TEAM PROJECT REPORT

Simulation Analysis of Traffic-Operation-Related Emission: A Research Experience and Classroom Implementation Plan

Submitted To

The RET Site
For
"Sustainable Engineering for Urban Needs:
Research Experiences for Middle and High School Teachers"

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ABSTRACT

The U.S transportation conformity program requires transportation plans, programs, and projects to "confirm to" the goals established in statewide transportation improvement programs (STIP). It requires that transportation activities will not cause new air quality violations, or worsen existing violations, or delay timely attainment of the National Ambient Air Quality Standards (NAAQS) for traffic-generated air pollutants such as carbon monoxide (CO) and particulate matters ($PM_{2.5}$). Recent studies also indicated that exposures to traffic emission increase the risk of adverse health effects for population, living, working, in particular for young developing children going to school near large roadways who are especially vulnerable to increased levels of air pollutants.

In this approach, microscopic traffic simulation model, VISSIM, emission factor simulator, MOVES (Motor Vehicle Emission Simulator) will be used. VISSIM is a microscopic, time step and behavior based traffic simulation software that models multi-modal traffic flow and realistically simulate urban and highway traffic flow, pedestrians and cyclist. It can be used to model traffic with various traffic control measures in both a 2D and 3D environment. MOVES is a emissions modeling tool, which can be used to estimate national, state, and county level inventories of criteria air pollutants, greenhouse gas emissions, and some mobile sourced air toxics from highway vehicles. For any given traffic scenario, VISSIM can be running to simulate the traffic operation and result in vehicle trip distribution aligned with other parameters that are required as inputs to MOVES, and the MOVES is used to estimate on-road emissions.

LITERATURE REVIE

The teachers were presented with literature from research done on traffic simulation software in addition to calculating project level emission using VISSIM and MOVES. The different pieces of literature allowed the teachers to gain insight on the different aspects of their project and some of the methods they would use while working on the project.

In regards to the goal of exploring methodology for analyzing the impact of traffic flow by using a simulation approach, the teachers were to become familiar with various computer simulation models.

Computer simulation of traffic is a widely used method in research of traffic modeling. With many software programs on the market, A Review of Traffic Simulation Software (Kotuesevski and Hawick, 2009) reported a comparison of features with respect to a set criterion. These criterion included (but is not limited to) open source and free use, creating traffic networks and associated vehicle patterns, simulation output, ability to simulate very large traffic networks, etc.

Furthermore, as reported in Simulating and Analyzing Incidents Using CORSIM VISSIM Traffic Simulation Software (2002), a key component in measuring the performance of a network using simulation software involves incidents and studying their impacts on a traffic system.

The use of traffic simulation software is further supported in an article titled, "VISSIM: a multi-parameter sensitivity analysis" (Lownes and MacHemehl , 2006). Traffic simulation is increasingly a preferred method of traffic analysis.

Along with the teachers creating a network using VISSIM, they were to calculate on-road emissions using field collected emission data. According to Nemalapuri (2010), the use of local data for modeling project level emissions have a large impact on the distribution of estimated emissions, and it can also significantly influence the accuracy of local scale air quality modeling assessments.

The literature reviewed by the teachers supported the goal of exploring the methodology for analyzing the impact of traffic flow operation on the on-road emissions by using a simulation approach.

GOAL AND OBJECTIVES

The goal of this research project is to explore the methodology for analyzing the impact of traffic flow operation on the on-road emissions by using simulation approach. In order to fulfill this goal, the following objectives needed to be completed:

- Setting up microscopic traffic models under the simulation software environment.
- Calibrating and validating the simulation models using field collected traffic data.
- Inputting the simulation results into an emission factor simulator to estimate the on-road emissions.
- Verifying the estimated on-road emissions using field collected emission data.

RESEARCH TASKS

In this research, the microscopic traffic simulation model, VISSIM (Verkehr In Städten - SIMulationsmodell -German for “Traffic in cities - simulation model”), and emission factor simulator, MOVES (Motor Vehicle Emission Simulator), are used. VISSIM (**Figure 1** on next page) is a microscopic, time step and behavior based traffic simulation software that models multi-modal traffic flow to realistically simulate urban and highway traffic flow, pedestrians and cyclist. It can be used to model traffic with various traffic control measures in both a 2D (two-dimensional) and 3D (three-dimensional) environment. MOVES is a emissions modeling tool, which can be used to estimate national, state, and county level inventories of criteria air pollutants, greenhouse gas emissions, and some mobile sourced air toxics from highway vehicles. For any given traffic scenario, VISSIM can be running to simulate the traffic operation and result in vehicle trip distribution aligned with other parameters that are required as inputs to MOVES, and the MOVES is used to estimate on-road emissions.

