Engaging Undergraduate Students in Transportation Studies through Simulating Transportation for Realistic Engineering Education and Training (STREET)

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ABSTRACT
The practice of transportation engineering and planning has evolved substantially over the past several decades. A new paradigm for transportation engineering education is required to better engage students and deliver knowledge. Simulation tools have been used by transportation professionals to evaluate and analyze the potential impact of design or control strategy changes. Conveying complex transportation concepts can be effectively achieved by exploring them through simulation. Simulation is particularly valuable in transportation education because most transportation policies and strategies in the real world take years to implement with a prohibitively high cost. Transportation simulation allows learners to apply different control strategies in a risk-free environment and to expose themselves to various transportation engineering methodologies that are currently in practice. Despite the advantages, simulation, however, has not been widely adopted in the education of transportation engineering. Using simulation in undergraduate transportation courses is sporadic and reported efforts have been focused on the upper-level technical elective courses. A suite of web-based simulation modules was developed and incorporated in the undergraduate transportation courses at University of Minnesota. The STREET (Simulating Transportation for Realistic Engineering Education and Training) research project was recently awarded by NSF (National Science Foundation) to develop web-based simulation modules, improve instruction in transportation engineering courses and evaluate their effectiveness. Our ultimate goal is to become the epicenter for developing simulation-based teaching materials, an active textbook, which provides an interactive learning environment for undergraduate students. With the hand-on nature of simulation, we hope to improve student’s understanding of critical concepts in transportation engineering and student motivation toward transportation engineering, and improve student retention in the field. We also would like to disseminate the results and teaching materials to other colleges so they can integrate these online modules in their current curricula.

KEYWORDS
Transportation Education and Training, Transportation Simulation, Roadway Geometry Design
INTRODUCTION
The practice of transportation engineering and planning has evolved substantially over the past several decades. Young graduates face a wide range of increasingly complicated problems from growing congestion and worsening air quality to environmental preservation and social equity concerns [1]. The task of transportation education in this era, as stated by an Institute of Transportation Engineers (ITE) Committee [2], is not only “to train students in how to do various activities associated with current practice”, but also “to provide students with the tools necessary to solve new problems that arise”. Previous studies, on the other hand, reveal the hourly requirement of transportation-related courses offered for undergraduate students is decreasing [3, 4], and entry-level engineers lack significant exposure to transportation engineering methodologies [3]. To solve this problem, the transportation engineering curriculum (including both content and teaching method) needs to be more rigorous and technically focused to meet market needs.

Most transportation-related courses, however, are still addressed in a traditional way with “chalk and talk” lectures, “paper and pencil” problem-solving, and class projects or papers on related topics [5, 6]. It often fails to motivate students and limits them from effectively assimilating and applying knowledge in their future work. This approach to transportation education does not expose undergraduate students to the myriad of challenging issues that would hopefully encourage them to pursue careers in transportation engineering. As a consequence, a recent survey [4] indicates the number of graduates in transportation engineering has decreased slightly despite increasing demand from the transportation industry. Finding qualified entry level transportation engineers has been a major concern for employers of transportation professionals for more than a decade [3], particularly considering the aging nature of the field. For example, within management and higher levels of engineers at the Minnesota Department of Transportation, the average age is between 55 and 60 years old [7]. As transportation problems are not going away, fresh ideas and a new generation of transportation professionals need to be brought into the field.

A new paradigm for transportation engineering education is necessary to better engage students and deliver knowledge. Simulation has been demonstrated as a promising strategy for teaching in various studies [8, 9, & 10]. Simulation allows learners to engage actively by running experiments, testing different strategies, and building a better understanding of the aspects of the real world which the simulator depicts [11]. In simulation, learners’ individual choices lead them down different paths toward different outcomes. Essentially, simulation allows students learn directly from the outcomes of their own actions [8, 12, & 13].

