Assessment of Introductory Transportation Engineering Course and General Transportation Engineering Curriculum

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Transportation engineering is a critical subdiscipline of the civil engineering profession as indicated by its inclusion on the Fundamentals of Engineering Examination and overlap with other specialty areas of civil engineering and as recognized by TRB, ITE, and ASCE. With increasing transportation workforce needs, low numbers of students entering the pipeline, and limited hours within undergraduate civil engineering programs, it is important to ensure that civil engineering students receive adequate preparation and exposure to career opportunities in the transportation engineering field. Thus, investigations into the status of transportation engineering within civil engineering programs and specifically the introductory transportation engineering course are essential for understanding implications to the profession. Relevant literature and findings from a new survey of civil engineering programs accredited by the Accreditation Board for Engineering and Technology is reviewed; that survey yielded 84 responses. The survey indicates that 88% of responding programs teach an introductory course in transportation engineering, and 79% require it in their undergraduate programs. Significant variation exists in the structure of the introductory course (number of credit hours, laboratory requirements, etc.). Common responses about improvements that could be made include adding laboratories, requiring a second course, and broadening course content. In addition, nearly 15% of instructors teaching the introductory course did not have a primary focus in transportation engineering. This finding should be investigated further, given that the course may be an undergraduate civil engineering student's only exposure to the profession.

Civil engineering, which deals with the planning, design, construction, operation, and maintenance of the built environment, is one of the oldest and broadest of modern engineering disciplines. The path to becoming a licensed civil engineer involves many steps, including earning a bachelor's degree from an accredited university [Accreditation is provided by the Accreditation Board for Engineering and Technology, Inc. (ABET)], passing two exams (the exams are the Fundamentals of Engineering examination, taken in the semester of or shortly after graduation; and the Principles and Practice of Engineering examination, taken after gaining 4 years of engineering experience) and 4 years of professional practice under the supervision of a licensed engineer (specific engineering license laws vary by state). There are 224 ABET-accredited civil engineering programs in the United States (*1*). As quantified later in this paper, these programs range from small (fewer than 10 faculty and graduating fewer than 30 students per year) to very large (more than 50 faculty and graduating about 200 students per year). No matter the size of the program they come from, graduates entering the civil engineering profession must possess knowledge of a wide range of civil engineering topics, many of which are included in the Fundamentals of Engineering or Professional Engineering examinations.

Transportation engineering is one of the knowledge areas for civil engineering students. Not only is it a part of the Fundamentals of Engineering examination for civil engineering and the emphasis area of one of the Principles and Practice of Engineering examinations, but there are also transportation-related aspects to virtually all of the specialty areas within civil engineering. Examples include the importance of drainage considerations in roadway design, impacts of soil properties on pavement design, balancing geometric design and structural design in bridges, along with many others.

Professional organizations such as TRB, ITE, and ASCE also play a key role in determining the appropriate subdisciplines that should be part of a civil engineering curriculum. Within TRB, the Transportation Education and Training Committee has the mission of facilitating communication between the academic, private, and government transportation communities to align education practices with workforce needs as well as identifying effective recruitment strategies for the profession (*2*). The ITE Transportation Education Council has similar goals of both increasing awareness of and recruiting for the transportation engineering profession while also supporting the needs of transportation educators through identifying emerging issues and gaps in alignment between educational institutions and the profession (*3*). ASCE identifies specialty areas of the profession through its technical institutes. While the Transportation and Development Institute is the only one specifically dedicated to transportation engineering, nearly all of the other

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institutes also encompass aspects of transportation engineering (*4*). ASCE also recognizes transportation as an area of increased focus for civil engineers of the future, through its vision of the profession in 2025 (*5*). Thus, transportation engineering is a critical component of a civil engineering education as recognized not only by the accreditation authority (ABET), but also by the leading professional societies.

