2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #36691

Investigating the Inclusion of Traffic Operations Concepts in Undergraduate Civil Engineering Curricula

Dr. Rebeka Yocum, Oregon Institute of Technology
Dr. Vikash V. Gayah, Pennsylvania State University

Dr. Vikash V. Gayah is an associate professor in the Department of Civil and Environmental Engineering at The Pennsylvania State University (joined 2012). He received his B.S. and M.S. degrees from the University of Central Florida (2005 and 2006, respectively) and his Ph.D. degree from the University of California, Berkeley (2012). Dr. Gayah's research focuses on urban mobility, traffic operations, traffic flow theory, traffic safety and public transportation. His research approach includes a combination of analytical models, micro-simulations and empirical analysis of transportation data. He has authored over 50 peer-reviewed journal articles, over 50 refereed conference proceedings, and numerous research reports to sponsors. He has worked on research contracts valued at more than $5 million, sponsored by the Pennsylvania, Washington State, Montana and South Dakota Departments of Transportation, US Department of Transportation (via the Mineta National Transit Research Consortium and the Mid-Atlantic Universities Transportation Center), Federal Highway Administration, National Cooperative Highway Research Program and National Science Foundation.

Dr. Gayah currently serves as an editorial advisory board member of Transportation Research Part C: Emerging Technologies, an editorial board editor of Transportation Research Part B: Methodological, an associate editor for the IEEE Intelligent Transportation Systems Magazine (an international peer-reviewed journal), a handling editor for the Transportation Research Record and is a member of the Transportation Research Board's Committee on Traffic Flow Theory and Characteristics (AHB 45), where he serves as a paper review coordinator. He has been recognized with multiple awards for his research and teaching activities, including the Dwight D. Eisenhower Transportation Fellowship, Gordon F. Newell Award for Excellence in Transportation Science, University of California Transportation Center Student of the Year Award, New Faculty Award by the Council of University Transportation Centers, the Cunard, Fred Burggraf and D. Grant Mickle outstanding paper awards by the Transportation Research Board, Harry West Teaching Award by the Department of Civil and Environmental Engineering at Penn State, Outstanding Teaching Award by the Penn State Engineering Alumni Society, and Faculty Early Career Development (CAREER) Award by the National Science Foundation.

©American Society for Engineering Education, 2023

Investigating the inclusion of traffic operations concepts in undergraduate civil engineering curricula

Abstract

Transportation engineering education has been a topic of interest for researchers in recent decades. Existing surveys of transportation engineering education focus largely on the introductory transportation engineering course and does not consider the extent to which different focus areas are covered in those courses. Traffic operations is a critical focus area within transportation engineering and is considered a focus area of the field by industry professionals and educators alike. Thus, investigation into traffic operations is covered in introductory and secondary courses across different instructors and universities is essential to gaining insight into the current state of transportation engineering education. This paper documents the results of a survey of how traffic operations concepts are integrated into undergraduate level civil engineering curricula in the United States and how these topics are taught. A survey was distributed to faculty at universities with civil engineering programs across the United States. The survey responses reveal concepts related to traffic operations are covered in a large majority of introductory transportation courses and many universities offer a secondary course covering concepts related to traffic operations. The survey also reveals that, while most instructors utilize active learning strategies in their classrooms, there is little collaborative effort that goes into developing these strategies. These findings warrant further investigation into the benefits that could accompany collaborative development of active learning strategies.

Introduction

Workforce development in the transportation engineering field has been a subject of interest over the last few decades. In 2003, the *Transportation Research Board* published a report highlighting shortages in the workforce and recommending larger focus be spent on training efforts for new recruits [1]. For the purposes of this paper, we focus on transportation engineering education at the university level as "training" for the next generation of engineers. In most university degree programs, transportation engineering is a specialization of civil engineering, along with other common specializations like structural engineering, water resources engineering, geotechnical engineering, materials engineering, and environmental engineering. This means transportation engineering not only competes for student attention among all other engineering disciplines, but it also competes for student attention within civil engineering. Transportation engineering requires specialized skill sets from students, educators, and industry professionals [2]. However, transportation students and instructors generally face challenges compared to their counterparts within the civil engineering discipline. Namely, introduction to transportation specific courses occurs late in a student's educational career [3], and many concepts in transportation do not benefit from previous knowledge of mechanical-based engineering concepts [4].

Even though the field has been prevalent for decades, research into its educational aspect is lacking. Research that does exist reveals course requirements for similar degrees vary across different universities in the United States and abroad [2],[3],[4]. While unsurprising, this brings up a question of how we can best prepare the next generation of transportation engineers from an educational standpoint. A recent study from 2013 provides a broad overview of the current state of students' introduction to transportation engineering via a survey of 84 of the 224 civil engineering programs accredited by the Accreditation Board for Engineering and Technology (ABET) [3]. This study revealed that 88% of responding universities offered an introductory course in transportation with 79% of responding universities requiring the course for undergraduate students in the civil engineering department. These courses ranged from three to four credit hours, with 26% including a laboratory component. The lack of laboratory components coupled with the discovery of only 85% of faculty having a transportation engineering background beg for further investigation into the state of transportation engineering curricula nationwide. The final question of the survey asked respondents to suggest modifications to their university's introductory transportation engineering courses. Most respondents suggested adding a laboratory to the introductory course or adding a second, more in-depth, course to the curriculum. This response reveals a need for further investigation into different aspects of transportation engineering curricula, specifically looking into the degree to which secondary courses are present in civil engineering programs seven years down the road.