Web-based education has become a popular and effective way of complementing classroom instruction in recent years. Online learning tools bring a classroom laboratory right in front of a student on the computer. Web-based learning tools offer the benefit of platform and location independence. Users can virtually access the learning tool anytime and anywhere around the world using computers with Internet access.

Clearly, this approach can be integrated with other distance learning approaches already in place for teaching transportation technologies. For example, several web research modules were developed by ITS institute at University of Minnesota for high school students [14]. Liao et al
[15] developed a web-based traffic simulation framework for transportation training and education. Helbing et al. [16] developed freeway traffic models to help people better understand on-ramp vehicle merging, lane-changing, car following, lane-closing, and signal control through online traffic simulation and visualization [17].

Simulation is valuable in transportation education because most transportation policies and strategies in the real world take years to implement with a prohibitively high cost, while simulation allows learners to “apply new skills in a risk-free environment” [8]. Simulation of a transportation system will also encourage students to move beyond atomistic equations that, to date, have constituted the majority of instruction in the course, and evaluate transportation issues in a holistic way. Despite the advantages, simulation, however, has not been widely adopted in the education of transportation engineering. Using simulation in undergraduate transportation courses is sporadic and reported efforts have been focused on the upper-level technical elective courses. Adopting simulation to illustrate critical concepts for courses like Introduction to Transportation Engineering is rare. Therefore the effectiveness of simulation has not been fully examined in transportation education practice, and its potential advantages over traditional ways of learning have not been widely acknowledged.

OUR APPROACH
To tackle these challenges and promote simulation in transportation engineering education, we have been developing and refining several web-based simulation modules that can be easily incorporated in the undergraduate transportation courses. Some of these simulation modules have been deployed and evaluated in a diverse setting and improved from evaluation results. The STREET (Simulating Transportation for Realistic Engineering Education and Training) research project was recently awarded by NSF (National Science Foundation, http://www.nsf.gov/) to develop web-based simulation modules, to improve instruction in transportation engineering courses and to evaluate their effectiveness. Our ultimate goal is to become the epicenter for developing simulation-based teaching materials, an active textbook, which offers an interactive learning environment to undergraduate students. With the hands-on nature of simulation, we hope to improve student understanding of critical concepts in transportation engineering and motivate students to learn more about transportation engineering, and improve student retention in the field.

Specifically, we have developed and tested in the classroom for the following simulation modules, namely, ROAD: Roadway Online Application for Design, ADAM: Agent-based Demand and Assignment Model, SONG: Simulator of Network Growth, and OASIS: Online Application of Signalized Intersection Simulation. We are currently developing SOFT: Simulation of Freeway Traffic. Our target undergraduate course is Introduction to Transportation Engineering, which is a required course for undergraduate students in most Civil Engineering Departments. However, the online simulation modules do have extended capabilities that will be useful in the teaching of highway design, traffic engineering and transportation system analysis. All simulation programs are web-based, which enable easy access and learning outside the classroom. It is noteworthy that commercial transportation simulation packages do exist. The commercial tools designed for professionals, however, are usually complicated and expensive, and thus inappropriate for classroom use, particular in the
introductory course which focusing on conceptual understanding. We do not intend to duplicate or even compete with the commercial packages. Our emphasis is to provide a simple web-based simulation tool that allows student to better understand the underlying theory in transportation engineering.

Prototypes of these simulation programs have been developed, including ROAD, ADAM, SONG and OASIS, through previous work over the last several years. Initial evaluation and testing including the prototypes of ROAD, ADAM and SONG have been conducted in the course offerings at the University of Minnesota - Twin Cities (UMN). The preliminary evaluation results are very positive and encourage us to pursue further.

Building upon the local implementation success, we also plan to engage as many as 20 transportation faculty members from different universities across the country. They will evaluate and test these simulation programs in their existing teaching curriculum and provide feedback to the project team for continuing improvement. We also plan to work with the Center for Transportation Studies at UMN to set up a mobile booth at the annual Minnesota State Fair and the Minnesota Transportation Museum to educate the public on current transportation problems. Many transportation problems, such as how traffic congestion is generated and propagated, have great public appeal and can be easily demonstrated through publicly-oriented versions of the simulation modules developed in this project. The proof-of-concept trial implementation at UMN for some of the prototype simulation modules are briefly described as follows.