In addition, the United States is faced with a shortage of students selecting engineering majors as compared with projected workforce needs. The transportation profession is not immune to such issues, and it faces even greater challenges, with nearly 50% of the transportation workforce eligible for retirement in the next 10 years and intense competition from other fields for capable workers (*6–8*). Furthermore, while the scientific aspects of most civil engineering specialties may be appreciated by the general public, this is not always true for transportation engineering. Even many civil engineering students do not realize the amount of science in transportation engineering, nor the extent to which all aspects of civil engineering interact with transportation systems (*9*). As faculty who teach transportation engineering courses, the authors regularly receive comments on teaching evaluations completed by students indicating surprise at how much engineering and science is involved in transportation engineering. It is no surprise then that many students do not appreciate how important it is to have an introduction to transportation engineering as part of their undergraduate education. Therefore, ensuring that civil engineering students are introduced to transportation engineering through their undergraduate coursework is essential for increasing their awareness of the importance, impact, and challenges of transportation engineering, as well as influencing them to consider the profession.

Through work by a subcommittee of the ITE Transportation Education Council, a survey was conducted to assess how transportation engineering is incorporated into undergraduate curriculum at accredited civil engineering programs. The survey gathered the following information:

- Size of individual civil engineering programs (faculty and number of students graduating per year);
- Transportation engineering faculty in each program, including both tenured and tenure-track and lecturers, adjunct, or visiting faculty; and
- Introductory course in transportation engineering, including the faculty who teach it, the textbook used, whether it is a required course, whether it has a laboratory component, and what could be done to improve the course.

In this paper are a summary of previous evaluations of the transportation curriculum, description of the survey methodology in gathering information for this project, presentation of the survey results, and insights offered into the following issues:

- Role that transportation engineering fills within the range of civil engineering programs that exist in the United States,
- Current status of the introductory course in transportation engineering in the overall civil engineering curriculum in the United States, and
- Opportunities for improving the introductory course to increase civil engineering students' understanding of the scope and importance of the transportation engineering profession.

BACKGROUND

The issues surrounding workforce development of transportation professionals are well documented, with the most comprehensive effort being a 2003 report entitled *The Workforce Challenge: Recruiting, Training, and Retaining Qualified Workers for Transportation and Transit Agencies* (*6*). That special report by TRB predicted workforce shortages in the profession and recommended strategies for transportation agencies to increase their focus on training programs. A study by Agrawal and Dill examined the recruitment issue by surveying civil engineering students about the factors influencing their focus area (*9*). This study found that only 12% of current undergraduate civil engineering students selected transportation as their focus area. The study went on to make the recommendation that freshman and sophomore civil engineering students should be exposed to the dynamic and varied career options that the transportation profession offers.

Previous studies have shown that the number of semester credit hours required for a bachelor's degree in civil engineering has remained constant in recent years, with a 2002 study showing the average at 130.4, a 2004 study finding 130.8, and a 2011 study reporting an average of 130.0 required hours (*10–12*). These findings are in contrast to those of the 1940s, when typical civil engineering programs required from 150 to 155 semester hours (*13*). With the limited number of credit hours now required, several studies in the past 10 years have researched the number of civil engineering programs requiring a transportation course. Data collected by ABET during each program's most recent accreditation as of 2001 were examined in one such study. This investigation included data from 90 of the 218 (41%) accredited civil engineering programs (*10*). Results showed that the majority (81%) of the programs required at least one transportation engineering course, for an average of 3.1 semester credits and 2.8 quarter credits. Of those requiring a transportation course, 9% required a laboratory section, and 9% required an additional transportation course. A review of 194 of the 220 accredited civil engineering programs as of 2004 found that 93% of the programs offered and 78% required at least one transportation course (*11*). Additionally, a study of Canadian universities found that 62% required one course or less (it is unclear from the unpublished data how many did not require a course), and 26% required two courses (*14*).

Agrawal and Dill researched the factors influencing recruitment into the transportation profession and also provided a snapshot of civil engineering programs from the summer of 2007 (*15*). This effort surveyed 99 civil engineering programs in the United States; each program included in the study was selected because it was one of the country's largest civil engineering programs, it was a program affiliated with the University Transportation Centers program (a program from the U.S. Department of Transportation), or it had Internet material showing transportation as an emphasis. In other words, the programs surveyed were preselected because they were likely to have a specialized transportation engineering program. This survey found that, of the 99 programs, only 76 (77%) required a course in transportation. Of those required transportation courses, 6 (8%) were required in the sophomore year, 52 (68%) were required in the junior year, 10 (13%) were required in the senior year, 7 (9%) provided flexibility to students, and for the remaining course, it was unclear to the researchers when it was required. This research found the lowest percentage of civil engineering programs requiring a transportation course, even though the programs surveyed were selected because they were viewed as likely to have a transportation specialization.

