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Bike-lane Traffic Impact Assessment Activity for High School Students (Work in Progress)

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Abstract

High school students use the surface transportation system virtually every day and can relate to traffic congestion, travel delays, and roadway safety. Moreover, trends observed in the Federal Highway Administration driver's license data and in the National Household Travel Survey data suggest that the popularity of active modes of transportation, such as cycling, is continuously increasing among the high school age group. In this paper, an activity is proposed to show how mathematical models can be used to assess the impact on traffic congestion of retrofitting a roadway with bike lanes. This paper builds upon the familiarity of students with the transportation system and pursues three objectives. First, students learn how math and physics principles can be used to model complex systems, such as a surface transportation system. Second, students are introduced to the decision-making process and before-and-after studies in which quantitative measures are used to support a decision. Third, students learn how engineers can potentially influence city planning and affect communities.

In the first steps, students learn how math can be used to model driver behavior and to develop car-following models. Then, students use traffic simulation software to model the flow on an urban corridor. The software considers traffic volume, speed limits, traffic signal timing, and the number of travel lanes to estimate performance measures such as the length of queues, travel delays, and CO_2 emissions. In the next step, students modify the simulation model and remove a travel lane to provide the space necessary for a bike lane and a buffer lane. Students discuss the traffic simulation model's outputs and make a recommendation about whether to install a bike lane on the roadway.

VISSIM traffic simulation software, a commercial software often used by engineering firms and public agencies to model transportation networks, was used in this activity. A classroom license for the software is available to educators at no charge. Twenty high school students in grades 9 through 12 participated during a one-week engineering summer camp at Saint Louis University. The activity was completed in two hours. Students worked in pairs, with one faculty member and two counselors facilitating the discussion and hands-on computer simulation. As a work in progress, this paper presents the author's primary observations about students' learning and discusses future directions for this research.

Introduction and Review of Literature

Restoring and improving urban infrastructure is identified by the National Academy of Engineering (NAE) as one of the grand challenges of engineering in the 21st century. One of the objectives in meeting this challenge is to integrate sustainable modes of transportation, such as walking, biking, and public transit, into the urban transportation system. This activity demonstrates a process used by transportation engineers to study the feasibility of retrofitting an urban street with a bike lane. The activity proposed in this paper is different from existing transportation-related outreach in three main ways:

1) The traffic simulation model can be customized to study a local street that is familiar to high school students participating in the activity.

2) The learning outcomes extend beyond data-driven decision making. The activity highlights the role of engineers in shaping communities and the importance of public engagement.
3) The activity provides a glimpse of a fully automated driving environment to students.

A review of the literature shows several activities that have been developed by educators to introduce middle and high school students to the transportation engineering profession. Luken and Mumbower (2010) proposed three such activities. The first investigated the tradeoff between various modes of transportation. The second aimed at informing students about design objectives in transportation projects. The third focused on users of transportation systems and the role of engineers in accommodating their needs. In the third activity, students were tasked with planning the daily activities of a household of two parents and two children. Elam et al. (2011) developed a web-based tool to introduce students to transportation history, road signs and pavement markings, traffic signal timing, crash reporting, hurricane evacuation, and alternative modes of transportation. The tool was designed to be part of high school transportation curricula. Islam and Brown (2013) developed a board game with rules similar to Monopoly. Each player takes the role of a transportation engineer and has to address the transportation needs of the city with the resources allocated to them. Shekhar et al. (2014) developed a "*Cloud-based, Collaborative, Scaled-up Modeling Environment (C^2SuMo)*" for traffic simulation. The tool was built using the Google Earth application programming interface (API), and implemented the Simulation of Urban Mobility (SUMO) as the computational engine. Activities were developed to study the impact of changes in signal timing plans and volume of passenger cars and trucks on travel delay and the length of the queue at an intersection.

Bike-lane Traffic Impact Assessment Activity

This section provides an overview of the bike lane impact assessment activity modules used in this study.

