road - Chesapeake, Virginia

Emissions flux is the time averaged covariance between the instantaneous deviations of the vertical wind velocity (w') and the concentration (Cx'), from their linear trends over the averaging period. A positive flux represents a net transfer upward into the atmosphere from

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the surface. A negative flux illustrates a net transfer from the atmosphere to the land surface.

In June of 2008, emissions of NO_x were measured at the intersection of Strickland Boulevard and Indian River Road near I-64. Emissions measurements taken throughout the day (0830-1730) at this location are shown in Table 1 below. From the table the hours from 0830-0930, 1130-1230, and 1630-1730 show NO_x emission loads of 210, 288, and 630 grams respectively, These hours represent the peak traffic flow times during the day, and correspond to: morning rush hour, lunch time, and late afternoon rush hour.

Table 1. Hourly recorded NOx emission loads (grams) at the Chesapeake, Virginia site location

Emission Hours	Amount of NO_x Emissions (grams)
0830-0930	210
0930-1030	271
1030-1130	563
1130-1230	288
1230-1330	215
1330-1430	171
1430-1530	438
1530-1630	778
1630-1730	630

2.5 Modeled Emissions Load

2.5.1 Basic Assumption

Figure 2 below shows the extent of the measurement footprint for this particular location. The footprint describes the extent of the area influencing measured emissions. As seen from the Figure, the majority of measurements included a nearby subdivision. Based on wind speeds and directions coming mainly from a northerly direction, we can make the assumption that concentrations and consequently emissions fluxes within the neighborhood are being influenced by the surrounding heavily traveled roads surrounding the measurement site.

Figure 2. Sampling footprint layout shown overlaid on a GIS map of the sampling location. Footprint shows majority of emissions affecting a local neighborhood.

2.5.2 Modeling Real-Time Emissions

Below are the adjusted sets of VISSIM emissions equations (post calibration), all variables were previously defined. The equations below were used to model the field recorded emissions in order to determine the accuracy level of the VISSIM software. Table 2 provides a comparison of the modeled emissions values versus the measured emissions values. As seen in the table, once calibrated, the model was able to predict measured emissions with 95.66% to 99.52% accuracy. Modeled standard deviations for NO_x concentrations ranged between 6 and 47 g.

<u>Morning 0830-0930</u>

$$K1 = 0.013283 - 0.0002692 \times Speed + 0.00001246 \times Speed^2 \quad (1)$$

$$K2 = .2629 \quad (2)$$

$$K3 = 0.0000015011 \times Speed^2 \quad (3)$$

$$Fuel\ Consumption = Total\ Distance\ Traveled \times K_1 + Total\ Stop\ Delay \times K_2 + Number\ of\ Stops \times K_3 \quad (4)$$

$$NO_x\ emissions = 13.6 \frac{g}{gal} \times Fuel\ Consumption\ (gal) \quad (5)$$

<u>Lunch 1130-1230</u>

$$K1 = 0.007083 - 0.0002492 \times Speed + 0.000000126 \times Speed^2 \quad (1)$$

$$K2 = .2209 \quad (2)$$

$$K3 = 0.0000010801 \times Speed^2 \quad (3)$$

$$Fuel\ Consumption = Total\ Distance\ Traveled \times K_1 + Total\ Stop\ Delay \times K_2 + Number\ of\ Stops \times K_3 \quad (4)$$

$$NO_x\ emissions = 13.6 \frac{g}{gal} \times Fuel\ Consumption\ (gal) \tag{5}$$

Late Afternoon 1630-1730

$$K1 = 0.006083 - 0.0002492 \times Speed + 0.000000126 \times Speed^2 \tag{1}$$

$$K2 = .1709 \tag{2}$$

$$K3 = 0.0000006601 \times Speed^2 \tag{3}$$

$$Fuel\ Consumption = Total\ Distance\ Traveled \times K_1 + Total\ Stop\ Delay \times K_2 + Number\ of\ Stops\ \times K_3 \tag{4}$$

$$NO_x\ emissions = 13.6 \frac{g}{gal} \times Fuel\ Consumption\ (gal) \tag{5}$$

Table 2. Percent difference calculations of real-time versus modeled emission

Time	Real-Time Emissions (grams)	Modeled Emissions (grams)	Modeled Standard Deviation	Percent Difference
Morning - (0830-0930)	210	211	± 6	0.48%
Lunch - (1130-1230)	288	276	± 19	4.17%
Late Afternoon - (1630-1730)	630	602	± 47	4.44%