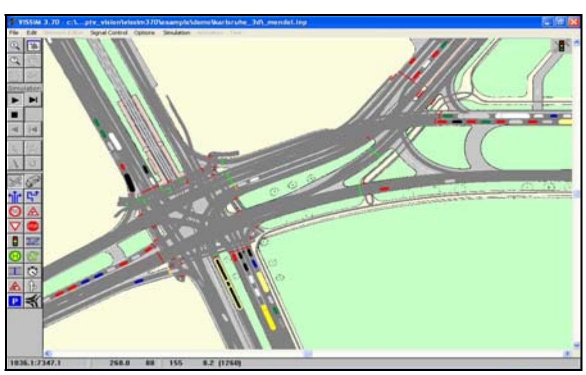

Figure 1. Transportation Simulation Software VISSIM Screen

The study site selected is located adjacent to Princeton High School at the intersection of Interstate I-75 and the Sharon Road exit # 15 in Cincinnati, OH. **Figure 2** illustrates the aerial map of the study intersection. The study site has a large volume of traffic traveling on I-75 and Sharon Road receives traffic from many different businesses and residents of Sharonville, Evendale, and Glendale.

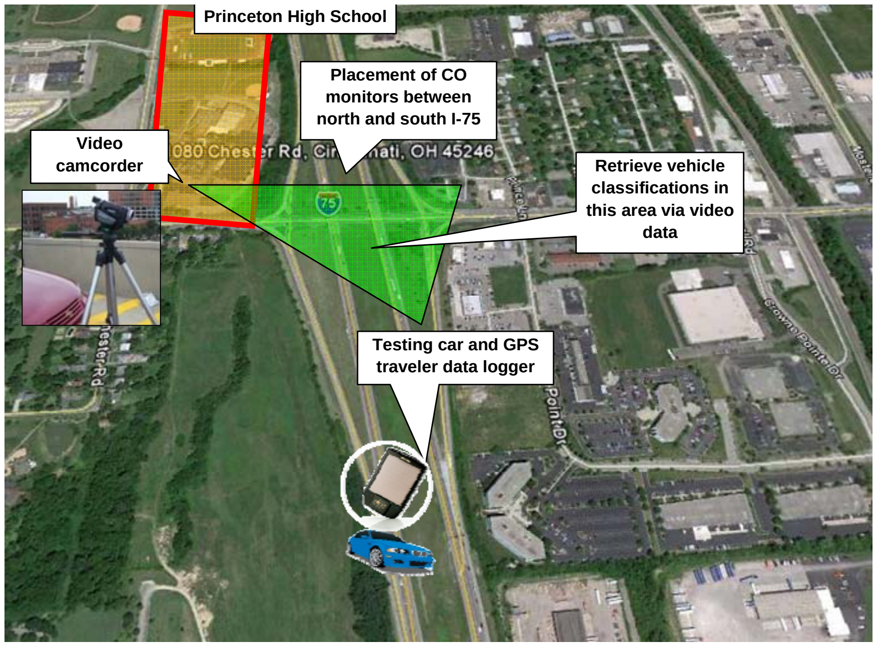

Figure 2. Data Collection and Required Instruments at the Study Site

In summary the research tasks by week were as follows:

- Week 1: Training and practice of basic traffic and emission theories and field data collection.
- Week 2: Training and application of simulation software and data analysis.
- Week 3: Training and application of simulation software and data analysis.
- Week 4: Training and application of simulation software and data analysis.
- Week 5: Conduct "what-if" analysis and set up hands-on examples for classroom implementation.
- Week 6: This week was devoted to preparing final presentation, final report, and summary.

METHODOLOGIES USED

The data collection for this project was designed to take place at multiple locations near Princeton High School using multiple video cameras, two CO sensors, and a GPS data logger.

In order to calibrate the simulation models, minor field data collection was needed. The data collection includes:

- Vehicle trajectory data gained by Global Positioning System (GPS) Travel Loggers to calibrate the travel behavior parameters involved in VISSIM.
- Traffic video data for validating the traffic flow rates with the VISSIM model.

- On-site CO measurement at the selected highway infrastructure to verify with the MOVES result.

A GPS travel data logger is equipped in a testing car, and this car is run along the selected freeway segment. In this study, the QSTARZ™ BT-Q1200 Ultra GPS Travel Recorder (see **Figure 3**) is adopted to collect the GPS data logger. The GPS travel data logger enables the researchers to measure travel time accurately. A camcorder and CO sensor (see **Figure 4**) is placed on an overpass across the selected highway segment to collect traffic video data and traffic-related CO emission, respectively.