AGENT-BASED DEMAND AND ASSIGNMENT MODEL (ADAM)

A prototype Agent-based Demand and Assignment Model (ADAM) was developed and used as an in-class project to enhance student’s learning on travel demand models. It was introduced to a undergraduate course Introduction to Transportation Engineering (CE3201) in spring semester 2006 at the Civil Engineering Department, University of Minnesota [18]. CE3201 is a required Civil Engineering course and it is taught every semester with up to 75 students, usually taken by sophomores or juniors (though out-of-sequence seniors often take the course to complete requirements). Students in CE3201 have a lecture that meets 2 hours a week and a computer lab that meets 1 hour each week. For the transportation planning portion of the course (approximately a month), three project assignments using ADAM were designed to incorporate the simulator into classroom learning, each for one class period. The first two assignments allow students to familiarize themselves with travel demand modeling and the simulator. The third assignment asks each student to develop a re-development plan of the Sioux Falls network under given situations using ADAM and to evaluate the efficiency of that plan.

The objective of this experiment is to investigate if the use of simulation can improve the learning outcomes, and test the hypothesis that ADAM can be an effective tool for enhancing students’ learning on the subject of travel demand modeling. The particular learning outcomes expected through using ADAM include:
• Understanding of travel demand modeling process,
• Stimulating new ways of thinking about the travel demand modeling beyond the traditional procedures,
• Developing problem-solving skills and judgment in infrastructure investment decision-making.

ADAM Implementation
ADAM aims to be easy to learn, platform independent, and consistent with present understanding of transportation theories. More details of this model can be found in Zhang and Levinson [19]. In this model, which treats the morning peak period for simplicity, each traveler is treated as an autonomous agent who hunts for a job on the network. After all travelers have found their jobs, a travel pattern of the city is established and the aggregate measure of effectiveness (MOE), such as vehicle-kilometers of travel (vkt), vehicle-hours of travel (vht), and network accessibility, can be measured. As travelers adjust their destination and route choices, the travel pattern will evolve until convergence is reached.

A snapshot of the simulator interface is shown in Figure 1. The interface is composed of three major panels. The aforementioned resulting patterns and MOEs can be examined after a simulation via the result panel. In the parameter panel, users are free to adjust model parameters such as travelers’ willingness to travel, sensitivity to travel cost, and flow-speed relationship within specified ranges. In the display panel, the topology of the examined transportation network is displayed. The simulator displays a simplified road network of the City of Sioux Falls, South Dakota (a standard test case in transportation research) as default.

Three project assignments were designed to incorporate the simulator into classroom learning, each for one class period. The first two assignments allow students to familiarize themselves with travel demand modeling and the simulator. And the third assignment asks each student to develop a re-development plan of the Sioux Falls network under given situations using ADAM and to evaluate the efficiency of that plan. More specifically, the objectives of three project assignment are:

• The first assignment helps students to understand the concept of travel demand modeling using ADAM.
• The second assignment helps students to understand the role of the global variables and the concept of elasticity. Students will alter global variables (for example, trip generation rate) on the model and explore the different outcomes that result from the exercise.
• The third assignment helps students to understand the effects of road construction on traffic and how to evaluate alternatives of network construction. Students will be policy makers and decide how to adapt the traffic of a road network to the development of a city. As a planner of the Sioux Falls City, student is supposed to propose improvement on the network given the budget constraint in order to adapt the traffic to the development of the city.

ADAM Evaluation and Results
Two surveys were conducted before and after the class project to evaluate the effectiveness of ADAM [18]. The pre-class survey was designed to collect students’ background information. The post-class survey was designed to assess students’ self-reported improvement in knowledge
and skills after using the simulator for a three-week period. The survey also collects students’ evaluations of the simulator as a learning tool.