Finally, as part of the Transportation Education Conference held in Portland, Oregon, in 2009, syllabi from the introductory transpor-

tation engineering course were collected from 30 of the attendees and analyzed to determine key attributes (*16*). This effort found that 25 (83%) of the civil engineering programs represented required a transportation engineering course. It was also found that a one-credit hour laboratory component was required in 6 (20%) of the courses. In 27 (90%) of the courses, the class seemed to focus predominantly on the highway mode of travel. Among the 30 courses reviewed, 9 textbooks were used, and no particular textbook was used in more than 9 (30%) of the courses.

METHODOLOGY

Survey Design

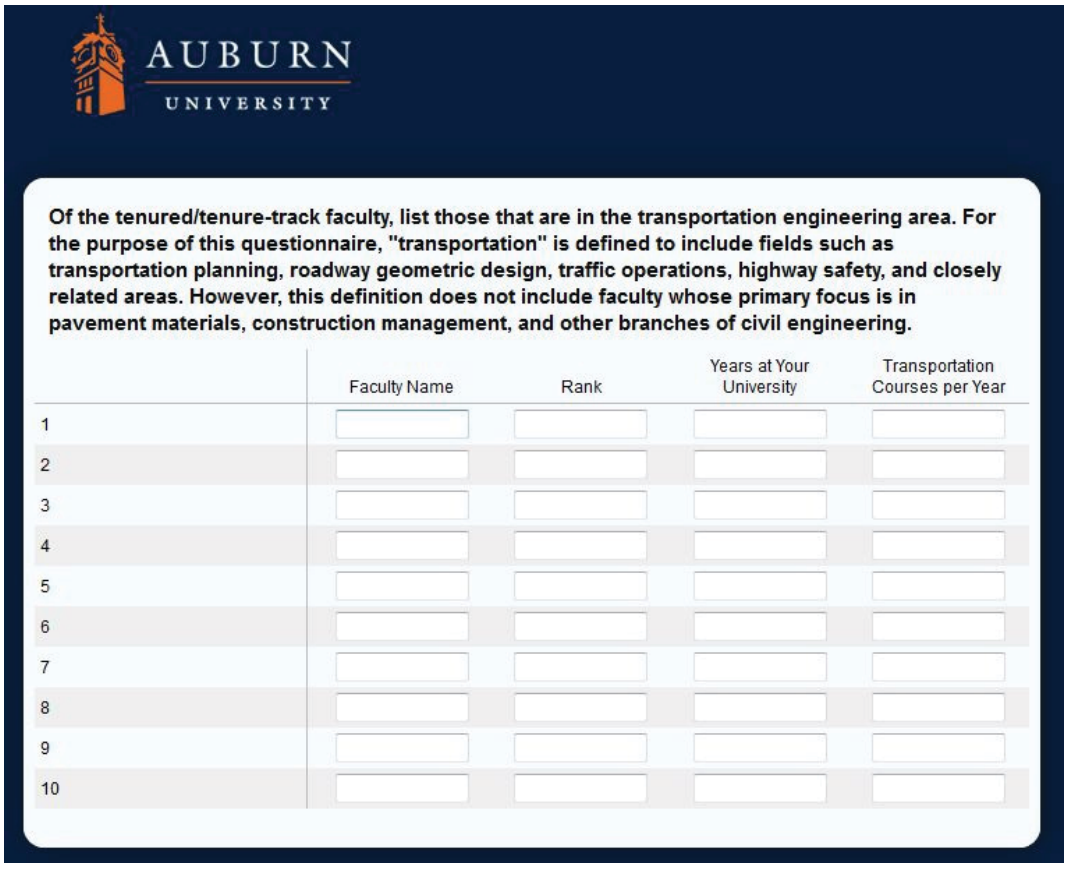
A survey containing 10 items was designed to collect civil engineering department demographics (institution name, number of tenured and tenure-track faculty, and number of students graduating per year), along with data specifically concerning transportation engineering education. The transportation-focused questions included inquiries related to both the faculty teaching in this area as well as to any required undergraduate level transportation engineering courses. Questions pertaining to faculty included name, rank, number of years at the institution, and number of transportation engineering courses taught per year. For the purpose of this survey, transportation faculty are defined as those with expertise in fields such as transportation planning, roadway geometric design, traffic operations, highway safety, and closely related areas. However, the definition excluded faculty whose primary focus is in pavement materials, construction management, and other branches of civil engineering.

