Simulating Transportation for Realistic Engineering Education and Training

Engaging Undergraduate Students in Transportation Studies

Chen-Fu Liao, Henry X. Liu, and David M. Levinson

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 engage students better. Simulation tools have been used by transportation professionals to evaluate and analyze the potential impact of design or control strategy changes. Simulation, which can effectively convey complex transportation concepts, is particularly valuable in transportation education. The use of simulation in transportation education gives students the opportunity to apply different control strategies in a risk-free environment and teaches them transportation engineering methodologies. Despite its advantages, simulation has not been widely adopted in transportation engineering education. Its use in undergraduate transportation courses is sporadic; the reported efforts have been primarily in upper-level technical elective courses. A suite of web-based simulation modules has been developed and incorporated into undergraduate transportation courses at the University of Minnesota. The Simulating Transportation for Realistic Engineering Education and Training (STREET) research project was recently awarded a grant by the National Science Foundation to develop web-based simulation modules, to improve instruction in transportation engineering courses, and to evaluate their effectiveness. The ultimate goal of the STREET project is to become the epicenter for the development of simulation-based teaching materials that provide undergraduates with an interactive learning environment. Given the hands-on aspect of simulation, the hope is that its use will improve student understanding of critical concepts in transportation engineering, and will also enhance student interest in transportation engineering and thereby increase their presence in the field. The intention is to disseminate the results and teaching materials to other colleges so they can integrate these online modules into their curricula.

The practice of transportation engineering and planning has evolved substantially during the past several decades. Transportation graduates confront a wide range of increasingly complicated problems, from growing congestion and worsening air quality to environmental preservation and issues of social equity (*1*). The task of transportation education now, as stated by an 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, however, have revealed a decrease in the hourly requirements of transportation-related courses offered for undergraduate students (*3, 4*), and entry-level engineers lack significant exposure to transportation engineering methodologies (*3*). To solve this problem, the transportation engineering curriculum, both in its content and teaching methods, must become more rigorous and technically focused to meet market needs.

Most transportation-related courses still depend on traditional methods: "chalk and talk" lectures, problem solving using paper and pencils, and class projects (*5, 6*). These courses and methods often fail to motivate students, limiting their ability to assimilate knowledge and apply it in their future work. This established approach to transportation education does not expose undergraduate students to the many challenging issues that would hopefully encourage them to pursue careers in transportation engineering. Consequently, as a recent survey has shown (*4*), there has been a slight decrease in the number of graduates in transportation engineering even though there has been increased demand from the transportation industry. For more than a decade, finding qualified entry-level transportation engineers has been a major concern for employers of transportation professionals (*3*), particularly in light of the overall aging of the workforce in the transportation field. For example, the average age of managers and of high-level engineers with the Minnesota Department of Transportation is between 55 and 60 (*7*). Given that transportation problems are not going away, fresh ideas and a new generation of transportation professionals need to be brought into the field.

To engage students and deliver knowledge better, then, a new paradigm for transportation engineering education is needed. In various studies, the use of simulation has been demonstrated to be a promising strategy for teaching (*8–10*). Simulation allows students to engage actively in their learning by running experiments, testing different strategies, and acquiring a better understanding of the real world through depiction of its aspects by the simulator (*11*). In simulation, learners' individual choices lead them down different paths toward different outcomes. Essentially, simulation allows students to learn directly from the outcomes of their own actions (*8, 12, 13*).

Web-based education has become a popular and effective complement to classroom instruction in recent years. Online learning tools bring a classroom laboratory to the student through a computer. Web-based learning tools offer the benefit of platform and location independence. Through the Internet, users can virtually access these learning tools anytime and anywhere.

Clearly, this approach can be integrated with other distance-learning methods already in use for teaching transportation technologies. For example, several web research modules for high school students have been developed by the Intelligent Transportation Systems (ITS)

Department of Civil Engineering, University of Minnesota, 500 Pillsbury Drive Southeast, Minneapolis, MN 55455. Corresponding author: C.-F. Liao, cliao@umn.edu.

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Institute at the University of Minnesota (*14*). Liao et al. (*15*) have developed a web-based traffic simulation framework for transportation training and education. Helbing et al. (*16*) have 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*).

The use of 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 would also encourage students to move beyond atomistic equations that, to date, have constituted the bulk of instruction in such courses, by allowing learners to evaluate transportation issues holistically. Despite its advantages, however, simulation has not been widely adopted in transportation engineering education. The use of simulation in undergraduate transportation courses is sporadic; the reported efforts have been primarily in upper-level technical elective courses. The adoption of simulation to illustrate critical concepts in such courses as Introduction to Transportation Engineering has been 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.