Thirty-seven students completed the course and responded to both surveys. Students’ background information was collected from the pre-class survey. Most students (36 out of 37) were engineering students. Students were approximately equally distributed among three classes: sophomore, junior, and senior, with an average age of just under 21. In terms of professional background, only one student had transportation related experience before the class. Thus, it was not surprising that most of the subjects assess their transportation-related knowledge and skills as poor. On the other hand, students overwhelmingly rated their computer knowledge as proficient and they actually reported spending on an average of 18 hours a week before the screen. All of them had access to the Internet at home. This finding favors the use of online simulation.

As the survey results indicated, students strongly agree that ADAM improves their understanding of travel demand modeling, transportation planning and transportation projects, which implies that ADAM is effective as learning tool. ADAM also significantly increases students’ perceived skills of identifying relationships between components in the transportation system, forming opinions and judgments. Students rate ADAM as an easy, clear and pleasant tool for learning, which is consistent with their positive overall evaluation of this simulator.

Overall, results from the trial implementation of using ADAM in CE3201 were very encouraging. The survey results revealed that a new teaching strategy of travel demand modeling based on ADAM can effectively improve students’ understanding of transportation planning. ADAM provides students to polish their skills on evaluating transportation projects and making decision according to measures of effectiveness. This motivates us to continue the development of other simulation modules that can be applied in the classroom setting.

ONLINE APPLICATION OF SIGNALIZED INTERSECTION SIMULATION (OASIS)

In current transportation courses, instructors usually spend a notable amount of time to help students understand the traffic signal control. The drawback of current curriculum is the tools used in the curriculum, in almost all cases, are inadequate. Because of time constraints, traffic models, such as Highway Capacity Software (HSC) or SYNCHRO, are usually used in most current curriculums. At the outcome of these courses, most of students have never touched a real-life signal controller and its associated signal controller cabinet. Given the complexity of the signal control logic (particularly on the vehicle actuated signal and its coordination), undergraduate students do not have the opportunity to understand the control logic fully. Especially in the complex situations that often occur in practice such as early return to green, queue spillback, and pedestrian actuations. This results in decreased student appreciation of the state-of-the-practice signal control and reduced understanding of how such situations are handled in engineering practice. The lack of “hands-on” experiences and exposure to advanced technologies in traffic signal control also prevent undergraduate students from being well-prepared for the transportation profession, licensure, and graduate study.

Sun, et al. [20] developed a One-of-A-Kind Traffic Research and Education Experiment (OAK-TREE) at the University of California at Irvine (UCI) during the Spring Quarter of 1996 to educate student on current traffic control practices. A traffic control laboratory was developed in which students could experiment with field equipment before they made field adjustments. These
instruments allowed the students direct access to field components that are typically inaccessible. However, they also reported that it was difficult to demonstrate and perform exercises based on the controller cabinet because the space in front of the cabinet door is very limited. Although this problem can be solved if more controller cabinets are available, the expense and space required generally prohibit such implementation. Therefore despite the overwhelmingly positive responses from the students, OAK-TREE was not offered a second time.

The goal of OASIS is to create an OAK-TREE like learning environment without requiring multiple controller cabinets. Internet accessible hardware-in-the-loop simulation (HILS) for traffic signal control will be adopted in OASIS. HILS concept has been introduced to the transportation engineering profession, particularly for traffic signal control [21]. HILS bridge the gap between simulation and reality by substituting simulation control systems with actual control systems. This process involves the physical replacement of simulated controllers with actual controllers. A HILS system, as shown in Figure 2, for traffic signal control has been built at the University of Minnesota through the on-going research on arterial signal performance measures. In our system, instead of using the so-called controller interface device (CID) connected to controller as in Bullock, et al. [21], a general data acquisition card (DAC) from National Instruments (http://www.ni.com/) is employed in a regular desktop PC and connected to the controller cabinet through its back panel. The desktop PC will then act as a server and enable us to access all functions of a controller cabinet (including controller) with remote access. This is ideal for training students short of physically appearing in front of the controller cabinet.