<u>Introduction to Transportation Modeling</u>: The activity starts with brainstorming solutions for improving the flow of vehicles at a busy intersection. The instructor facilitates the discussion to arrive at solutions such as modifying the intersection in one of several ways: two-way stop, all-way stop, signal-controlled, roundabout, or interchange. In the next step, the instructor raises the question of methods for assessing the effectiveness of those alternatives. Potential answers from students include building a physical model, observing similar intersections in the city, and modeling the design scenarios on a computer. The students and instructor then discuss the practicality, accuracy, and cost of each evaluation method. Computer simulation is the most accurate and practical method for evaluating design alternatives, and could cost less than other three methods. The students are then asked to suggest the road characteristics and design-scenario aspects that should be incorporated into a traffic-simulation model. Volume and percentage of heavy vehicles, number of lanes, lane width, speed limit, and signal timing are among the factors that should be considered. The other key question is how to replicate behavior of drivers in a computer.
<u>Car following models</u>: These models explain how cars follow each other on the road. A computer traffic simulation program implements these models to replicate drivers' behavior. Equation 1 shows a car following model developed by General Motors researchers in the 1950s.

$$\dot{x}_f(t+\Delta t) = \alpha[\ddot{x}_f(t) - \ddot{x}_l(t)] \qquad \text{(Equation 1)}$$

where $\ddot{x}_f(t)$ and $\ddot{x}_l$(t) are the acceleration rate of a following vehicle and a lead vehicle, respectively, at time t. The expression $\dot{x}_f(t+\Delta t)$ is the speed of a following vehicle at time Δt after t. The term α is a constant value. These car following models, combined with physics kinematics equations, can be used to calculate the location and trajectory of vehicles. Students use these models to calculate the movement of two vehicles over a 5-second period. It is assumed that Δt is 1 second. The instructor emphasizes that animations and transportation measures of effectiveness obtained from traffic simulation models are developed according to car following models.

Transportation measures of effectiveness (MOEs): In the next step, the instructor and students discuss indexes that could be used to quantify the quality of travel experienced by road users. Students are asked to reflect on their personal daily travel experiences and mention when they think the transportation system is or is not working well for them. Through guided discussions, students typically list indexes such as travel delay, length of vehicle queues at intersections, and number of vehicle stops before traveling through an intersection as MOEs of the transportation system. The instructor can allude to environmental MOEs such as fuel consumption, fuel cost, and emissions from vehicles and their impact on users and nonusers of the road.

Studying Traffic Impacts of a Bike Lane: In the next step, the instructor facilitates a conversation about active modes of transportation, such as cycling and walking, and discusses their health benefits and impacts on the environment. The discussion then transitions into the NAE grand challenge and the need for restoring and improving urban infrastructure. It highlights that urban streets were historically designed to move vehicles faster and that other modes of transportation were not necessarily considered in the designs. The instructor then refers to Grand Boulevard, a street next to the summer camp site. There are three lanes on the northbound Grand Boulevard (Figure 1-a). The far right lane is an 8-foot-wide dedicated right-turn-only lane and appears underutilized (Figure 1-b). It appears that this lane could be retrofitted as a bike lane. Students are asked to propose a method for analyzing the impact of such a change. They are guided to determine MOEs for the decision-making process and to identify the data needed to develop a simulation model of the street.

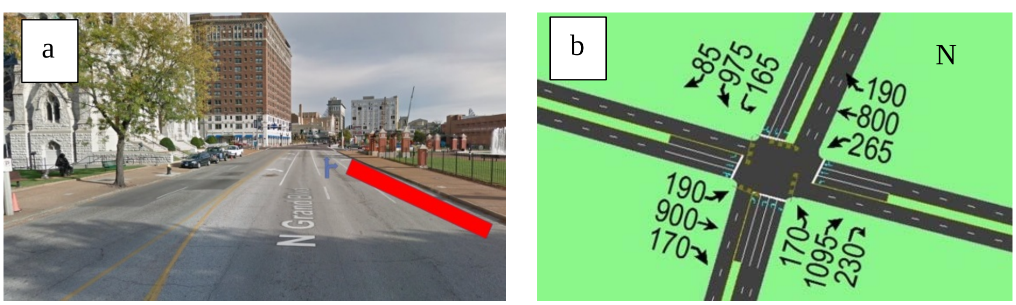

Figure 1: a) street view of northbound Grand Boulevard b) AM peak-hour traffic volume (vehicle/hour) at Grand BLVD and Lindell BLVD intersection

The instructor elaborates on the data-driven decision-making process in roadway engineering projects. The existing roadway conditions, commonly referred to as a no-build scenario, are studied first, and MOEs for no-build scenarios are determined. In the next step, the design alternatives are modeled, and MOEs for scenarios are determined. The instructor then outlines the proposed process for a bike-lane traffic impact assessment:

1) Students are provided with a traffic simulation model of Grand Boulevard next to the Saint Louis University campus (Figure 2). Students run the model and observe the traffic movement of vehicles in the network. They are instructed to record the MOEs of the network at the intersection of Grand Boulevard and Lindell Boulevard. Table 1 is provided to record the performance of a no-build scenario. Table 1 MOEs are defined and explained to the students.