Course-related items included course prefix, title, number of credit hours, laboratory requirements, whether or not the course was required of all undergraduates, faculty teaching the course within the last 2 years, textbook required, and recommendations to improve the course. All survey items were constructed in an open-ended format to allow respondents to enter program-specific information.

To facilitate acquisition of a nationally representative sample of ABET accredited civil engineering programs in the United States, an Internet-based survey tool (Qualtrics) was selected for survey delivery. The survey tool allowed the use of a variety of question and response types so that the most meaningful and representative information could be obtained from respondents. Figure 1 shows an excerpt from the survey that was distributed to ABET-accredited civil engineering programs.

Questionnaire Participants

The survey was distributed to 224 ABET-accredited civil engineering programs in the United States. To develop the contact list, a complete list of accredited programs was acquired directly from ABET. Transportation engineering professors known by the authors were first added to the school database, followed by contact information for professors who participated in the Transportation Educators Conference at Portland State University in 2009. Remaining contacts were obtained through school websites (identified by research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Of the tenured/tenure-track faculty, list those that are in the transportation engineering area. For the purpose of this questionnaire, "transportation" is defined to include fields such as transportation planning, roadway geometric design, traffic operations, highway safety, and closely related areas. However, this definition does not include faculty whose primary focus is in pavement materials, construction management, and other branches of civil engineering.

	Faculty Name	Rank	Years at Your University	Transportation Courses per Year
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

FIGURE 1 Example of survey question format.

FIGURE 2 Number of tenured and tenure-track faculty in responding civil engineering programs, spring 2012.

or teaching history in transportation engineering). From this distribution list, each of the 224 programs was contacted by individual email. Follow-up e-mails were also sent to nonresponding programs approximately 3 weeks after the initial distribution of the survey. In some cases, more appropriate contacts for the survey were provided by those initially receiving the e-mail request. Those faculty were subsequently contacted to increase the size of the respondent sample.

Level of Response

In total, 84 of the 224 ABET-accredited civil engineering programs completed the survey, representing universities from 34 U.S. states. Fifty programs responded as a result of the initial e-mail message, and an additional 34 were captured with reminder e-mails. Figures 2 and 3 show the geographic distribution of responding civil engineering programs across the country by the number of tenured or tenure-track faculty and the number of bachelor's degrees awarded annually. As seen in both figures, the survey respondents are well distributed across the country, and there is a wide distribution of program size.

FINDINGS

Characteristics of Transportation Engineering Programs and Faculty

A key objective of this study was to capture information on transportation engineering faculty and the role that they fill in civil engineering programs, and then to develop a demographic interpretation of the current transportation engineering faculty in the United States. For the survey, responses came from 84 programs. About 87% (n = 73) of these programs have tenured or tenure-track faculty in transportation engineering. Among the departments with transportation engineering faculty, the average number of tenured or tenure-track faculty is 15.1, and an average of 64 graduates are produced annually. On average, there are 2.3 transportation engineering faculty per program, which constitute 15.2% of the total faculty among these civil engineering departments.

Among transportation engineering programs represented in the survey, there are 166 tenured or tenure-track faculty. Distribution of these faculty by rank is 39.8% full professors, 31.3% associate

FIGURE 3 Number of BSCE degrees awarded per year in responding civil engineering programs.