A virtual controller interface, as shown in Figure 3, was developed to replicate controller menu so students can enter signal control parameters as if they were programming a real traffic controller. The graphical user interface for actuated signal control, as shown in Figure 4, allows students to use the computer mouse as a vehicle to activate loop detectors and simulate the traffic signal control logic second by second. Animation of controller governing clocks are used to illustrate minimum green, maximum green, green extension and how these parameters are used to govern the signal phase termination such as gap-out and max-out. Students can also try different signal timing plans through the virtual controller interface during the simulation.

The advantage of OASIS is that students can learn how to develop signal timing plans through hands-on experience. They develop the signal timing plan using the appropriate equations, translate these plans into something that will work in a traffic controller, implement the plan in the controller, and then see how traffic responds via a computer animation.

ROADWAY ONLINE APPLICATION FOR DESIGN (ROAD)
There are several commercially available software packages that offer flexible design of roadway geometry [22] and evaluation of potential impact. However, these tools are generally complicated, expensive, and have a relatively steep learning curve. The purpose of this development work is not to reinvent the wheel but to provide a simpler tool that can be accessed easily by students to help them better understand the roadway geometry design.

ROAD Implementation
The early development of ROAD software focuses on the geometry design components and criteria. A digital contour map is used as reference image in the background for students to lay
out their roadway design. The web-based tool provides ease of design and adjustment of construction lines and horizontal and vertical curves. It also allows students to place the roadway construction line/curve on proper location on the contour map and other environmental constraints, as shown in Figure 5. Vertical design includes the additional capability of adjusting vertical curve intersect point (PVI) to minimize earth cutting or filling. The roadway design software tool can automatically produce design reports and mass diagrams for earthwork estimation. The ROAD software also includes features to allow users to save or load horizontal and vertical design separately. A 3D roadway geometry model can be generated by the ROAD software based on the geometric data from the horizontal trajectory and the elevation data from the vertical curve design using the Virtual Reality Modeling Language (VRML). A VRML client (plug-in) is required (for example, the Cosmo Player [23]) to animate the 3D roadway design.

Traditionally, transportation engineering students validate their final roadway geometry design by verifying their calculations and make sure all design criteria are met. They do not have the opportunity to visualize nor examine the final roadway design through a 3D model/animation. Creating a 3D roadway model in a virtual reality environment allows students to examine their design and experience any potential sight distance issue which may not appear in separate calculation of horizontal and vertical design. From the 3D view, as illustrated in Figure 6, students can place themselves in the driver’s seat, travel along their roadway design in virtual world and experience the geometric curves from driver’s perspective at maximum design speed. The 3D animation provides an invaluable opportunity for students to evaluate sight distance and potential safety concern.

ROAD Deployment
ROAD software was deployed as a lab module in a civil engineering undergraduate class in 2006 and 2007 at University of Minnesota. Before the roadway geometry design lab assignment, students were given a homework exercise to design a single curve roadway geometry using the traditional ruler and pencil approach. The homework exercise is to ensure students understand the design process, equations and calculations without the assistance of the computer software. A digital contour map was provided to students for a two-lane highway design connecting a visitor center on the map to an existing road network using the ROAD software tool. Students were asked to design and recommend a route connecting the visitor center to the existing road network through two potential access points. Alignment parameters and other design criteria were provided to students for the roadway geometry design. Students were divided in groups for the design project. Each group consisted of two or three people. Each group was required to submit a short report describing their design including the horizontal, vertical alignments and results.

