Transportation Engineering Curriculum: Analytic Review of the Literature

David S. Hurwitz, A.M.ASCE[1]; Kristen L. Sanford Bernhardt, M.ASCE[2]; Rod E. Turochy, M.ASCE[3]; and Rhonda K. Young, M.ASCE[4]

Abstract: Transportation engineering curricula at the undergraduate and graduate levels are critical to the development of technical competency in future transportation engineering professionals—those who will be responsible for the planning, design, construction, operation, and maintenance of safe and efficient transportation systems. This paper provides an analytic review of journal articles and refereed conference papers addressing how transportation engineering curricula have changed over time. The literature review found 51 articles for analysis, with an increased frequency of those publications over time. Curriculum issues described in these papers include how transportation fits broadly within engineering programs and, more specifically, within civil engineering programs, which topics are addressed in transportation courses, and how these courses attend to stakeholder needs. This analytic review of the literature provides a resource for transportation engineering educators, administrators, and researchers to consider how transportation curricular issues have been treated in the literature historically as the community continues to develop and implement the transportation engineering curricula of the future. The findings will inform transportation engineering educators of the state of the practice in transportation engineering curricula. **DOI: 10.1061/(ASCE)EI.1943-5541.0000275.**

Author keywords: National Transportation Curriculum Project (NTCP); Transportation engineering curriculum; Transportation engineering education.

Introduction

Transportation engineering typically is viewed as a subdiscipline of civil engineering, along with fields such as construction, structural, geotechnical, environmental, and water resources engineering. However, as is the case to some extent with all civil engineering subdisciplines, certain characteristics of transportation engineering make it unique and present opportunities and challenges distinct from other civil engineering subdisciplines. For example, while roadway and pavement design are mechanics-based, other areas of transportation engineering are more closely connected with human factors, public policy, and economics.

Anecdotally, conversation has been ongoing for decades regarding the best preparation for transportation professionals. Options include the civil engineering degree, a stand-alone degree in transportation, and a variety of specialized certificates. If transportation professionals are prepared within civil engineering programs, they typically are eligible to become licensed as professional engineers, and the programs that prepare them must meet the ABET accreditation standards for civil engineering programs. Because of the breadth of the transportation discipline (across modes and sectors), questions about appropriate preparation involve a wide variety of stakeholders. Further, ongoing concerns have been raised about the adequacy of workforce development as much of the transportation workforce approaches retirement (TRB 2003; CUTC 2012).

The historical nature of these discussions notwithstanding, a thorough literature review revealed no existing published review or synthesis of the literature on the topic. Thus, this topic both by the nature of its import and lack of previous documentation seems an appropriate domain for an analytic literature review. Borrego et al. (2014) published an article documenting the lack of systematic literature reviews in the engineering education domain and developed a template for conducting such reviews. This approach, discussed in more detail in a subsequent section, is applied in this paper to examine the place of transportation engineering education within the academy.

This analytic review provides transportation engineering educators and administrators with better access to the existing body of knowledge. Understanding these past discussions on broad issues such as transportation's role within civil engineering programs, breadth versus depth of transportation content, and needs for additional education or specialized degrees can lead to more productive dialogue in the future.

This paper begins with a description of the methodology for the review. Next, it discusses the results in terms of the selected articles and the content of those articles, organized by research question. Finally, it assesses current practices and suggests next steps for researchers and educators.

Background

A recent application of the systematic literature review process described by Borrego et al. (2014) in transportation engineering education focused on instructional practices (Hurwitz et al. 2015). That study specifically considered two research questions: (1) What instructional practices have transportation engineering educators

[1]Associate Professor, Oregon State Univ., 101 Kearney Hall, Corvallis, OR 97331 (corresponding author). E-mail: david.hurwitz@oregonstate.edu

[2]Associate Professor, Lafayette College, 319 Acopian Engineering Center, Easton, PA 18042. E-mail: sanfordk@lafayette.edu

[3]Associate Professor, Auburn Univ., 238 Harbert Engineering Center, Auburn, AL 36849. E-mail: rodturochy@auburn.edu

[4]Associate Professor, Gonzaga Univ., Herak 212, Spokane, WA 99203. E-mail: youngr1@gonzaga.edu

Note. This manuscript was submitted on May 30, 2015; approved on November 2, 2015; published online on January 25, 2016. Discussion period open until June 25, 2016; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Professional Issues in Engineering Education and Practice***, © ASCE, ISSN 1052-3928.