Figure 3. The GPS Data Logger and the Interface of Its Software

Figure 4. Camcorder for Videotaping (left) and CO Sensor (right)

Two video cameras were available for use in this project and strategic locations were necessary for these devices so that the traffic data could be accurately recorded at all relevant locations. The proposed location for one camera was the roof of Princeton High School. Upon arriving to the site, this location was found to be too dangerous due to no protection while climbing to the roof location. The space adjacent to the press box at the football field was then selected for its unobstructed view to both directions of the traffic on Interstate I-75. The second camera was then set up on the sidewalk approximately 50 feet east of the exit from I-75 South onto Sharon Rd. This location was selected due to the ability to see all traffic at both intersections critical to the site. These intersections include the exit locations from I-75 North and I-75 South.

The CO sensors were placed in locations that allowed for data to be collected in two areas. They were split between a near interstate position adjacent to the south bound lanes of I-75 and adjacent to the intersection of the exit ramp from south bound I-75 and Sharon Rd.

The GPS data loggers were placed in two different vehicles which were to travel at the pace of traffic during the collection from exit 14 to exit 16 on I-75. Two rounds trips were completed by each vehicle from approximately 2:30-3:30pm and from 4:30-5:30pm.

After the traffic was recorded for north and south bound I-75 and all local traffic at the intersections for the exits from I-75 and Sharon Road, traffic counters were used in the lab to attain the vehicle types and distribution in this location. The data which was collected at the site is presented in **Tables 1, 2** and **3** on next page.

Upon completing the data collection, the participants used this data to calibrate the traffic simulation using VISSIM. The data from the traffic simulation was then recorded to be used as a calibration in MOVES. The data from this program was then used to compare to the recorded input from the CO sensors. The purpose to comparing the data from the MOVES output to the recorded CO sensors is to validate if the model used in simulation is correct.

TRAINING RECEIVED

Training activities for learning fundamental traffic theories, data collection, and simulation software were conducted. The teachers were first introduced to fundamentals of traffic and emission theories and simulation by using VISSIM. VISSIM was used to analyze performance of traffic scenarios with varied traffic conditions. The Graduate Student Mentor provided guidance to these training activities (see **Figure 5** on next page).

The training for this project involved learning how to setup simulations in VISSIM and MOVES. The participants also received training in data collection by use of a GPS recorder, CO sensor, and multiple types' traffic counters. They also worked on understanding the details involved in validating data. One key issue was comparing data from the CO sensor to the output of MOVES. The CO data was recording using different units so it was necessary to learn about the Gaussian Dispersion Model to find the equivalent values in the same unit of measure.

RESEARCH FINDINGS

The product from this research was the comparison from the MOVES software and the CO sensor. One of the main objectives of the project was to create a model using the data from the field and simulations using VISSIM and MOVES to be able to accurately predict the CO emissions at the site location. The data collected from the CO sensor at the site location provided a CO level of 2.36 mg/m3. To find the value from the MOVES program, the Gaussian Dispersion Model was used to convert from parts per million to mg/m3. The resulting data from the VISSIM and MOVES programs was 0.243mg/m^3. At first glance this is clearly off by an order of magnitude of 10, but there are multiple reasons for this difference. The simulation only took into account the traffic on the northbound portion of the site

Table 1. Hourly Volume Data for All Vehicles and Heavy Vehicles (HV) on I-75

		Northbound I-75		Southbound I-75	
		Vehicles	Percent HV	Vehicles	Percent HV
3:10 PM	Average	4982	9.5%	4718	8.0%
4:20 PM	Rush	5608	5.4%	4784	3.0%
4:50 PM	Congestion	5496	5.9%	3524	3.7%

Table 2. Hourly Volume Data for All Vehicles and Heavy Vehicles at Exit on Sharon Road From I-75 Northbound

		Northbound I-75 Exit							
		From East			From South			From West	
		R	TH	Percent HV	R	L	Percent HV	TH	L
3:10 PM	Average	270	638	5.3%	212	366	1.6%	550	218
4:20 PM	Rush	326	572	5.5%	300	386	0.5%	496	192
4:50 PM	Congestion	86	532	8.0%	224	342	3.5%	532	178

Table 3. Hourly Volume Data for All Vehicles and Heavy Vehicles at Exit on Sharon Road From I-75 Southbound

		Southbound I-75 Exit							
		From North			From East		From West		
		R	L	Percent HV	TH	L	R	TH	Percent HV
3:10 PM	Average	272	336	6.5%	672	332	366	432	2.3%
4:20 PM	Rush	350	312	13.5%	698	260	422	376	1.6%
4:50 PM	Congestion	214	286	14.7%	612	262	434	424	1.4%

Figure 5. Graduate Student Mentor Showing to the Teacher How to Create Traffic Signal

study. So, a large number of vehicles were not used in the simulation including the traffic on the southbound portion of I-75 and all traffic on the local roadways. When considering this information, the result is that our model was a good model for this site location. Future research will be needed to continue to find accurate models for all areas of interest.