Aside from course structure, specific concepts covered in transportation engineering is another topic of interest among researchers. Transportation engineering is a large field encompassing many different sub-fields; e.g., transportation planning, roadway design, travel behavior, policy, and traffic operations, among others. Recent work aimed to uncover how different professionals prioritize what topics students cover in their transportation engineering courses [5],[6]. One survey compared responses from practicing engineers and educators revealing that several traffic operations-related topics broke into the top third most important concepts covered in a transportation engineering education [5]. Another survey found "detailed knowledge of traffic operations analysis procedures" ranked highest among technical skills employers considered "important employee competencies" [6]. In 2011, traffic operations was identified as one of seven key focus areas covered in introductory transportation engineering courses [7]. Existing literature reviews investigate the current state of transportation engineering education, specifically focused on the introductory course taught at the university level. Researchers focus on teaching practices [4] and course structure [2], offering some additional insight into transportation engineering education, but a specialized analysis is lacking. To the authors best knowledge, there is no existing comprehensive overview of how traffic operations related concepts fit into transportation engineering education at the university level in the United States. In response to this need, coupled with the fact that traffic operations has grown as a research area over the past few decades, largely as a result of technological advancement [8], this work seeks to understand how concepts related to traffic operations are included in transportation engineering curricula at the university level nationwide.

Traffic operations is a topic that civil engineering students have innate experience with since people continuously interact with the transportation system and are affected by its operation performance [9]. Thus, the teaching of traffic operations material can benefit from students experiences and curiosity via active learning techniques. The benefits of classroom implementation of active learning techniques have been accepted for decades [10]. Active learning has proven to be an effective method of instruction in engineering courses in general [11] and in transportation engineering courses specifically [12], aiding students in understanding the complexities that accompany engineering studies. Because engineering knowledge is organized in a hierarchical way (individual concepts build upon one another), implementation of active learning strategies lowers the chances of students "missing a step" when learning how to solve complex problems [13]. Student experiences with traffic operations are plentiful and, when used strategically, can be capitalized upon to improve comprehension of complex concepts and materials. Experimental work has been done to gauge effectiveness of active learning strategies in transportation engineering courses [14] - [19]. Concept maps [14], games [15], problem-oriented and project-based learning [16], group work [17], simulation [18], and inquiry-based learning [19] are a few strategies researchers have focused on in previous work. Active learning strategies may be widely used, however a review of instructional practices used in transportation engineering courses reveals a lack of dissemination of teaching practices across universities [4].

This paper aims to add to the existing survey-based literature by collecting responses from universities nationwide. The goal is to understand how traffic operations concepts are covered and how active learning strategies are utilized in different programs that offer transportation engineering courses. Specifically, this work seeks to answer the following questions:

- When are civil engineering students being exposed to transportation engineering and traffic operations material?
- To what extent are concepts related to traffic operations taught at different universities nationwide?
- How are active learning strategies developed when teaching concepts related to traffic operations?
- What level of consistency exists between different universities/instructors when teaching material related to traffic operations?

The results can be used to envision ways transportation engineering education, specifically related to traffic operations, could be improved throughout the country.

The rest of the paper is as follows: first, a background of similar work is summarized, next, a brief description of the survey methodology is presented, finally, survey results are summarized and discussed.

Methodology

This section provides an overview of the methods used to answer the above questions, including a description of the survey that was used, the group of individuals that were contacted to answer the survey, and the set of those that responded to the survey.

Survey description

A survey was created to gain insight into how different universities incorporate traffic operations concepts as part of their transportation engineering curricula and instructional methods used to engage students with this material. Respondents were told in the survey that the "…survey is specifically focused on the teaching of traffic operations/engineering, including topics such as traffic stream characteristics, data collection studies, intersection control/warrants, signal control and design, Highway Capacity Methodologies, transportation impact studies, signal coordination, among others. Highway design and transportation planning topics are not explicitly considered."

The survey was also used to gauge interest in the creation of a repository of information (e.g., lecture notes, homework assignments, exams and other course materials) to share ideas/topics and promote the use of active learning strategies used when teaching traffic operations.

The specific objectives of the survey were to obtain the following information:

- How students in the university's degree program are exposed to traffic operations topics, including:
    - If included in an introductory course in transportation engineering or only covered in a follow-up or elective course
    - Course details and requirements
    - Textbooks and software used to cover this material
- Instructional strategies used in courses that cover concepts related to traffic operations, including active learning strategies
- Specific topics and concepts covered related to traffic operations
- Demographic information about instructors

The survey consisted of 74 potential questions, though various questions were only presented based on responses to previous questions. The questions consisted of mostly multiple choice or fill-in-the-blank responses, and respondents were allowed to upload their course syllabus so the research team could extract relevant pieces of information. The survey was electronically coded into the Qualtrics survey software and took approximately 15 minutes to answer.

The survey was intended to reach all colleges and universities in the United States with a civil engineering undergraduate program. To ensure as many of these colleges and universities were captured, a list of 231 schools was obtained from an email list serve of all civil engineering department chairs/heads in the US. The research team browsed websites for each participating school and identified either faculty members with a background in transportation engineering or—failing this—associated department heads. These individuals were then contacted in December 2020 (with a reminder in February 2021) to participate in the survey or forward the survey along to the most appropriate person at that school to provide the information (i.e., instructors of transportation engineering courses). Responses were received between December 2020 and February 2020. Respondents were entered into a raffle for one of several gift cards to motivate response rate.

Survey Participants

Of the 231 universities that were contacted, responses were received from 108 respondents at 54 unique universities yielding a response rate of 23.4% at the university level. A map showing the distribution of responding universities is presented below in Figure 1. The responding universities provide significant spatial coverage across the United States, apart from the mid-west. The research team compared the set of universities that responded vs. those that did not and found no significant patterns to explain why responses were received from some universities and not from others. However, anecdotal evidence obtained from directed emails to some (non)respondents during the survey period suggests that response likelihood was based primarily on time availability at the time of survey receipt. Most respondents answered within 1 week of either the survey request or reminder.