APPROACH

To tackle these challenges and promote the use of simulation in transportation engineering education, several web-based simulation modules have been developed and refined, which can be easily incorporated into undergraduate transportation courses. Some of these simulation modules have been deployed and evaluated in diverse settings, and improvements have been made from those evaluation results. The Simulating Transportation for Realistic Engineering Education and Training (STREET) research project was recently awarded a grant by the National Science Foundation to develop web-based simulation modules, to improve instruction in transportation engineering courses, and to evaluate their effectiveness. The ultimate goal of the STREET project is for it to become the epicenter for the development of simulation-based teaching materials that provide undergraduates with an interactive learning environment. Given the hands-on aspect of simulation, the hope is that its use will improve student understanding of critical concepts in transportation engineering and will also motivate students to learn more about transportation engineering and improve student retention in the field.

Specifically, several simulation modules have been developed and tested in the classroom: the Agent-Based Demand and Assignment Model (ADAM), the Online Application of Signalized Intersection Simulation (OASIS), the Roadway Online Application for Design (ROAD), and the Simulator of Network Growth (SONG). Also under development is the Simulation of Freeway Traffic. (All are available at http://street.umn.edu.) The target undergraduate course is Introduction to Transportation Engineering, which is a required course for undergraduate students in most civil engineering departments. The online simulation modules have extended capabilities that will be useful during the teaching of highway design, traffic engineering, and transportation system analysis. All simulation programs are web-based, allowing them to be accessed easily and enabling learning outside the classroom. Commercial transportation simulation packages do exist; however, these commercial tools, which are designed for professionals, are usually complicated and expensive and are therefore inappropriate for classroom use, particularly in an introductory course, which focuses on conceptual understanding. The aforementioned simulation programs (ADAM, OASIS, ROAD, SONG) are not intended to duplicate or even compete with commercial transportation simulation packages; instead, these programs are intended to provide simple web-based simulation tools that allow students to better understand underlying theories in transportation engineering.

Initial evaluation and testing of 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 positive and encourage further work.

On the basis of the local implementation success, it is intended 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 teaching curricula and will then provide feedback to the project team so that the modules can be further improved. There are also plans to work with the Center for Transportation Studies at UMN to establish mobile booths at the annual Minnesota State Fair and the Minnesota Transportation Museum, places where the public can learn about current transportation issues. The public is greatly interested in many transportation problems, such as the generation and propagation of traffic congestion, and these issues can be easily demonstrated through public-oriented versions of the simulation modules developed during this project. A description follows of the proof-of-concept trial implementation at UMN for some of the prototype simulation modules.

AGENT-BASED DEMAND AND ASSIGNMENT MODEL

A prototype of ADAM was developed and used as an in-class project to enhance student learning about travel demand models. ADAM was introduced into an undergraduate course, Introduction to Transportation Engineering (CE3201), in the spring semester of 2006 at the Department of Civil Engineering, UMN (*18*). CE3201 is a required civil engineering course and is taught every semester. CE3201 has up to 75 students and is 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 h each week and a computer lab that meets 1 h each week. For the transportation planning portion of the course (which lasts approximately 1 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 create a redevelopment plan for the Sioux Falls, South Dakota, road network under given situations by using ADAM and then to evaluate the efficiency of that plan.

The objectives of this experiment are to investigate whether the use of simulation can improve learning outcomes and to test the hypothesis that ADAM can effectively enhance student learning about travel demand modeling. The particular learning outcomes expected through using ADAM include

- Understanding the travel demand modeling process,
- Stimulating new ways of thinking about travel demand modeling beyond the traditional procedures, and
- Developing problem-solving skills and judgment in infrastructure investment decision making.

ADAM Implementation

ADAM is designed to be easy to learn, platform-independent, and consistent with present understanding of transportation theory. More details of this model are given by Zhang and Levinson (*19*). In this model, which treats the morning peak period for simplicity, each traveler is treated as an autonomous agent who is hunting for a job on the network. After all travelers have found their jobs, a travel pattern of the city is established and aggregate measures of effectiveness (MOEs) such as vehicle kilometers of travel, vehicle hours of travel, and network accessibility can then be measured. As travelers adjust their destination and route choices, the travel pattern evolves until a convergence is reached.

Figure 1 shows a snapshot of the simulator interface. The interface has three major panels: result, parameter, and display. Via the result panel, users can examine the aforementioned resulting patterns and MOEs after a simulation. Via 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. Via the display panel, users can view the topology of the examined transportation network. The simulator displays a simplified road network for Sioux Falls (a standard test case in transportation research) as the default.

Three project assignments were designed to incorporate the simulator into classroom learning, each for one class period. 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 global variables and the concept of elasticity. Students 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 to evaluate alternatives of network construction. Students act as policy makers and decide how to adapt the traffic of a road network to the development of a city. Acting in the role of a planner for the city of Sioux Falls, the student proposes improvements to the road network, while working within a budget constraint.