employed to improve student learning at the undergraduate and graduate levels? (2) What techniques have been used to measure student learning in transportation engineering education? Results indicated that a wide variety of simulation, visualization, concept mapping, and other active learning techniques have been implemented in transportation engineering classrooms; however, they have been developed and implemented predominantly by a researcher or a team of researchers at a single institution. There is a clear need for work that promotes more widespread adoption of these techniques. Numerous techniques for measuring student learning have been documented in the transportation engineering education literature, including the use of surveys with open-ended questions, in-person interviews, the direct assessment of student work, and concept mapping. However, the most compelling assessments include both qualitative and quantitative evidence. There is a clear need to more rigorously evaluate the student learning resulting from the implementation of novel instructional practices in transportation engineering classrooms.

Methodology

The analytic review of the literature described here adapted the approach modeled by Borrego et al. (2014). The approach entails a four-step process to make sure that it addresses the research questions that are asked. Specifically, Borrego et al. suggest that researchers (1) define the research questions, (2) define the scope of inquiry, (3) find sources, and (4) apply appropriate exclusion criteria (Fig. 1).

Research Questions

The research questions under consideration determine whether any particular article should be included for analysis. As such, the questions must be defined carefully so as to capture the existing literature while focusing on the particular interest of the researchers. The primary goal of this analytic literature review is to document how transportation engineering curricula have changed over time.