ROAD Evaluation and Results
At the beginning of the lab assignment, a one-hour tutorial was given to students on how to use the ROAD software. Students have about five weeks to work on their design as a group in the Civil Engineering computer lab or from their personal PC at home. To evaluate the effectiveness of the ROAD software, a survey was conducted in class after students turn in their project reports. There were 60 students who returned the evaluation form in spring semester 2006. In fall semester 2006, we had 46 participants return the surveys. The results from both surveys indicated that students gained broader perspective on various design processes. The software tool allows them to modify the geometric design and analyze the outcomes iteratively.
SIMULATION OF NETWORK GROWTH (SONG)
The Simulator of Network Growth (SONG) supports the learning of the transportation network development process. The growth or decline of transportation networks is normally treated as the result of top-down decision-making in long-range planning efforts of metropolitan planning organizations (MPOs). However, changes to transportation networks are essentially the result of numerous small decisions by property owners, firms, developers, towns, cities, counties, state department of transportation districts, MPOs, and states in response to market conditions and policy initiatives [24]. This system behavior demonstrates the characteristics of decentralized systems, where organized patterns and structures can emerge not because of centralized control, but because of the interactions among decentralized system components. In SONG, transportation networks are treated as decentralized systems that demonstrate the property of self-organization. The simulator models behaviors of individual system components (network links) and small decisions, and then demonstrates the patterns resulting from interactions among the component models.

As shown in Figure 7, users can adjust parameters to change travelers’ value of time, their willingness to travel a given distance (time), tolls, how revenue and cost change in response to changes in road speed, flow and distance traveled and how investments are determined based on link performance. By adjusting these parameters, users can test the effects of these factors on the resulting network forms, which are visualized in terms of speeds or volumes on network links represented by different colors and thickness of the links.

SONG is distinct from other transportation simulation programs in that it is a network growth model. Given its features, SONG is expected to have a value in teaching transportation network evolution and the interrelationship of transportation and land use planning. The usefulness and efficacy of SONG as an educational tool by adopting it into a transportation planning or engineering course was verified through an experiment conducted on a senior/graduate level course on Transportation Systems Analysis (CE5214) at the University of Minnesota [6]. Students performed significantly better in learning network development patterns and in developing their ability to identify a relationship of components in transportation systems. Students also learned to establish criteria to evaluate and prioritize solutions in developing decision-making skills and in-depth understanding of the investment decision making process.

STREET DISSEMINATION AND EVALUATION PLAN
As part of the STREET project, we aim to disseminate the results, online teaching materials and help others to adopt the materials and taking steps toward self-sustained distribution. A major step in our dissemination plan is to recruit faculty from other schools across the country and help them integrate the simulation modules in their curriculum. We have been communicating our simulation module development with transportation faculty outside UMN and have received positive responses. Many faculty members have expressed interest in the simulation modules, and are willing to use these modules in their course offerings.
Our evaluation effort has two major hypotheses. First, the simulation modules will improve student understanding of critical concepts in Transportation Engineering and lead to student learning better than in a course without these simulation tools. Second, the simulation modules will improve student motivation toward transportation engineering and improve student retention.

**Evaluation of Learning**

The evaluation methodology used in the pilot implementation of ADAM in CE3201 at UMN produced reasonable results. The methodology can be improved and the results will become more credible when the simulation modules are adopted across multiple semesters at UMN and multiple universities. Comparative studies can be conducted on two groups of students across multiple semesters or multiple universities: the control group receiving the traditional case study-based assignment and the treatment group taking simulation-based assignments. A comparative study on the two groups aims to discover whether students learn better with simulation than without it. In the comparative study, the control assignment and treatment assignment are designed such that the objectives, substances, and workloads are of no significant difference. They differ, however, in that the treatment assignment is based on the simulation platform. It allows students to make changes and see outcomes of their actions. It allows students to see the visualized outcomes. It is interactive and allows students to learn through “doing”.

The evaluation will involve two steps: control students’ background differences and other confounding factors, and compare learning outcomes between the two groups. Data for the evaluations are collected from a pre-assignment survey, a post-assignment survey, coursework, and final exam. Beyond the simulator, many other factors also affect students’ learning. An analysis of these factors provides critical information for determining whether the differences in learning outcomes can be attributed to the effects of the simulator. In particular, students’ academic background, relevant prior experiences and knowledge, computer proficiency, and learning styles are expected to affect their performance in the assignment.