2.6 Health Effects Related to NO_x Exposure

The state of Virginia released 351,489 short tons of Nitrogen Oxides into the atmosphere in 2008. Virginia Beach emitted 7,437 short tons of NO_x, 87.1% or 6,479 short tons are classified as mobile pollutants. Current scientific evidence links short-term NOx exposures, ranging from 30 minutes to 24 hours, with adverse respiratory effects including airway inflammation in healthy and increased respiratory symptoms in people with asthma. Individuals who spend time on or near major roadways can experience short-term NOx exposures considerably higher than measured by the current network. Approximately 16% of United States housing units are located within 300 feet of a major highway, interstate, railroad, or airport (approximately 48 million people or over 10% of the entire United States population). NOx exposure concentrations near roadways are a particular concern for susceptible people with asthma asthmatics, children, and the elderly.

North of Indian River Road (the road modeled for emissions output) is a residential neighborhood. Young new families with children and elderly couples occupy this residential zone. According to *Areavibes*, an air quality and health safety website, Virginia Beach has an air quality index that is 5% less than the Virginia average and 16.2% less than the national average. Virginia Beach also has a pollution index 345.9% greater than the Virginia average. *Areavibes* reported that Virginia Beach has had 68 days during the year where the air quality was moderate or poor.

Less than a mile stretch of Indian River near I-64 produced 1128 grams of NO_x (1.128 kg) from a total time of 0830-0930, 1130-1230, and 1630-1730. These three times represent the morning, lunch and rush hour traffic times. From simply these 3 hours each day during the workweek, this small stretch of Indian River Road produces 905.8 lbs of NO_x (45.3% of a ton) each year. Due north of Indian River Road near I-64 is a residential zone currently occupied by young children and elderly citizens.

According to previous research the city of Virginia Beach has multiple locations where NO_x emissions levels are close to passing the primary standards set forth by the National Ambient Air Quality Standards (NAAQS). The primary standards provide safe levels of NO_x exposure to ensure public health protection, including protecting the health of "sensitive populations such as asthmatics, children, and the elderly. This modeled sight according to previous research is safe with a NO_x concentration of 22 ± 7 ppb. However, this was in 2008. More research needs to be conducted to see what the current NOx concentration is in the area, due to an increase in cars over the 4 year gap.

IV. CONCLUSION

If we can correlate we can estimate. Since the modeled emissions are based on traffic operations, then it is possible to measure emissions at every intersection and road. This research proves that it is possible to create a real time emissions model using the FLAME to gather real time emissions data. This paper also provides proof of developing a traffic model in the VISSIM traffic software and creating a set of equations to model the emissions along the tested road.

This research is not only applicable to measuring emissions at intersections, roads, highways, and freeways, but it is directly related with the population's health and the local ecosystem's health. The emissions of produced from this road have direct consequences as mentioned above on human and environmental health. This research can be used to determine and validate the air quality for residential zones, and possible health and environmental effects of local traffic. As mentioned previously, the EPA has Virginia Beach listed as a safe air quality zone; however, this research and preceding research show that the EPA needs better methods of quantifying emissions in local areas. The EPA's air quality profile of Virginia Beach is not as accurate, and should use real time emissions modeling as a standard of reporting air quality.

This location produces over 1.1 kg or 2.4 lbs of NO_x emissions between 0830-0930, 1130-1230, and 1630-1730. This does not include the other hours of the day. This information can be used to determine the long term health effects for the people living in the local residential area. The modeled sets of equations are within a 4.5% percent difference of the real time emissions measured in 2008. We can accurately predict and estimate the emissions load for a given location using within 4.5%. In order to perfect the model, we would need to test similar locations in the area, to validate the sets of models. In order to further the validation of the model, we would have to develop a correlation and comparison for each new simulation run.

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