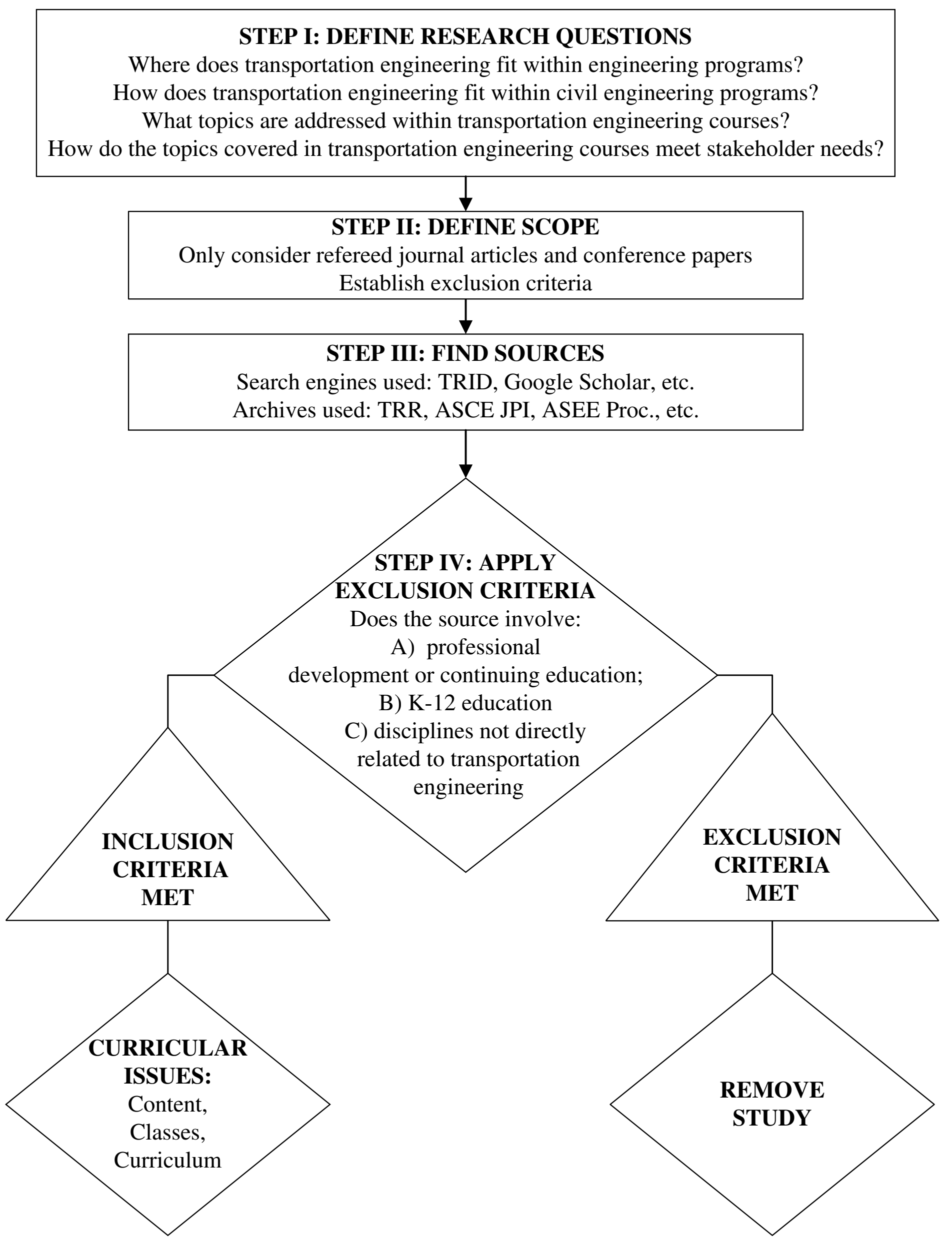

Fig. 1. Flowchart of systematic literature review process

To address this research goal, the following research questions were developed:

- Where does transportation engineering fit within engineering programs?
- How does transportation engineering fit within civil engineering programs?
- What topics are addressed within transportation engineering courses?
- How do the topics covered in transportation engineering courses meet stakeholder needs?

Finding and Cataloging Sources

Because this article is intended to serve as a reference for the broader community and because the authors are concerned about the quality of the articles being reviewed, the scope of sources was limited to refereed journal articles and refereed conference papers. The following search engines and digital archives, in addition to article reference lists, were examined for relevant articles:

- ASCE *Journal of Professional Issues in Engineering Education and Practice*: http://ascelibrary.org/journal/jpepe3;
- *ASEE Annual Conference Proceedings*: http://www.asee.org/search/proceedings;
- *European Journal of Engineering Education*: http://www.tandfonline.com/toc/ceee20/current#.VBqT7fldWSo;
- Google Scholar: http://scholar.google.com;
- Web of Science (Thomson Reuters): http://wokinfo.com/;
- *International Journal of Engineering Education*: http://www.ijee.ie/;
- *ITE Journal* and Annual Meetings: http://www.ite.org/library/;
- *Journal of Engineering Education*: http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2168-9830;
- Transportation Research International Database (TRID): http://trid.trb.org/; and
- *Frontiers in Education Conference Proceedings*: http://erm.asee.org/frontiers.html.

In each archive, numerous combinations of the following search terms were used:

- Education,
- Instruction,
- Instructional practices,
- Traffic,
- Transport,
- Transportation,
- Transportation curriculum,
- Transportation education,
- Transportation engineering curriculum, and
- Transportation engineering education curriculum.

Criteria for Inclusion or Exclusion

Based on the research questions, criteria were developed for including relevant sources and excluding those outside of the scope.

Specifically, the focus was on collegiate undergraduate and graduate transportation education. Therefore, articles focusing on K-12 education, informal education, professional development, and continuing education were excluded. Articles focusing on other subdisciplines of civil engineering were also excluded.

Within this scope, articles focusing on curricular issues were included. Curricular issues included concerns such as the assigning of content to particular courses and related tradeoffs between breadth and depth, sequencing of transportation courses at the undergraduate level, and changes in curriculum in response to changes in the profession. Papers focusing on transportation within the context of a specific degree program, such as civil engineering, were also included.

Results

Results are organized into two main sections: a description of the final article database and an examination of papers that focused on curricular issues in transportation engineering education. Each researcher independently reviewed the manuscripts, and the manuscripts were then discussed by the group of researchers. Thus, the interpretations of the articles reviewed resulted from the collective understanding of all four researchers.

Final Article Database

After exclusion criteria were applied, a total of 51 articles (36 refereed journal and 15 refereed conference articles) were included in the database for further analysis; all 51 articles were selected for discussion in this paper. Journal articles were sourced from the *Transportation Research Record* (*TRR*): *Journal of the Transportation Research Board*, the ASCE *Journal of Professional Issues in Engineering Education and Practice* (*ASCE JPI*), and the *Institute of Transportation Engineers Journal* (*ITE Journal*). Conference proceedings were sourced from the *ASEE Annual Conference Proceedings* (*ASEE Proc.*), the *ITE Annual Conference Proceedings* (*ITE Proc.*), and *ITS Quarterly*. The *2014 Journal Citation Report* lists the impact factor for *TRR* as 0.556, *ASCE JPI* as 0.716, and *ITE Journal* as 0.147 (Thomson Reuters 2015). No impact factors for the remaining journals and conference proceedings are available. The publication years for articles included in the database range from 1969 to 2014 (Fig. 2).