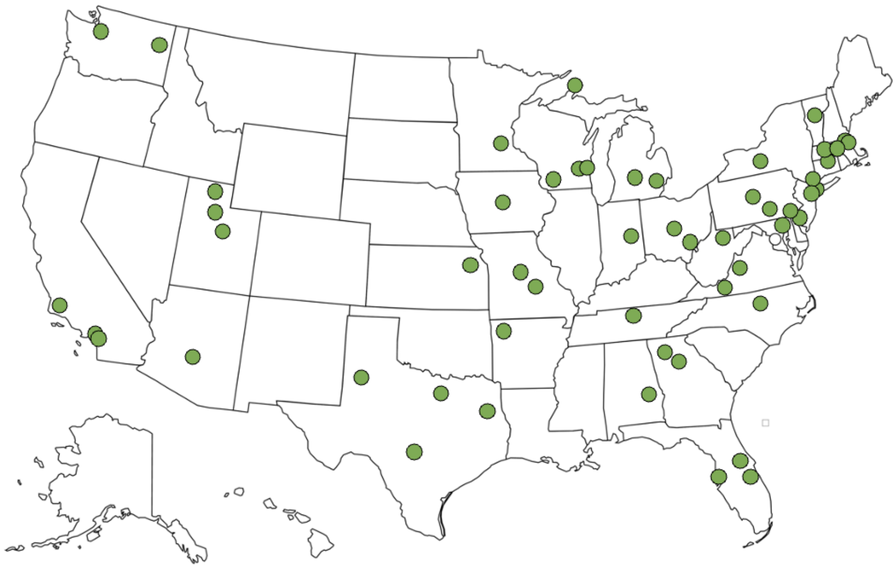


Figure 1. Distribution of responding universities nationwide

The figure in Appendix A, presents a graphical summary of the distribution of various respondent attributes, including amount of teaching experience, primary discipline, and position type. Figure a shows that respondents had a nearly uniform distribution of teaching experience, revealing transportation engineering faculty are diverse in experience and likely as a result, age. Unsurprisingly, Figure b shows 97% of respondents with a civil engineering background. Participants were not asked for their specific focus within civil engineering, so the percentage of respondents with backgrounds in transportation engineering specifically may not be reflected in that 97%; however, a review of the respondent information suggests that this 97% accurately reflects a background in transportation engineering. This supports the notion that transportation engineering courses are mostly being taught by individuals with a background in or closely related to transportation. Figure c shows most respondents as tenure or tenure track faculty members at their universities. A small portion of respondents are non-tenure track faculty members or are in administrator positions.

Findings

This section summarizes the major findings obtained from the survey on how traffic operations concepts are covered in undergraduate civil engineering curricula.

Traffic Operations Covered in an Introductory Transportation Course

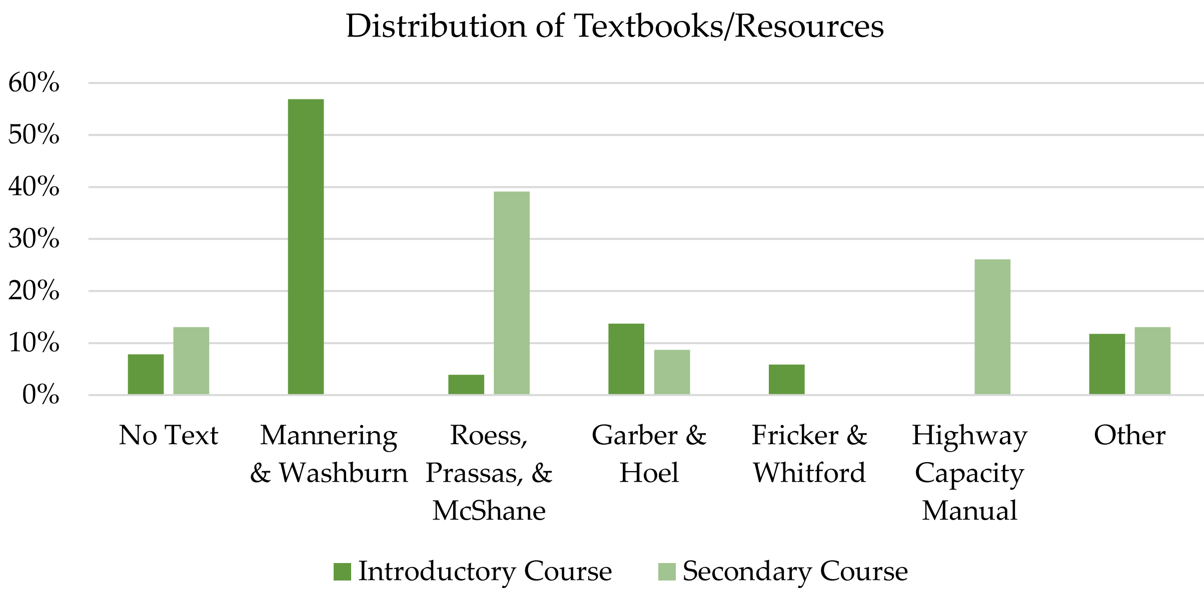
A large majority (93.5%) of respondents stated concepts related to traffic operations were covered in a required *Introduction to Transportation Engineering*-type course. The most common course title was in fact "Introduction to Transportation Engineering", though many schools used different course titles including "Highway Engineering", "Traffic Engineering", "Traffic Operations/Control", "Transportation Systems", "Transportation Planning and Design", and "Traffic Flow Theory". A large majority (85.71%) of courses were required for undergraduate students in the civil engineering program, but 14.29% of these introductory courses were elective (i.e., not required). A complete distribution of textbooks and software used in introductory courses as well as the years they are offered is shown in Figure 2a, b, and c, respectfully. Textbooks that were most used included the following:

- *Principles of Highway Engineering and Traffic Analysis*, Mannering and Washburn
- *Traffic Engineering*, Roess, Prassas and McShane
- *Traffic and Highway Engineering*, Garber and Hoel
- *Fundamentals of Transportation Engineering*, Fricker and Whitford
- *Highway Capacity Manual*, Transportation Research Board