In this study, self-reported learning styles are anticipated to be assessed with Kolb [25]’s Learning Style Inventory (LSI), and Felder-Silverman [26]’s Index of Learning Styles (ILS). LSI is an established tool for learning style assessment; while ILS is developed mainly to assess learning styles of engineering students [27]. It is expected the educational benefits of simulation are most likely to be captured by students with preferences to learn through watching and doing, and students who prefer visual and active styles of learning.

With students’ background differences and other confounding factors being controlled, students’ learning outcomes are compared to determine whether the use of simulation leads to different learning by the two groups. Learning outcomes are measured with three criteria: (1) time taken to complete the assignment, (2) achievement of learning objectives, including subject understanding, and skills improvement, and (3) students’ reflections on the learning experiences with the assignments. Student performance is assessed both through surveys in terms of their perceived improvements on skills and subject understanding, and through their performance on the final exam. Depth of learning is assessed in terms of understanding, understanding the subject in a different ways, and incorporating learners’ own position and perspectives [28]. A deep learning goes beyond the given situation or problem, and explores the larger issues...
represented by a particular problem [29]. Simulation is different from surface learning, which is tied to a specific learning situation given, such as a text, problem or assignment [28, 29]. Simulation is expected to be more productive and valuable in promoting deep learning because of user interaction and complex interplay of variables provided through the simulation.

**Evaluation of Motivation and Retention**

One of the stated goals of the simulation modules is to motivate students on the topics of transportation engineering and encourage and recruit of highly motivated, intellectually talented students into transportation profession. Therefore besides the evaluation of learning, we will conduct student exit interview when they complete the course and longitudinal survey to evaluate motivational factors and retention rate. The University of Minnesota, Department of Civil Engineering also conducts an exit survey of students, and we will attach more specific questions to that to assess longer-term retention.

In particular, we are concerned with three kinds of motivational factors during student exit interview when finishing the course:

- Do students find the current course with simulation engaging? An engaging course is more likely to lead to learning [30, 31].
- Do students find transportation engineering engaging?
- Would students consider taking future transportation courses and entering the transportation profession?

An additional area of evaluation that we plan to introduce is longitudinal tracking of students as they continue their careers. Our plan is to use a combination of email surveys and in-person or phone interviews. We want to know:

- Do these students take more transportation courses?
- Do these students become transportation engineers?

At the end of each year, students who have taken the transportation course will be surveyed by email to ask about the transportation classes they have taken. Also, a sample of students who have taken the course will be interviewed (by phone or in person) a year or two after graduation to understand how the course has affected their later career and interaction with simulation. These data will also be used to inform further development of the course materials.

**SUMMARY**

The focus of the STREET research project is to develop web-based simulation modules to improve instruction in the *Introduction to Transportation Engineering* course that is a standard part of undergraduate civil engineering programs (http://street.umn.edu/). Although simulation has proven to be a powerful tool in encouraging active learning in other disciplines, it has not been fully adopted in transportation engineering to this date. The modules are also suitable for upper-division transportation courses and cover fundamental topics in transportation engineering such as travel demand modeling, geometric design, traffic flow, and traffic signal control. The web-based interface allows easy access for users without the high cost associated with commercially available simulation products. The simulation-based materials form an active textbook, which offers an interactive learning environment to undergraduate students. The
modules will be rigorously evaluated and tested in course offerings from civil engineering programs across the country. Developed simulation modules will also be disseminated to the public through interactive exhibits at the Minnesota Transportation Museum and the Minnesota State Fair.

Professor David Levinson and Henry Liu are working on an online textbook, *Fundamentals of Transportation* (http://en.wikibooks.org/wiki/Fundamentals_of_Transportation). Developed simulation modules aforementioned and other teaching materials will be integrated into the online textbook as an active textbook, which will offer an interactive learning environment to undergraduate students.

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