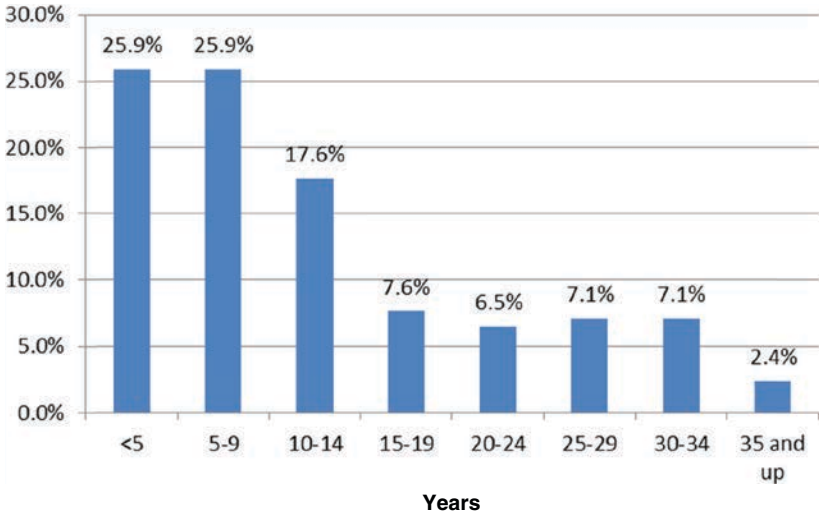

FIGURE 4 Distribution of transportation engineering faculty, by years of service.

professors, and 28.9% assistant professors. The average length of service among these faculty members is 12 years. The 25th percentile is 4.0 years, the 50th percentile is 8.5 years, and the 75th percentile is 18 years. Figure 4 illustrates the distribution of the tenured and tenure-track transportation engineering faculty by years of service at their current institutions. Fifty-two percent of these faculty have fewer than 10 years of service. This finding indicates a relatively young faculty exists in transportation engineering who can be expected to contribute to transportation engineering education for many years to come, but it shows that slightly less than half of the faculty have a decade or more of experience.

Many programs use adjunct faculty, such as lecturers, retired professors, and graduate students to assist in meeting their teaching needs. Thirty-seven percent of the programs responding to the survey use adjunct faculty to support their transportation programs. Among these programs, an average of 1.8 adjunct instructors are used; these adjunct faculty teach an average of 3.0 courses per year.

Status of First Course in Transportation Engineering

The first or introductory course in transportation has been identified as a critical touch point in developing student interest in transportation as a career path or focus area. This course has also been the focus of many recent efforts, including those by the National Transportation Curriculum Project, to improve the quality of the learning experience for civil engineering undergraduates. Of civil engineering programs, 88% ($n = 74$) offer such a course, and 79% ($n = 66$) of civil engineering programs require this course for the bachelor's degree; this proportion is fairly consistent with other assessments of the curriculum in the last decade.

The structure of this course, with respect to credit hours, laboratories, and other features, varies among institutions. Of these courses, 82% ($n = 61$) are 3 credit hours, while 18% ($n = 13$) have 4 credit hours. Also, 74% ($n = 55$) do not have a laboratory component, while 26% ($n = 19$) do. These numbers are fairly consistent with the sample of 30 syllabi reviewed in 2009 as noted previously. For the first course, 106 instructors were used within the last 2 years (summer term 2010 through spring term 2012) among the 74 institutions offering the course. The positions of those instructors are provided in Figure 5. Interestingly, adjunct faculty constitute 14% of the instructors for the first course in transportation engineering. Position titles for most of the adjunct faculty are lecturer or instructor. Also of interest is the extent to which instructors of the first course may not be experts in transportation. Distribution of these instructors by area of expertise is shown in Figure 6; only 85% have a focus in transportation. Twelve percent had identifiable primary focus areas in other areas in civil engineering (environmental, geotechnical, materials, and structures), and 3% did not have a focus area readily identified.