ADAM Evaluation and Results

Surveys were conducted before and after the class project to evaluate the effectiveness of ADAM (*18*). The survey before the class project was designed to collect students' background information. The survey after the class project was designed to assess students' self-reported improvement in knowledge and skills after using the simulator for a 3-week period; this survey also collected students' evaluations of the simulator as a learning tool.

Thirty-seven students completed the course and responded to both surveys. The survey conducted before the class project collected

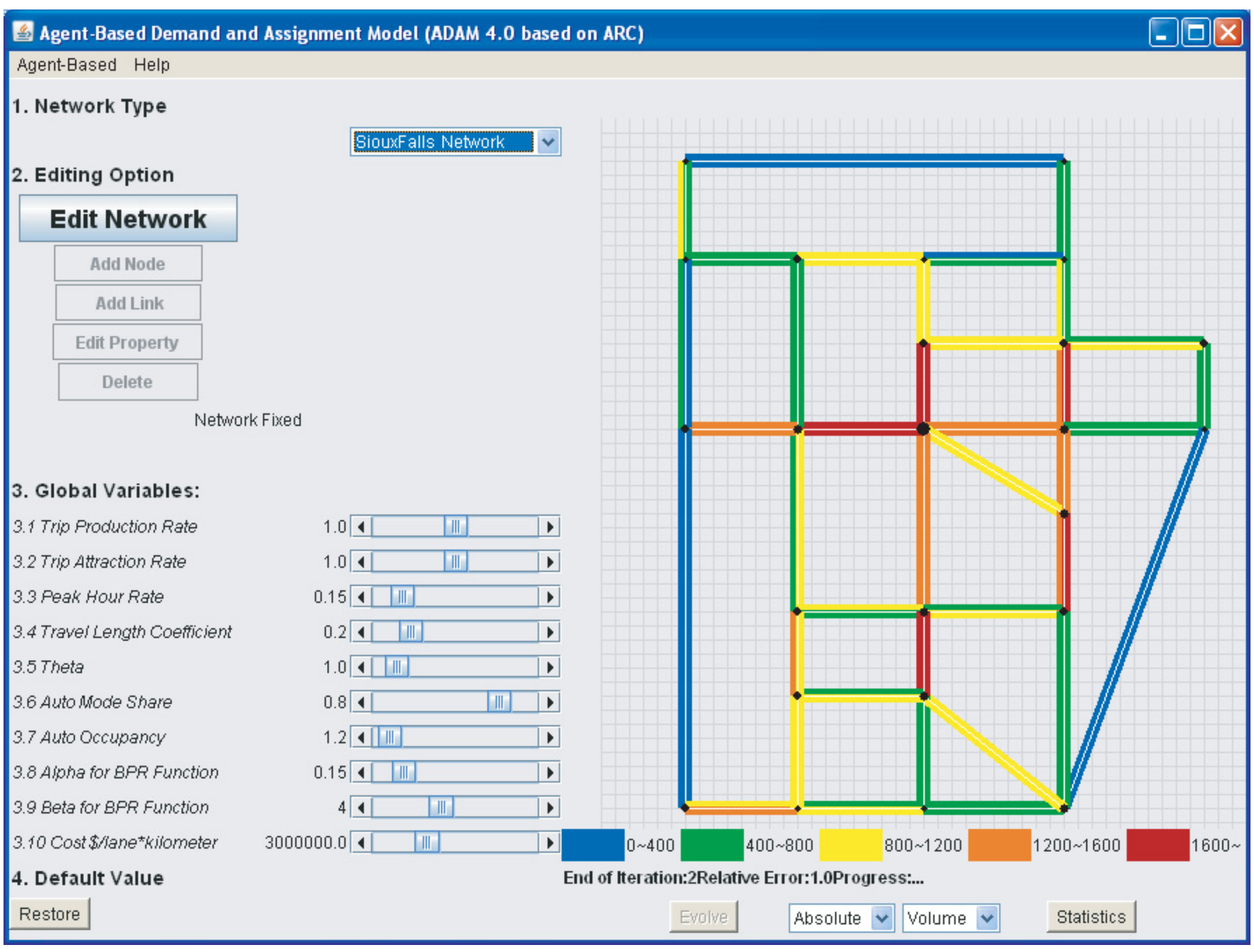

FIGURE 1 Online graphical user interface of ADAM.

a variety of background information on participating students. Most of them (36 out of 37) were engineering students. There was an approximately equal distribution of students among three classes: sophomore, junior, and senior. The students' average age was just under 21. In terms of professional background, only one student had transportation-related experience before taking the class. Thus, it was not surprising that most of the subjects assessed their transportation-related knowledge and skills as poor. On the other hand, students overwhelmingly rated their computer knowledge as proficient, and they reported spending an average of 18 h a week before the screen. All of them had access to the Internet at home. These findings favor the use of online simulation.