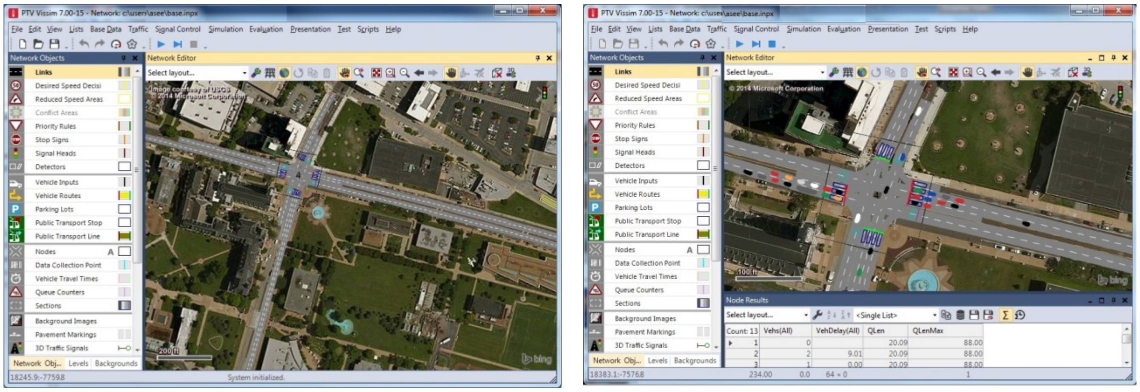

Figure 2: Coded street network (no-build) in the traffic-simulation model

2) Students are then asked to work in pairs and remove the far right lane from Grand Boulevard and revise the lane configuration at the intersection of Grand Boulevard and Lindell Boulevard. Step-by-step instructions for tweaking links, connectors, and routing decisions in the model are provided through PowerPoint slides. It is recommended that students be allowed 35 minutes to recode the model.

3) Students are asked to run the model and observe the simulation animation to identify potential congestion problems and report the MOEs once the simulation is complete. A table similar to Table 1 is provided to the students for reporting the MOEs.

4) Each pair is asked to analyze MOEs in no-build and build scenarios and make a recommendation whether to remove the traffic lane. Removal of the far right lane will result in an increase in travel delay of vehicles. The instructor introduces the students to trade-offs between competing objectives for accommodation of all modes of transportation. Engineers could optimize the existing resources or propose alternative solutions that would improve

Table 1: Transportation measures of effectiveness (MOEs) for no-build scenario

Turning movement	Number of Vehicles (veh)	Vehicle Delay (sec)	Queue Length (ft)	Maximum Queue Length (ft)
Northbound right				
Northbound through				
Northbound left				
Westbound right				
Westbound through				
Westbound left				
Southbound right				
Southbound through				
Southbound left				
Eastbound right				
Eastbound through				
Eastbound left				
Overall Intersection				

accessibly and performance of transportation system for citizens. The examples include optimizing the signal timing plan for the new intersection layout configuration, or identifying a parallel corridor that is more bicycle friendly with respect to both safety and mobility of cyclists.

5) In the final step, students are asked to remove the traffic signals from the simulation model to create a *traffic madness* scenario. They are encouraged to run the model and observe the simulation animation. With no traffic control device at the intersection, vehicles travel through the junction without reducing speed or yielding to other vehicles. Students are asked to investigate the intersection travel delay and other MOEs. The simulation model would report almost no travel delay and student would agree that the intersection is more efficient for moving vehicles. Students are asked whether they think this scenario could become a reality someday. This question can lead to an open-ended conversation about autonomous vehicles and opportunities and challenges with regard to technology, user acceptance, privacy, legal issues, and the role of engineers and scientists in addressing the pertinent issues.

Initial Observations and Findings

This section presents instructor observations from working with high school students on implementation of this activity as part of a week-long engineering summer camp. Students worked together in pairs to modify the traffic-simulation model. All the teams were able to successfully run models and report the traffic performance measures before and after removing the lane. Few teams had begun to write down the transportation performance measures before the simulation period was complete, and thus a fair comparison of the two scenarios was not possible. In future, we will elaborate more on what constitutes a fair comparison. The one-hour session was sufficient to complete the simulation activity. The study of Grand Boulevard next to campus helped students make the connection between an engineering design process and a real-world transportation situation that they used during the one-week summer camp. In general, students were aware of the civil engineering profession; however, they were not familiar with the sub-discipline of transportation engineering.

As stated earlier, this activity is a work in progress, and no quantitative data was collected. For next steps, quantitative metrics will be developed to assess students' learning and evaluate the success of this activity, which will be presented to high school students as part of Siant Louis University engineering summer camps in June and July 2017.

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