Course Resources

The survey generated 69 responses to the question, "Which textbook do you use?" The clear leader, cited 24 times, was *Principles of Highway Engineering and Traffic Analysis* by Mannering and Washburn (5th ed.) or one of its earlier versions. This is a concise book of 336 pages that focuses on highway engineering topics. The second most cited book (16 times) was Garber and Hoel's *Traffic and Highway Engineering* (4th ed.) or one of its earlier versions. At 1,248 pages,

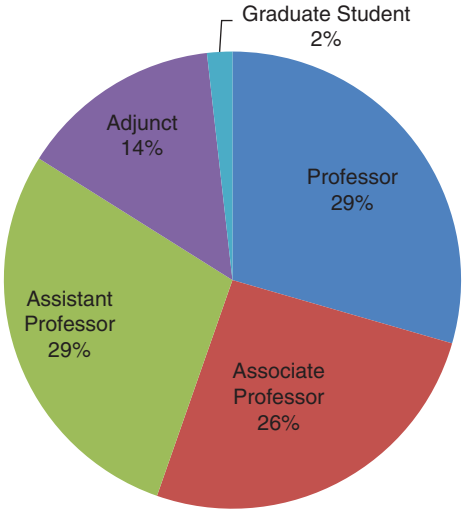

FIGURE 5 Distribution of instructors of first course, by rank.

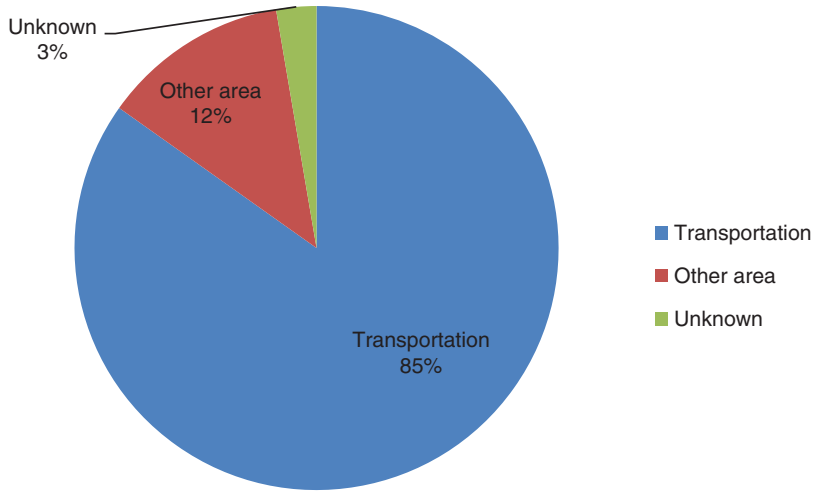

FIGURE 6 Distribution of instructors of first course, by expertise.

Garber and Hoel can be used as a reference text or for a sequence of courses on highway engineering. In third place, cited 11 times, was *Fundamentals of Transportation Engineering: A Multimodal Systems Approach* by Fricker and Whitford. Its 792 pages include chapters on public mass transportation, air transportation, freight transportation, and energy and sustainability. Other textbooks cited in the survey responses were *Transportation Engineering and Planning* (3rd ed.) by Prevedouros and Papacostas (5 responses) and *Introduction to Transportation Engineering* by Banks (3 responses). The rankings in the survey are consistent with the sellers rank normally given for each book at amazon.com (http://www.amazon.com).

A challenge for authors and adopters of transportation engineering textbooks is the rate at which important resources in the field change. The 2000 edition of the *Highway Capacity Manual* has been replaced by the 2010 edition. AASHTO's Green Book (*A Policy on Geometric Design of Highways and Streets*) and the *Manual on Uniform Traffic Control Devices* undergo changes at irregular intervals that the transportation engineer must heed; new editions of these two documents were released in 2011 and 2009, respectively. In 2010, the new *Highway Safety Manual* was published. Pavement design engineers are making the transition from the empirical method based on the AASHO Road Test more than 50 years ago to the *Mechanistic–Empirical Pavement Design Guide.* Today, none of the textbooks as mentioned has been updated to reflect the changes in all of these documents in the last 3 years. New developments place added responsibility on the instructor to be aware of changes between editions of any textbook adopted and to decide how to address the corresponding material. Likewise, example problems and homework exercises often depend on realistic and up-to-date values of input data or parameters, which may change as technology and public policy evolve. One recourse is to have students, as part of an assignment, use resources such as the Internet to update values, for example, average automobile fuel economy in miles per gallon, FAA forecasts of airline boardings, or performance of hybrid buses. Another strategy is to arrange with a publisher to create a customized textbook from multiple sources, but this can come with minimum sales requirements and resale restrictions. Online textbooks, including wiki textbooks, may also have a future. Whatever textbook or alternative is chosen, however, the responsibility for an engaging classroom experience remains with the instructor.