As indicated by the survey results, students strongly agreed that ADAM improved their understanding of travel demand modeling, transportation planning, and transportation projects: a finding implying that ADAM is an effective learning tool. ADAM also significantly enhanced students' perceived skills in identifying relationships between components in the transportation system and in forming opinions and judgments. Students rated ADAM as an easy-to-use, clear, and pleasant tool for learning, which was consistent with their positive overall evaluation of the simulator.

Overall, the results from the trial implementation of ADAM in CE3201 were encouraging. The survey results revealed that a new strategy for teaching travel demand modeling based on ADAM can effectively improve students' understanding of transportation planning. ADAM helps students polish their skills in evaluating transportation projects and making decisions according to MOEs. This motivates the continued development of other simulation modules that can be applied in the classroom setting.

ONLINE APPLICATION OF SIGNALIZED INTERSECTION SIMULATION

In current transportation courses, instructors usually spend a considerable amount of time in helping students understand traffic signal control. However, the tools used in transportation curricula are, in almost all cases, inadequate. Because of time constraints, traffic models such as Highway Capacity Software or SYNCHRO are often used. Most students, when they start these courses, have never touched a real-life signal controller or its associated cabinet. Given the complexity of signal control logic (particularly of the vehicle-actuated signal and its coordination), undergraduate students do not have the opportunity to fully understand the control logic, especially in complex situations that often occur in practice such as early return to green, queue spillback, and pedestrian actuations. This leads to decreased student appreciation of the state of the practice in 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 prevents 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 during the spring quarter of 1996 to instruct students 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, it was found to be difficult to demonstrate and perform exercises based on the controller cabinet because the space in front of the cabinet door was limited. Although this problem can be solved by making more controller cabinets available, the expense entailed and space required by this solution generally prohibit such implementation. Therefore, despite an overwhelmingly positive response from students, OAK-TREE was not offered a second time.

The goal of OASIS is to create an OAK-TREE-like learning environment but without the need for multiple controller cabinets. An Internet-accessible hardware-in-the-loop simulation (HILS) system for traffic signal control, which is being introduced to practice (*21*), is adopted into OASIS. HILS bridges the gap between simulation and reality by substituting simulation control systems with actual control systems. This process involves physically replacing simulated controllers with actual controllers. A HILS system for traffic signal control, as shown in Figure 2, has been built at the University of Minnesota through ongoing research on arterial signal-performance measures. In this system, instead of using a controller interface device connected to a controller as proposed by Bullock et al. (*21*), a general data acquisition card (DAC) from National Instruments (www.ni.com/) is employed in a regular desktop PC and connected to the controller cabinet through its back panel. The desktop PC then acts as a server and enables remote access to all functions of a controller cabinet (including the controller). This is an ideal setup for training students, short of physically stationing them in front of the controller cabinet.

A virtual controller interface was developed to replicate the controller menu so that students could 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 3, allows students to use the computer mouse as a vehicle to activate loop detectors and simulate the traffic-signal control logic second by second. Animations 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.

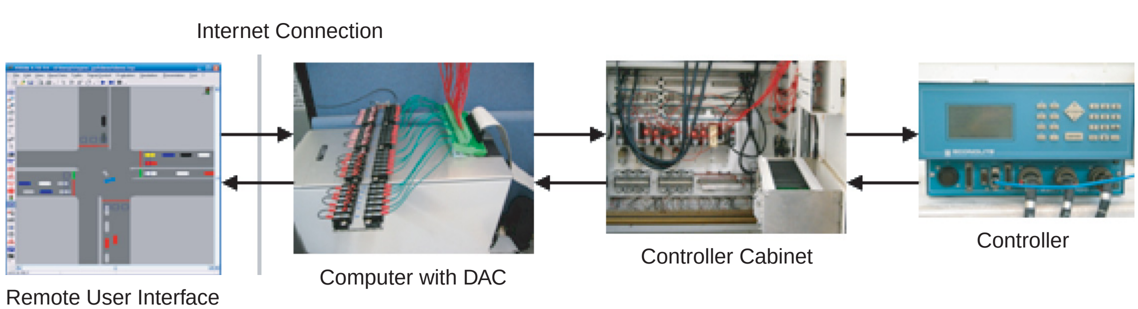

FIGURE 2 Hardware-in-the-loop traffic signal control.