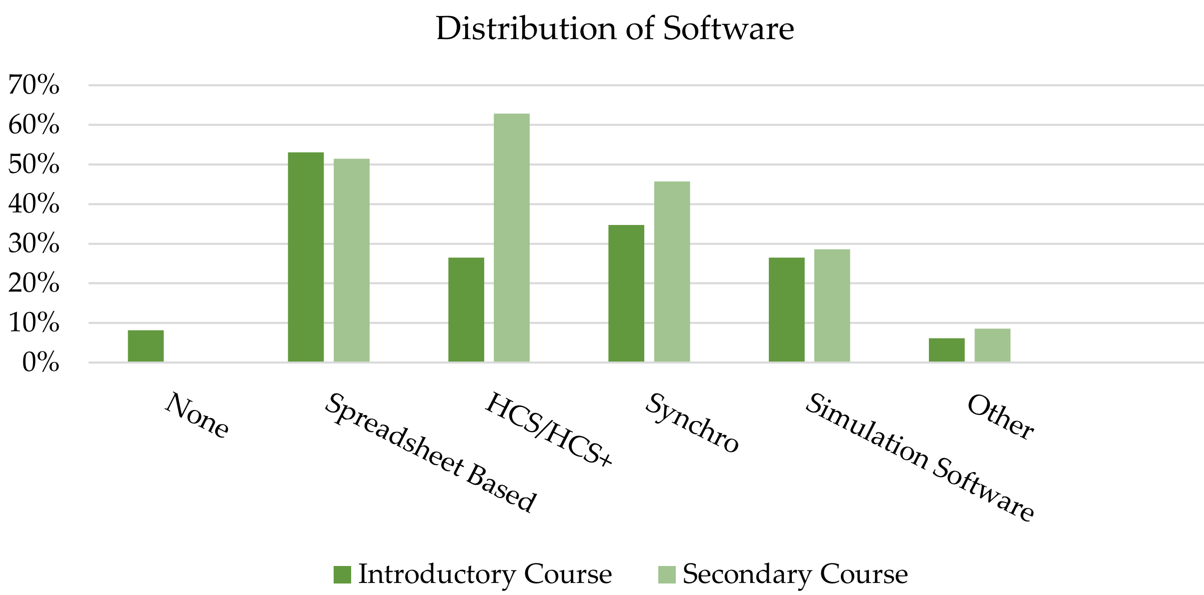
Interestingly, most introductory courses used Mannering and Washburn's *Principles of Highway Engineering and Traffic Analysis* text. Use of software was more evenly spread among respondents with a majority (53.06%) of intro courses utilizing spreadsheet-based software. However, several courses utilized dedicated software for traffic operations problems, including *Synchro* or *HCS/HCS+*. Over 25% of the introductory courses also integrated some type of simulation software. Nearly 90% of these introductory courses were offered at the junior (or third year) level or later. These results confirm that—unlike other engineering fields and civil engineering subdisciplines—students are generally not made aware of the field of transportation engineering or exposed to concepts of traffic operations until very late in their academic journey.

Traffic Operations Covered in a Specialized Course

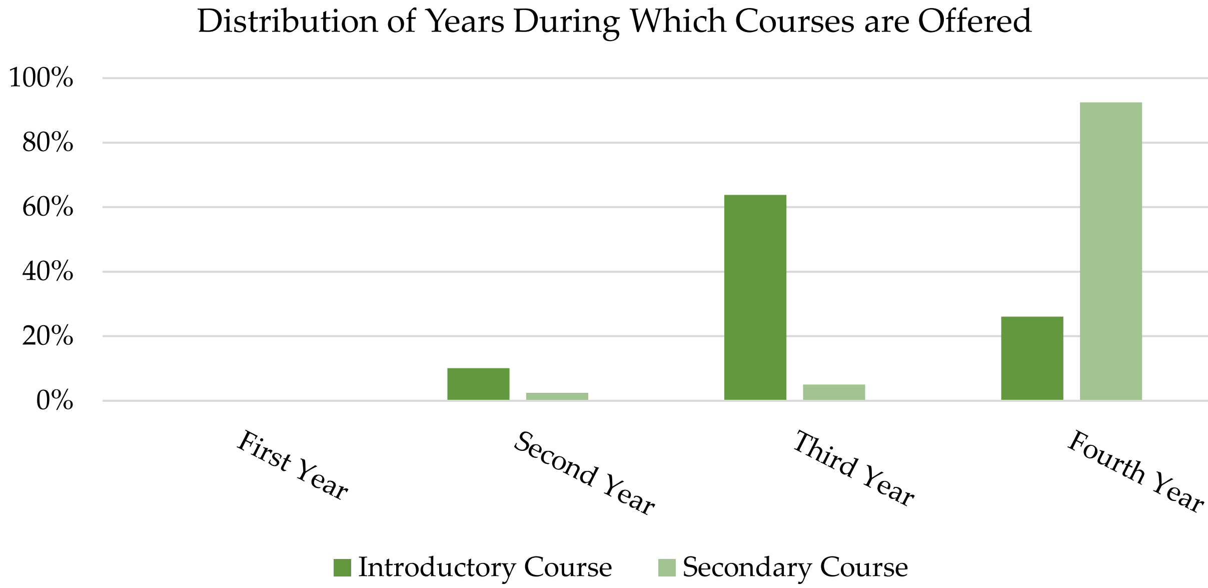
A large fraction of schools (69.51%) also indicated that another, non-introductory course that covered traffic operations concepts was also available in the curriculum. Unlike the introductory courses discussed previously, these courses are primarily elective courses with 85.71% of courses not being required for undergraduate civil engineering students. A complete distribution of textbooks and software used in these secondary courses as well as the years they are offered is shown in Figure 2a, b, and c, respectfully. Textbook use is slightly more evenly distributed among these courses, but the majority of specialized courses in traffic operations tends to use either Roess, Prassas and McShane's *Traffic Engineering* or the *Highway Capacity Manual*. The former textbook has a specific focus on signalized intersection operations, while the latter covers general methods to quantify operational performance of a range of facility types. A majority (62.86%) of secondary courses utilized *HCS/HCS+*, which appears to supplement the use of the *Highway Capacity Manual* and suggest a strong focus on assess operational performance of different facilities. A small portion (28.57%) of courses utilized specialized simulation software including *VISSIM*, *VISSIO*, *SimTraffic*, *CORSIM*, and *Integration*. Like the intro courses discussed previously, none of these courses are available to first year students and these non-introductory courses are primarily only taken by students in their last year (over 90% are offered for senior-level students).