Fig. 2 shows that more has been published in this area of inquiry in the 2000s than previously, suggesting that interest is increasing and that scholars are recognizing the importance of publishing their discussions of these questions. In the publications included for analysis, the average number of authors was 2.4 (median 2), with a minimum of 1 and a maximum of 8 authors (excluding committee-written publications); the average number of citations in these publications was 16 (median 10), with a minimum of zero and a maximum of 132 citations. Given these averages, it is reasonable to say that the previous work was collaborative and grounded in the literature.

Fig. 3 compares the development of the body of literature dealing with curriculum issues and with the literature on instructional practices. The data for the journal articles and conference papers that focused on instructional practices were originally documented in Hurwitz et al. (2015). This figure shows that the curriculum issues discussed in this paper date further back but have a lower frequency over the last 5 years, indicating that more of the recent discussion is focused on how transportation engineering is being taught as opposed to what is being taught.

A nearly 25 year gap separates the first identified paper discussing transportation engineering curriculum issues (1969) and the first paper discussing instructional practices (1994). It also appears that relatively recent papers focused on instructional practices in transportation engineering education have been published at a higher frequency. From 2010 through 2013, papers on instruction practices were published more than twice as frequently as those on curriculum issues.

Evolution of Curricular Issues

The literature on curricular issues was broadly categorized into articles that discussed programs for future transportation