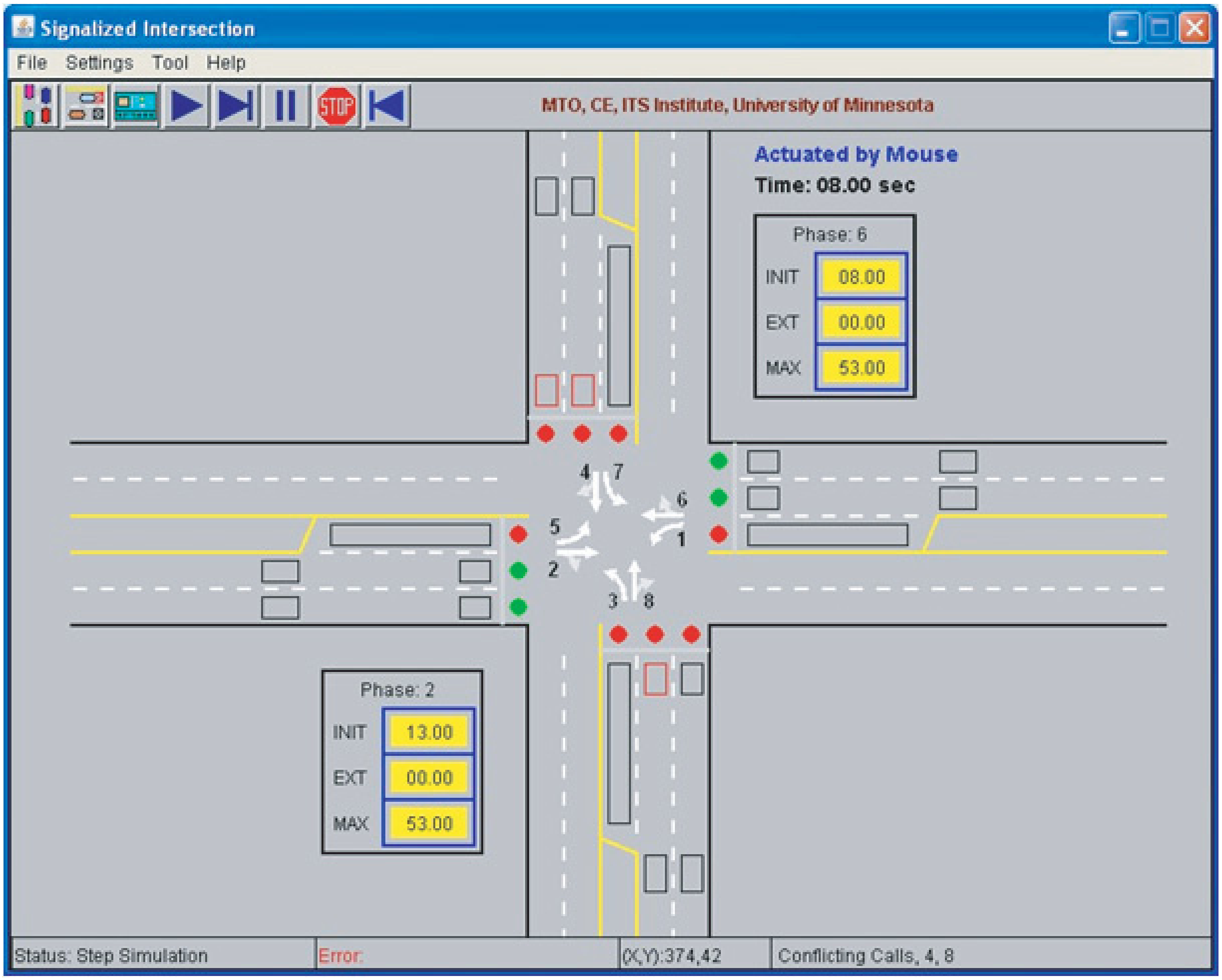

FIGURE 3 Graphical user interface of OASIS.

The advantage of OASIS is that it enables students to learn how to develop signal timing plans through hands-on experience. Learners develop the signal timing plan by using the appropriate equations, translating these plans into something that would work in a traffic controller, implementing the plan in the controller, and then seeing how traffic responds via a computer animation.

ROADWAY ONLINE APPLICATION FOR DESIGN

Several commercially available software packages offer flexible design of roadway geometry (*22*) and evaluation of potential impacts. However, these tools are generally complicated and expensive, and their use requires a relatively steep learning curve. The purpose of the ROAD software 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 roadway geometry design.

Software Implementation

The early development of the ROAD software focused on the geometry design components and criteria. A digital contour map is used as the background reference image on which students lay out their roadway design. The web-based tool provides ease of design and adjustment of construction lines and horizontal and vertical curves. The software permits students to place the roadway construction line or curve on its proper location on the contour map while allowing for environmental constraints, as shown in Figures 4 and 5. The vertical design aspect includes the additional capability to adjust the vertical curve intersect point 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 that allow users to save or load horizontal and vertical design separately. A three-dimensional (3-D) roadway geometry model can be generated by the ROAD software on the basis of geometric data from the horizontal trajectory and elevation data from the vertical curve design by using Virtual Reality Modeling Language (VRML). A VRML client (plug-in) is required [for example, Cosmo player (*23*)] to animate the 3-D roadway design.