a. Distribution of textbook use in introductory and secondary courses covering traffic operations related concepts



b. Distribution of software used in introductory and secondary courses covering traffic operations related concepts



c. Years introductory and secondary courses covering traffic operations related concepts are offered

Figure 2. Comparative distributions of textbook and software use as well as years courses are offered between introductory transportation courses and secondary transportation courses covering concepts related to traffic operations

Concepts Covered in Courses

The surveyed aimed to gather more information about traffic operations content that was covered in undergraduate civil engineering curricula. This content was broken into 13 unique topics, and various concepts were identified for each. The specific topics were:

1. Introduction to traffic engineering
2. Components of a traffic stream
3. Traffic control devices
4. Traffic stream properties
5. Volume studies and characteristics
6. Speed, travel time, and delay studies
7. The hierarchy of intersection control
8. Basic principles of signalized intersections
9. Fundamentals of signal timing and design
10. Analysis of signalized intersections
11. Transportation impact studies
12. Signal coordination
13. Actuated signal control

Appendix B provides a summary of the concepts (broken up by topic) that respondents indicated were included in their undergraduate curriculum. Responses are provided for all respondents (out of a total of 108 responses) and for those who only indicated their university had an introductory course that covered concepts related to traffic operations (out of a total of 22 responses).

Participants were also asked about topics or concepts that were not specifically included in the list. The most stated topics that were not included were parking studies and queueing analysis, in addition to several non-operations topics (e.g., geometric design, pavement design and traffic safety).

Overall, there seems to be a good match between topics/concepts covered in university curricula that cover traffic operations concepts in multiple courses (third column) and cover these concepts in only an introduction course (fourth column). Several topics seems to have broad coverage of individual concepts across both the set of all courses and just introductory courses. These include:

- Introduction to traffic engineering
- Traffic stream properties
- The hierarchy of intersection control
- Basic principles of signalized intersections
- Fundamentals of signal timing and design

The topics with the least coverage across concepts include:

- Analysis of signalized intersections
- Transportation impact studies
- Signal coordination
- Actuated signal control

The information in Appendix B also provides insight into which topics/concepts for which additional information are critically needed to share with instructors.

Instructional methods

A tabular summary of instructional methods used for courses that cover traffic operations materials (both introductory and follow-up courses) is provided in Table 1. Table 1a, provided in text and in Appendix C, summarizes responses by instructional method and Table b, provided in Appendix C, groups common responses together. The most common responses included are traditional instructional methods, including: in-person instruction with PowerPoint, in-class examples lead by the instructor, and in-person instruction with board work. The courses also have hands-on components or demonstrations that provide students with experiences associated with working in traffic operations; e.g., student interaction with software or instructor demonstration of software. The least common method was students being provided with time to solve in class examples alone, although instructors generally provided students with time to work on problems in small groups. Such active learning has been shown to be critical to improve student understand of material, as described in the review of the literature. Interestingly, software is integrated into most courses: over 70% either include software demonstrations or student use of engineering software.

Table b in Appendix C provides a summary of the most common response patterns among individual instructors. The table reveals that the most common response was from instructors who used all nine instructional methods. In fact, the vast majority of respondents used at least six instructional methods in their course, which suggests variation in how the traffic operations material is presented. followed by instructors who used more than one instructional method. The analysis of responses revealed that most instructors use a combination of methods in their courses.

Table 1. Instructional methods used by instructors

a). Tabular summary by instructional method

Instructional Method Used	% Respondents Indicated "Yes"
1 - In Person Instruction with Powerpoint	96%
2 - Analysis of Field Data	93.33%
3 - In Person Instruction with Board Work	78.67%
4 - In Class Examples	78.67%
5 - Student Interactions with Software	73.33%
6 - Instructor Demonstration of Software	69.33%
7 - In Class Problems – Students Work in Small Groups	68.00%
8 - Field Data Collection	64.00%
9 - In Class Examples – Students Work Alone	49.33%

There is a significant number of instructional methods that take advantage of the interactive nature of transportation engineering; e.g., field data collection and analysis of field data. Most respondents (80%) also stated their courses utilized real world case studies and examples, with 36.36% of those studies done in partnership with local or state public agencies. Common case studies include signal design and analysis, level of service analysis, traffic study, and other examples of data analysis. When asked how these case studies were developed, common responses included personal experience, use of literature, use of publicly available data, and collaboration with a colleague. Around one third of respondents stated their case studies were developed in partnership with public agencies at the local or state level, which illustrates that instructors are incorporating real-world transportation sciences of interest to a community into the classroom. Mostly, these partnerships aided instructors in gathering data for use in their case studies, and, in some cases, agencies provided insight into areas of interest in order to make the case studies more realistic.

When asked specifically about the use of active learning techniques, most respondents (73.9%) claimed to specifically utilize active learning strategies to aid in student comprehension of materials. Table 2 provides a summary of specific active learning strategies that are utilized in these courses. Table 2a, provided in text and in Appendix D, summarizes responses by active learning strategy and Table b, provided in Appendix D groups common responses together. Many of these strategies are related to active problem solving, either individually or in groups. Problem-based learning is utilized in nearly half of the courses, which verifies the use of real-world case studies and problems in traffic material. Other strategies include term projects, field studies, presentations, review meetings, project reports, use of new technologies, and crowdsourced research. The most common combinations included think/pair/share and other or think/pair/share, other, and student problem solving in class.