Suggested Modifications for Introductory Course

The final question of the survey gave respondents an open-ended question asking for suggested modifications or improvements to the introductory course that instructors would implement if not constrained by time. Despite the free entry nature of the question, 75% of respondents (n = 63) answered this question, and there was a considerable amount of consistency across the 63 responses provided. Additionally, some responses alluded to multiple improvements based within the introductory course. Table 1 synthesizes the aggregated responses for this critical question.

SUMMARY AND CONCLUSIONS

The survey and corresponding analysis of the response data revealed several interesting aspects related to the role of transportation engineering within the civil engineering curricula at a sample of accredited programs in the United States. Among the most significant findings are these:

- Responses were received from about 37% of the accredited civil engineering programs.
- Only about 12% of the responding programs do not have transportation tenured and tenure-track faculty on their staff. About 40% of the transportation faculty are full professors, with the remaining 60% about equally split between assistant and associate professors.
- Adjunct faculty are used in 37% of programs to meet the needs for teaching transportation courses.
- Of the responding programs, 88% teach an introductory course in transportation engineering, with 79% of the programs requiring the introductory course for an undergraduate civil engineering degree.
- Great variation exists in the structure of the introductory course. About 25% of the courses have a laboratory component, and 82% of the courses are 3 credit hours. Also, 14% of the courses were taught by adjunct faculty.
- Survey results show that only 85% of those teaching the introductory course have a primary background in transportation engineering, meaning that 15% of those teaching the introductory course have a background in an area other than transportation. Transportation expertise did not include faculty with expertise in

TABLE 1 Suggested Modifications and Improvements to Introductory Transportation Course

General Topic	Number of Responses[a]	Overview of Discussion
Introductory laboratory or second course	25	The majority of responses citing the desire to add a laboratory referenced the intent to provide more real-world or hands-on activities such as traffic counts and software. When citing the addition of a second course (3 responses), there was a specific desire to increase the topics covered and the depth to which topics are covered.
Improved materials	12	Responses included the desire for access to interactive and supplemental resources for use within the course. Specific references included access to interactive activities, case studies, improved textbooks to mirror the actual course content, and data collection equipment.
Topics covered	10	These responses alluded to modifications to the current topics covered within the course. Most often cited (5 of 10 responses) was to make the course more intermodal. Additional topics cited included vehicle dynamics, surveying, and pavement design.
Aspects of course offering	10	Responses related to the course offering included improved background of course instructor (4 responses), sequence the course earlier in the civil engineering curriculum (2 responses), smaller class sizes (2 responses), and improved consistency across the various instructors who teach the course (2 responses).
Field trips	3	Consistent with the desire to add more real-world or hands-on activities, 3 responses specifically cited more field trips.
Software	2	2 responses referenced the desire to add software-related components to the course.
Other	3	Additional responses included strengthened prerequisites, improved teaching assistants, and student involvement.

[a]Number of responses exceeds 63, because several responses included multiple improvements.

materials or pavements. At some universities, these are the faculty who are teaching the introductory transportation engineering course.

- Also found was that 73% of the courses use one of three textbooks: Mannering and Washburn, Garber and Hoel, or Fricker and Whitford.
- Of the suggestions offered for improving the introductory course, the most commonly mentioned are adding a laboratory or a second course in transportation, improving the course materials, increasing the intermodal or multimodal aspect of the course, and other general comments.

Some opportunities exist for improvements, including increasing the number of tenured or tenure-track faculty who have transportation engineering expertise and broadening the content of the introductory course to include more laboratory and field work and related activities. Doing so is particularly important for making undergraduate students more aware of the complexity of transportation engineering and encouraging them to consider the field. One concern is the status of the 140 programs that did not respond to the survey. There are many reasons why these programs might not have responded; some of these programs may not address transportation engineering at all and therefore chose not to respond.

This working group of the ITE Transportation Education Council will continue to examine the status of transportation engineering education in the United States and implications for the profession. Future work may include an investigation into the numbers of students entering the transportation engineering profession on graduation from accredited civil engineering programs.

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