Traditionally, transportation engineering students validate their final roadway geometry design by verifying their calculations and ensuring all design criteria are met; they do not have the opportunity to visualize or examine the final roadway design through a 3-D model. Creating a 3-D roadway model in a virtual reality envi-

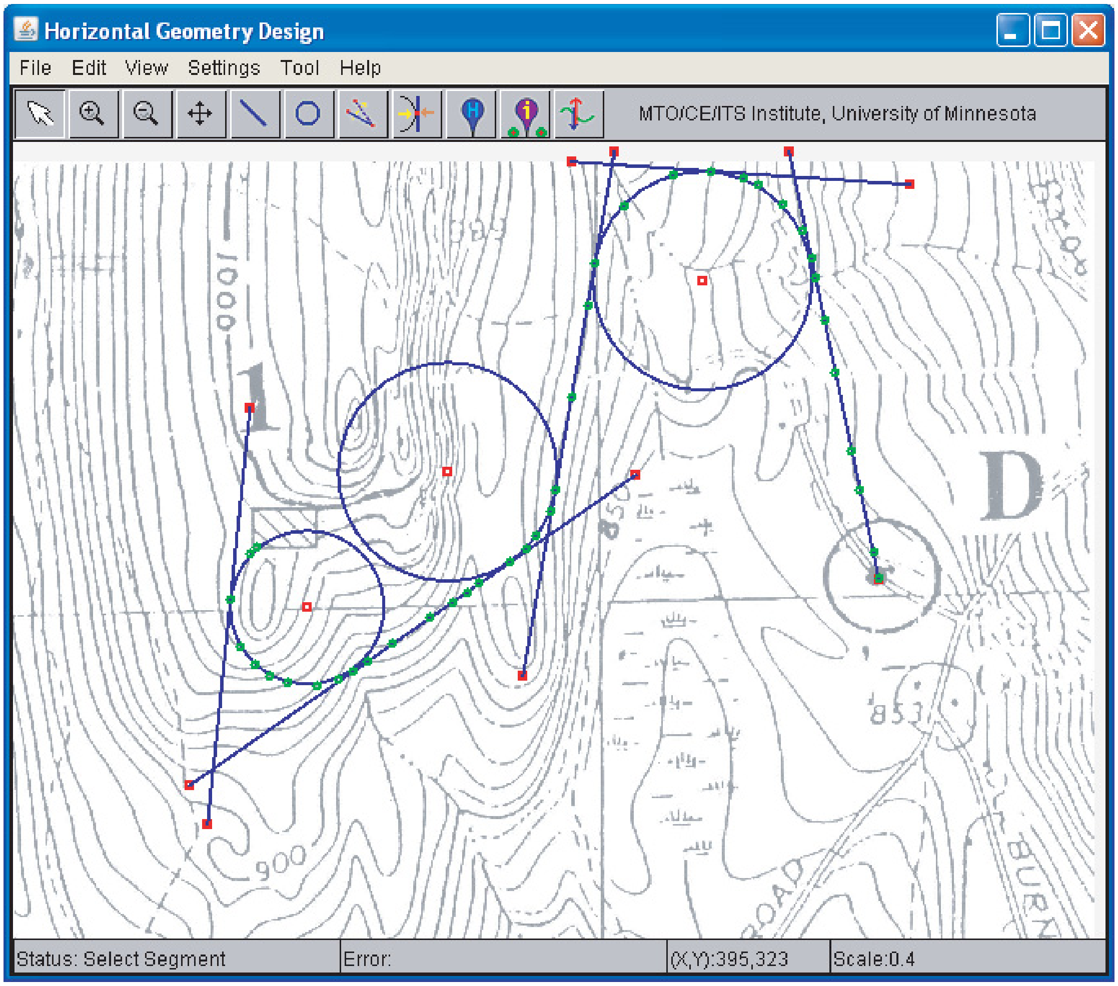

FIGURE 4 **Roadway geometry design—horizontal design.**

ronment allows students to examine their designs and to view any potential sight distance issue that may not be apparent from separate calculations of horizontal and vertical design. From the 3-D view afforded by the ROAD software, as illustrated in Figure 6, students can place themselves in the driver's seat, travel along the road created by their roadway design in a virtual world, and experience the geometric curves from a driver's perspective at maximum design speed. The 3-D animation provides an opportunity for students to evaluate sight distances and to identify potential safety concerns.

Software Deployment

ROAD software was deployed as a lab module in a civil engineering undergraduate class in 2006 and 2007 at the University of Minnesota. Before they were given the lab assignment on roadway geometry design, students were given a homework exercise to design, using the traditional ruler-and-pencil approach, a single-curve roadway geometry. This exercise was intended to ensure that students could understand the design process, equations, and calculations without the assistance of the computer software. In the lab, students were given a digital contour map for designing a two-lane highway 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. For their roadway geometry designs, students were given alignment parameters and other design criteria. Students were divided into groups for the design project. Each group had two or three people. Each group was required to submit a short report describing its design including the horizontal and vertical alignments and results.