Table 2. Active learning strategies utilized by instructors

a). Tabular summary by active learning strategy

Active Learning Strategy Used	% Respondents Indicated "Yes"
1 - Student Solving Problems Individually in class	61.11%
2 - Students Solving Problems in Groups in class	57.04%
3 - Problem-Based Learning	55.56%
4 - Think/Pair/Share	35.19%
5 - Inquiry-Based Learning	22.22%
6 - Other	12.96%
7 - Muddiest Points	11.11%
8 - Minute Papers	3.70%

From the spread of responses for each active learning strategy shown in Table b in Appendix D, it is clear that while active learning strategies are utilized in the classroom, it was most common for a given instructor to utilize between one and three active learning strategies. When asked how these strategies were developed, the most common answer was personal trial and error. Other common responses include teaching workshops/resources provided by the university, and course resources. Only one respondent stated they developed active learning strategies with the help of peers or colleagues. These responses highlight a lack of dissemination between instructors regarding active learning strategies and suggest that transportation engineering instructors could benefit from additional material on how to integrate a wider range of active learning into their courses.

Discussion and conclusions

The survey provides insights into how traffic operations material is taught at undergraduate civil engineering programs in the United States. The results find that students are generally being introduced to both transportation engineering (as a whole) and traffic operations topics relatively late in their degree programs (third year or after). While individual areas of civil engineering are typically formally introduced at this time, students may often receive a light introduction to these areas in other required courses. For example, statics and strength of materials courses often prime students to ideas in structural or geotechnical engineering via both the materials covered and relevant examples. Similarly, fluids dynamics courses may also prime students to ideas in water resources or environmental engineering. However, these early introductions do not exist for transportation and traffic topics. Anecdotal evidence from several instructors in the survey suggest that students are genuinely interested in transportation engineering but feel committed to other areas in civil engineering due to this early exposure to and selection of the other areas. This is especially true since many students push this introductory course off until their senior year—likely since it does not serve as a prerequisite for other mandatory courses. This suggests that is critical to engage civil engineering students in transportation-related topics earlier to help make the field more attractive to students. For example, traffic operations concepts can be integrated into required courses to similarly prime students to these ideas. Examples include statistics, programming, and numerical methods—among others—which are generally taken earlier in a student's degree program and could help expose students to the field. Though it should be noted in general that including material on other subdisciplines of civil engineering in these required courses would also be beneficial.

The results also revealed that traffic operations related concepts are covered on a large scale in introductory transportation engineering courses at different universities. Secondary courses that cover traffic operations more deeply exist on a smaller scale. Both introductory and specialized courses tend to utilize real-world case studies, taking advantage of the natural interaction and curiosity that students have with the transportation system. These courses also introduce students to various software that they will utilize as practicing transportation engineers (e.g., spreadsheet-based software, Highway Capacity Software, Synchro). However, there are several topics that are not covered as broadly as others. These tend to be topics that get into detailed operational concepts, such as analyzing operation of signalized intersections, signal coordination, actuated signal control or traffic impact studies. Transportation engineering instructors may benefit from modules/materials that were made available on these topics to integrate into their courses and provide students with this information.

Most respondents stated they utilized active learning strategies when teaching these courses (72.6%). The most common response when asked about the development of these strategies was trial and error. Instructors largely came up with and evaluated active learning strategies on their own. A few respondents noted outside resources either online or at the university level, and only one respondent mentioned learning strategies from other instructors. These results open the door for further investigation into the effective development, implementation, and evaluation of active learning strategies in transportation engineering education. Specifically, collaborative efforts should be considered when developing these strategies. The benefits of collaborative development could then be explored, and steps could be taken to implement the beneficial processes within individual universities or across larger teams/groups.

The results also reveal some suggestions for improvement in the teaching of this material moving forward. While software was used in many (~70%) of these courses, providing hands-on experiences with traffic software appears to be a relatively simple way to improve course experience and provide students with skills that can be used later in their career. Simply active learning strategies – such as minute papers or muddiest points – seems to be relatively rare in these courses; however, these are easy ways for instructors to integrate active learning, get student feedback, and help clarify conceptual issues. Providing transportation engineering instructors with information and examples on these areas could also be beneficial.

References

[1] "The Workforce Challenge—Recruiting, Training, and Retaining Qualified Workers for Transportation and Transit Agencies," Transportation Research Board of the National Academies, Washington, D.C., SR 275, 2003.

[2] D. Hurwitz, et. al., "Transportation Engineering Curriculum: Analytic Review of the Literature," *J. Prof. Issues Eng. Educ. Pract.*, Vol. 142, No. 3, 2016.

[3] R. Turochy, et. al., "Assessment of Introductory Transportation Engineering Courses and General Transportation Engineering Curriculum," *Transportation Research Record: Journal of the Transportation Research Board*, No. 2328, pp. 9-15, 2013.

[4] D. Hurwitz, "Transportation Engineering Instructional Practices: Analytic Review of the Literature," *Transportation Research Record: Journal of the Transportation Research Board*, No. 2480, pp. 45-54m 2015.

[5] R. Turochy, "Structuring the Content of the First Course in Transportation Engineering: Perspectives of Engineers and Educators," *J. Prof. Issues Eng. Educ. Pract.*, Vol. 139, No. 3, pp. 206-210, 2013.

[6] G. Hawkins and K. Chang, "Employers' Perspectives on Needs for Critical Skills and Knowledge in the Transportation Field," *Institute of Transportation Engineers, ITE Journal; Washington,* Vol. 86, Iss. 6, pp. 34-37, 2016.

[7] A. Bill, et. al., "Development of knowledge tables and learning outcomes for an introductory course in transportation engineering," *Transp. Res. Rec.,* Vol 2211, pp. 27-35, 2011.

[8] K. Sinha, et. al., "Development of Transportation Engineering Research, Education, and Practice in a Changing Civil Engineering World," *J. Transp. Eng.,* Vol. 128, No. 4, pp. 301-313, 2002

[9] Y. Mehta, *Innovative Techniques to Teach Transportation Engineering*, Proc. of ASEE 113th Annual Conference, June 18-21, 2006, Chicago, Illinois.

[10] C. Meyers and T. Jones, *Promoting active learning. Strategies for the college classroom*, Jossey-Bass, 1993.

[11] S. Freeman, and S. Eddy, "Active learning increases student performance in science, engineering, and mathematics," *Proc. of the National Academy of Sciences – PNAS,* Vol. 111, No. 23, pp. 8410-8415, 2014.