CLASSROOM IMPLEMENTATION PLAN

The lesson is titled, "Traffic Lights … What's the Big Deal?" This will be a lesson used at the beginning of the year to introduce students to the art of working together in a group and brainstorming ideas to a given problem. The lesson is for a 9th grade Algebra I class and will take one 45 minute class period. The purpose of the activity is to have students defend their own ideas and those that they choose to adopt as determined by successfully attending to 80% of rubric items.

The students will be given the Pre-Test. After the pre-test have been completed, the teacher will introduce the class to his/her time spent during the Summer RET 2011 program. The poster will be shown as well as the traffic video. The teacher will discuss the field of engineering touching on the fact that engineers work collaboratively with other professionals to be problem solvers. The "problem solvers" quote will lead into the explanation of the project at hand.

Students will be shown the intersection in question and will be asked to come up with a solution to the traffic light signal timing. While the problem is the signal timing, the goal of the lesson is effective group work.

Students will be placed in groups of three and will be given a double sided rubric. The teacher will review the rubric with the class as a whole and explain that each member of the group will complete a rubric for the members of the group.

Students will be given time to ask the teacher any clarifying questions and then will be given 15 minutes to brainstorm ideas to fix the traffic signal timing. At the end of the 15 minutes, the group must come to a consensus and communicate their plan in some written format of their choice. The written format will be up to the students … it could be a drawing, a paragraph, etc. Students will be given 5 minutes to complete this process.

At the end of the group session, students will return to their seat and complete the rubric for the other two members of their group.

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APPENDIX: LESSON PLAN

1A. Traffic & Mathematics

Teachers: Bert Martini and Gabrea Bender
Subject: Algebra I
Grade: 9th Grade
Durations: 1 – 45 minute class period at beginning of school year

1B. Engineering theme is transportation engineering

2. Ohio Common Core Mathematics Standards

High School Modeling

ACT Quality Core Standards:

- Mathematical Processes Learned in the Context of Increasingly Complex Mathematical & Real-World Problems:
  - Apply problem-solving skills to the solution of real-world problems.

STEM Standard:

- Data Analysis, Statistics and Probability:
  - Develop and evaluate inferences and predictions that are based on data.

3. Goal & Objectives

After actively participating in a brainstorming session, students will defend their own ideas and those that they choose to adopt as determined by successfully attending to 80% of rubric items.

4. Misconceptions

Designing the traffic signal pattern for an intersection would be an easy task.

5. Materials Needed

- Pen/Pencil
- Traffic Video
- Traffic Poster
- Screen shot of Intersection
- Rubric

6. Instructional Strategies

- Hands on lesson
- Activity
- Pair/Share
- Peer Critique

7. Utilize Technology

- Smartboard

8. Learner Participation

- The students will be given the Pre-Test. (3 min)
- Teacher will introduce the class to his/her time spent during the Summer RET 2011 program. (3 min)
- The poster will be shown as well as the traffic video. (3 min)
- The teacher will discuss the field of engineering touching on the fact that engineers work collaboratively with other professionals to be problem solvers. The "problem solvers" quote will lead into the explanation of the project at hand. (5 min)
- Students will be shown the intersection in question and will be asked to come up with a solution to the traffic light signal timing. While the problem is the signal timing, the goal of the lesson is effective group work. Students will be placed in groups of three and will be given a double sided rubric. The teacher will review the rubric with the class as a whole and explain that each member of the group will complete a rubric for the members of the group. Students will be given time to ask the teacher any clarifying questions and then will be given 15 minutes to brainstorm ideas to fix the traffic signal timing. (15 min)
- Each group must come to a consensus and communicate their plan in some written format of their choice. The written format will be up to the students … it could be a drawing, a paragraph, etc. (5 min)
- At the end of the group session, students will return to their seat and complete the rubric for the other two members of their group. (5 min)

9. Assessment

- Pre and Post Test
- Rubric for evaluation of group work

10. Essential Review Questions

1) What career fields exist for studying and working in the field of traffic?
2) How does traffic affect you?
3) List the considerations that must be made when designing the timing of traffic signals.
4) How is mathematics used in the study of traffic patterns?
5) What societal impacts can you see for those who work in the traffic related fields?

11. Pre/Post Questions

1) What career fields exist for studying and working in the field of traffic?
2) How does traffic affect you?
3) List the considerations that must be made when designing the timing of traffic signals.
4) How is mathematics used in the study of traffic patterns?
5) What societal impacts can you see for those who work in the traffic related fields?

12. Reflection