Software Evaluation and Results

At the beginning of the lab assignment, students received a 1-h tutorial on how to use the ROAD software. Students had about 5 weeks to work on their design as a group either in the civil engineering computer lab or from their personal PCs at home. To evaluate the effectiveness of the ROAD software, a survey was conducted in class after students turned in their project reports. Sixty students returned the evaluation form in the spring semester of 2006, and 46 participants returned the survey in the fall semester of 2006. The results from both spring and fall surveys indicated that students gained broader perspectives on various design processes. The software

FIGURE 5 Roadway geometry design—vertical design.

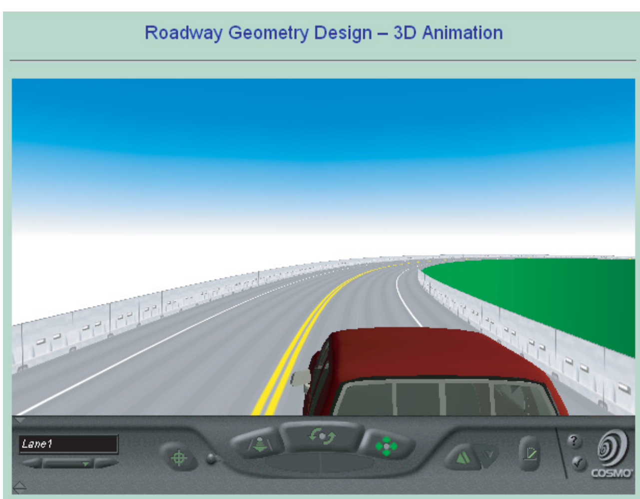

FIGURE 6 ROAD—drive-through animation.

tool allowed them to modify their geometric designs and analyze the outcomes iteratively.

SIMULATOR OF NETWORK GROWTH

SONG supports learning about the process of transportation network development. 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). Changes to transportation networks, however, are essentially the result of numerous small decisions by property owners, firms, developers, towns, cities, counties, states and state department of transportation districts, and MPOs in response to market conditions and policy initiatives (*24*). This system behavior demonstrates the characteristics of decentralized systems, in which organized patterns and structures emerge not from centralized control but due to the interactions among decentralized system components. SONG treats transportation networks 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 of SONG can adjust a number of parameters and test their affects on the resulting network forms, which are visualized in terms of speeds or volumes on network links represented by different colors and line thicknesses. Among the factors users can adjust are travelers' value of time, their willingness to travel a given distance (time), tolls, how revenues and costs change in response to fluctuations in road speed, flow and distance traveled, and how investments are determined on the basis of link performance.

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

STREET DISSEMINATION AND EVALUATION PLAN

Part of the intent of the STREET project is to disseminate results and online teaching materials, help others adopt these materials, and move toward self-sustained distribution. A major step in the project's dissemination plan is to recruit faculty from other schools across the country and help them integrate the simulation modules into their curricula. Transportation faculty outside of UMN have been kept informed of simulation module development, and their responses have been positive. Many faculty members have expressed interest in the simulation modules and a willingness to use these modules in their course offerings.

This evaluation effort is based on two major hypotheses. First, the simulation modules will improve student understanding of critical concepts in transportation engineering and lead to students learning better than they would in a course that does not use these simulation tools. Second, the simulation modules will enhance student motivation toward the transportation engineering field and will improve student retention.