[12] A., Rodrigues da Silva, N. Kuri, and A. Casale., "PBL and B-learning for civil engineering students in a transportation course," *J. Prof. Issues Eng. Educ. Pract.*, pp. 305-313, 2012.

[13] U. Jørgensen, "Historical accounts of engineering education," in *Rethinking engineering education,* K. Edstrom, Springer, Boston, 2014.

[14] C. Prado da Silva Jr., H. Fontenele, and A. Rodrigues da Silva, "Transportation Engineering Education for Undergraduate Students: Competencies, Skills, Teaching-Learning, and Evaluation," *J. Prof. Issues Eng. Educ. Pract.,* Vol. 141, No. 3, 2015.

[15] Q. Wang, and M. Abbas, "Designing web-games for transportation engineering education," *Comput. Appl. Eng. Educ,* Vol. 26, pp. 1699-1710, 2018.

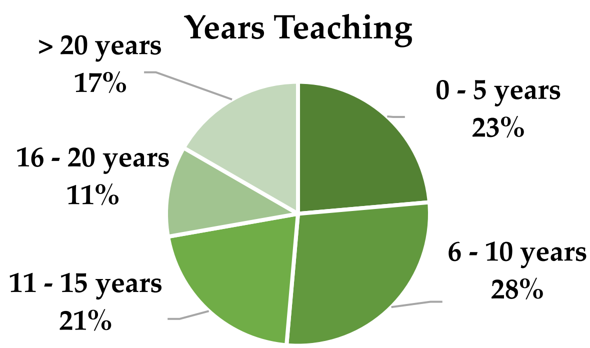
[16] L. Mingxin, and A. Faghri, "Applying Problem-Oriented and Project-Based Learning in a Transportation Engineering Course," *J. Prof. Issues Eng. Educ. Pract.,* Vol. 142, No. 3, 2016.

[17] J. A. Weir, "Active Learning in Transportation Engineering Education," PhD dissertation, Dept. Civil Eng., Worcester Polytechnic Institute, Worcester, MA, 2004.

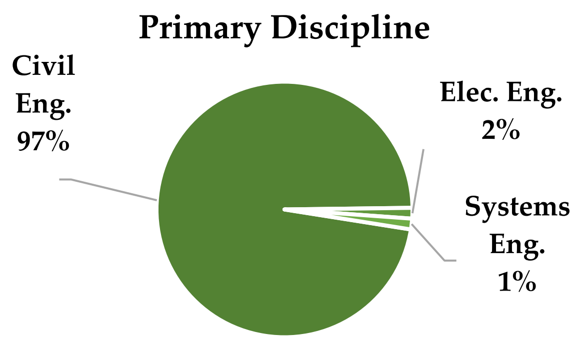
[18] C. Liao, H. Liu, and D. Levinson, "Simulating Transportation for Realistic Engineering Education and Training: Engaging Undergraduate Students in Transportation Studies," *Transportation Research Record: Journal of the Transportation Research Board*, No. 2109, pp. 12-21, 2009.
[19] I. Guler, S. Cutler, and S. Zappe, *Work in Progress: Inquiry Based Learning in Transportation Engineering*, Proc of ASEE Virtual Conference, 2020.

Appendix A

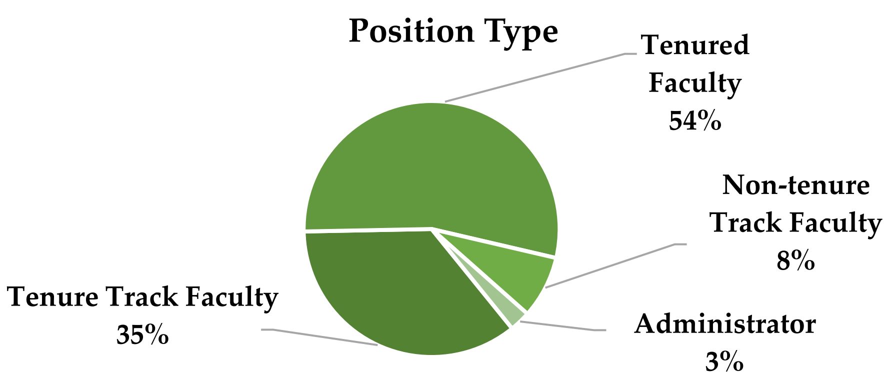
Graphical distribution of survey respondent attributes



a. Distribution survey respondents' teaching experience



b. Distribution of survey respondents' primary discipline



c. Distribution of survey respondents' position type

Appendix B

Concepts related to traffic operations covered by survey respondents

Topic	Concepts	Number of positive responses (out of 108)	Number of positive responses (out of 22)
1	Identify the objectives of a traffic engineer	58	17
	Explain how traffic engineering fits within the larger transportation engineering field	59	18
2	Identify different types of diversity within traffic stream components	53	17
	Identify two most important ways drivers differ (with respect to traffic operations)	36	10
	Discuss how we deal with this diversity as traffic engineers	35	9
	Derive stopping sight distance equations using kinematic equations of motion	57	17
3	Define requirements for traffic control devices and regulatory terms used by the MUTCD	52	14
	Describe types of traffic control devices	61	18
	Determine where warning signs should be placed according to the MUTCD	28	9
4	Define macroscopic traffic stream properties	69	21
	Compare and contrast time-mean and space-mean measurements	68	20
	Relate microscopic traffic stream properties to macroscopic traffic stream properties	54	16
	Describe the shape of relationships between traffic stream characteristics (bivariate relationships)	62	20
5	Describe the most common type of volume characteristics	64	20
	Describe how to collect traffic volume data	64	19
	Identify the types of temporal variations that exist in traffic volumes	55	16
	Use coverage and control counts to estimate traffic volumes with limited data	34	8
	Explain how statewide counting programs are performed and how to derive and use daily and monthly variation factors from volume data	25	8
	Explain the difference between observed volumes, demand, and capacity	56	16
	Estimate origin-destination tables from limited count data	12	3
	Describe a cordon count study	18	4
6	Define metrics such as speed, travel time and delay	69	20
	Explain how to perform a spot speed study and how to analyze data obtained	49	12
	Explain how to perform a travel time study	40	9
	Estimate control delay at an intersection	54	12
7	Explain the advantages and disadvantages of traffic signal control	55	17
	Discuss the different levels of traffic control provided at an intersection	53	15
	Explain the differences in the type of control provided at each intersection	50	12
	Apply warrants to determine if a traffic signal should be installed	45	16
	Calculate intersection sight distance requirements	38	14

Topic	Concepts	Number of positive responses (out of 108)	Number of positive responses (out of 22)
8	Calculate the minimum cycle length at a signalized intersection	63	20
	Describe the basic terminology related to traffic signal operation	62	20
	Explain the concepts of lost times and saturation flow	62	19
	Relate the capacity of an intersection to cycle length and number of phases	61	20
	Describe the three components of delay	52	15
	Estimate uniform delay	47	13
9	Determine appropriate cycle length and assign green time	61	18
	Explain the signal timing process	60	16
	Determine critical volume through intersections	60	15
	Draw a phase diagram and ring diagram for a given timing plan	58	12
	Calculate lost times	58	13
	Describe different signal timing plans	55	18
	Calculate clearance and change intervals	52	18
	Determine if left-turn phases are required	45	18
	Check if pedestrian requirements are met	43	13
10	Explain the required inputs of the HCM methodology for signalized intersection	50	12
	Estimate level of service for the lane group based on delay and v/c ratio	50	9
	Estimate the saturation flow rate of an approach when field measurements are not available	48	8
	Estimate delay and level of service for a signalized	48	11
	Calculate the various components of delay for a lane group	43	13
	Calculate arrival flow rates for an intersection accounting for progression	34	14
	Discuss the differences and similarities between HCM 2000 and 2010 methodologies for signalized intersection analysis	15	2
11	Describe the purpose of a transportation impact study	33	6
	Explain the basic steps involved for a transportation impact study	29	5
12	Describe how signal coordination is related to signal offsets and bandwidth	47	12
	Calculate ideal signal offset in one direction	33	9
	Describe typical coordination plans and when they are useful	22	4
	Determine a coordination plan for two directions	21	3
	Explain how coordination changes in networks	18	4
13	Describe the benefits and disadvantages of actuated signal control	51	15
	Explain the types of signal actuation	49	15
	Describe the operational features of an actuated signal controller	34	9
	Determine the signal timing plan for an actuated signal	20	2
	Predict phases sequences of an actuated signal	17	4

Appendix C

Instructional methods used by instructors

a). Tabular summary by instructional method

Instructional Method Used	% Respondents Indicated "Yes"
1 - In Person Instruction with Powerpoint	96%
2 - Analysis of Field Data	93.33%
3 - In Person Instruction with Board Work	78.67%
4 - In Class Examples	78.67%
5 - Student Interactions with Software	73.33%
6 - Instructor Demonstration of Software	69.33%
7 - In Class Problems – Students Work in Small Groups	68.00%
8 - Field Data Collection	64.00%
9 - In Class Examples – Students Work Alone	49.33%

b). Tabular summary by response

	Instructional Method Used								
# of Respondents	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
16	√	√	√	√	√	√	√	√	√
7	√	√	√	√	√	√	√	√	
4	√		√	√			√		√
4	√	√	√	√	√	√		√	√
3	√	√	√	√			√	√	√
3	√	√	√	√	√	√		√	
2	√	√		√	√	√		√	
2	√	√	√	√	√	√	√		√
2	√	√		√	√	√	√	√	
2	√	√	√	√	√			√	
2	√		√	√	√	√	√		
1				√				√	
1	√			√					
1	√			√			√		√
1	√	√		√	√	√			
1	√			√	√	√			√
1	√	√			√	√		√	
1	√	√	√	√				√	√
1	√		√		√	√	√		
1	√	√	√	√				√	
1	√	√	√	√					
1	√		√	√			√		
1	√		√	√		√	√		
1	√	√	√	√	√	√		√	
1		√		√	√	√	√	√	
1	√	√	√	√	√		√	√	
1	√	√	√	√			√		√
1	√	√		√	√	√	√		
1	√	√		√	√		√	√	
1		√	√		√	√	√		
1	√			√			√		
1	√								
1	√	√		√			√		√
1	√	√		√	√	√	√		√
1	√	√	√	√	√	√	√		
1	√	√	√	√	√	√			
1	√	√	√		√	√			
1	√		√	√	√	√	√		√
1	√	√	√	√				√	

Appendix D

Active learning strategies utilized by instructors

a). Tabular summary by active learning strategy

Active Learning Strategy Used	% Respondents Indicated "Yes"
1 - Student Solving Problems Individually in class	61.11%
2 - Students Solving Problems in Groups in class	57.04%
3 - Problem-Based Learning	55.56%
4 - Think/Pair/Share	35.19%
5 - Inquiry-Based Learning	22.22%
6 - Other	12.96%
7 - Muddiest Points	11.11%
8 - Minute Papers	3.70%

b). Tabular summary by response

	Active Learning Strategy							
# of Respondents	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
5	√		√					
4	√		√	√				
5		√						
3	√							
2			√			√		
2	√	√	√					
2	√	√						
2		√		√				
2						√		
1	√						√	
1	√	√	√				√	
1	√	√						
1		√	√		√			
1	√	√		√	√			
1			√		√			
1	√	√	√	√		√		
1	√	√	√	√			√	
1			√	√	√			
1	√	√	√	√	√			
1	√	√			√			
1		√	√	√	√		√	√
1		√	√					
1	√	√	√	√				
1	√			√				
1	√	√						
1	√	√		√				
1	√		√				√	
1		√	√	√			√	
1				√				
1		√	√		√			
1	√		√		√			
1	√	√	√	√	√			√
1		√				√		
1	√		√	√	√			
1	√	√				√		
1	√	√	√		√			