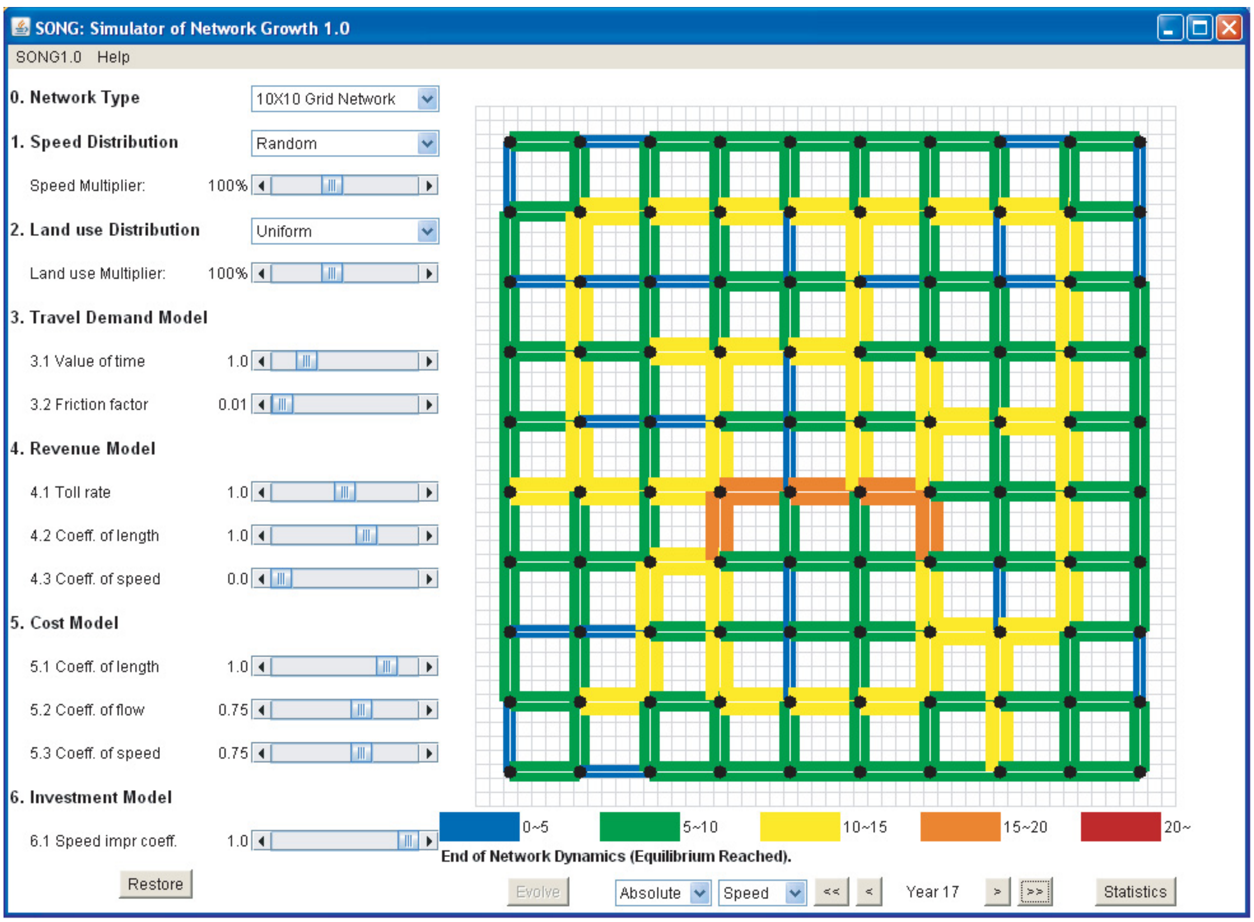

FIGURE 7 Online graphical user interface of SONG.

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 at multiple universities. Comparative studies can be conducted on two groups of students across multiple semesters or multiple universities: a control group that receives assignments based on the traditional case study approach, and a treatment group that receives simulation-based assignments. A comparative study on the two groups intends to discover whether students learn better with simulation than without it. In the comparative study, the assignments given to both control and treatment groups are designed so that there are no significant differences between them in terms of objectives, substances, and workloads. The difference is that the treatment group's 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 involves two steps: to control for students' background differences and other confounding factors and to compare learning outcomes between the two groups. Data for the evaluations are collected from a preassignment survey, a postassignment survey, course work, and a final exam. There are many other factors besides the use of the simulator that affect students' learning. An analysis of these factors provides critical information for determining whether the differences in learning outcomes can be attributed to the use of the simulator. In particular, the academic backgrounds of participating students, their relevant prior experiences and knowledge, their 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's Learning Style Inventory (LSI) (*25*) and Felder and Silverman's Index of Learning Styles (ILS) (*26*). LSI is an established tool for learning style assessment; ILS has been developed mainly to assess learning styles of engineering students (*27*). It is expected that the educational benefits of simulation are most likely to be captured by students with preferences to learn through watching and doing and by students who prefer visual and active styles of learning.

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

Evaluation of Motivation and Retention

One of the stated goals of simulation module use is to motivate students' interest in the topic of transportation engineering and to encourage them to pursue these studies, and thus to enhance the recruitment of highly motivated, intellectually talented students into the transportation profession. Therefore, the exit interviews of students conducted upon completion of the course as well as longitudinal surveys, will evaluate motivational factors and retention rate. The University of Minnesota, Department of Civil Engineering conducts an exit survey of students, and more specific questions will be attached to assess longer-term retention.

In particular, there are three types of motivational factors to look for during the student exit interviews upon completion of the course:

- Do students find the current course with simulation engaging? (*30, 31*).
- Do students find the topic of transportation engineering engaging?
- Would students consider taking future transportation courses and entering the transportation profession?

An additional evaluation element to be introduced will be through longitudinal tracking of students as they continue their careers. The plan is to use a combination of e-mail surveys and in-person or phone interviews, to determine as time goes by whether the students take more transportation courses and whether they eventually become transportation engineers.

At the end of each year, students who took the original transportation course will be surveyed by e-mail to ask about any subsequent transportation classes they have taken. In addition, a sample of students who took the original course will be interviewed (by phone or in person) a year or two after their 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. Although the use of simulation has proven to be a powerful tool in encouraging active learning in other disciplines, to date it has not been fully adopted into transportation engineering education. The modules are also suitable for upper-division transportation courses. They 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.

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