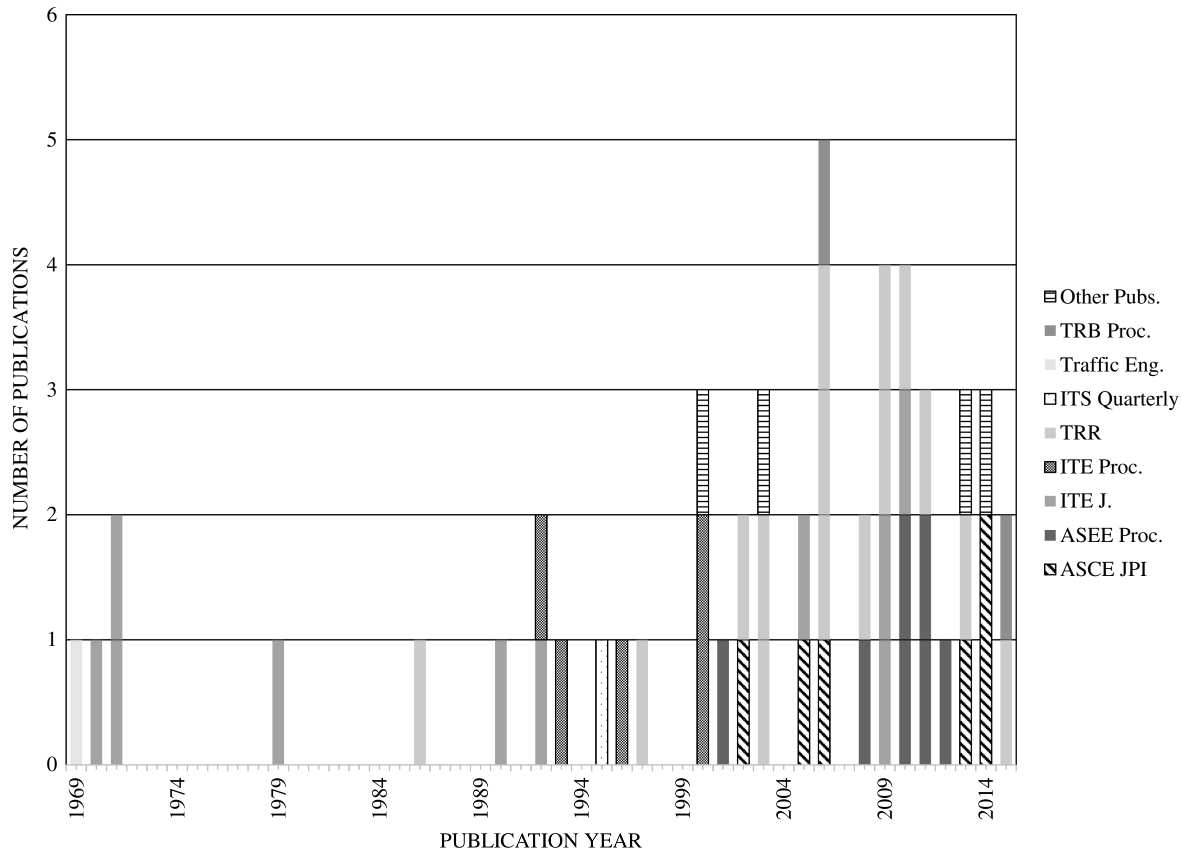

Fig. 2. Frequency of refereed journal and conference publications addressing transportation curriculum issues, by year

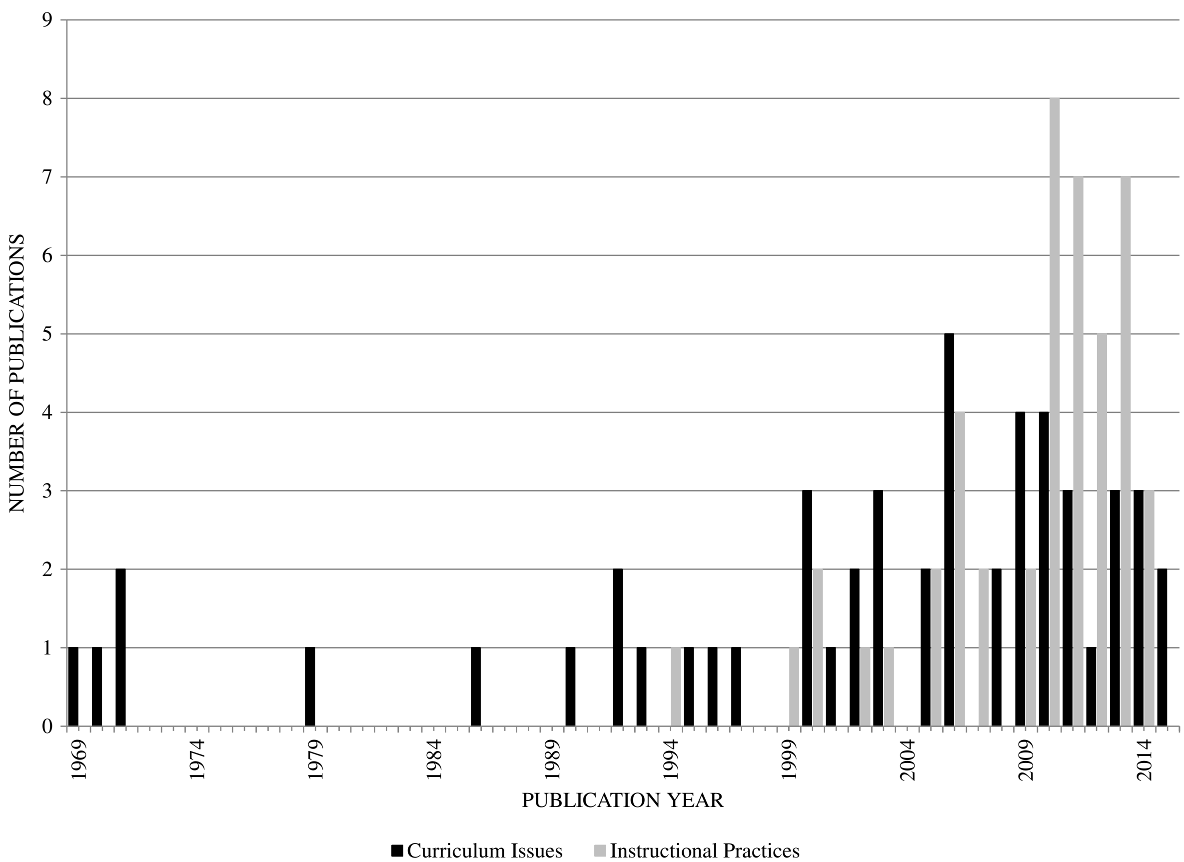

Fig. 3. Frequency of refereed journal and conference publications focused on curriculum issues and instructional practices, by year

professionals within the university system, articles on workforce requirements and degree selection at the university level, articles on how transportation courses fit into engineering degree programs, and articles that discuss the content of the transportation courses.

Where Does Transportation Engineering Fit within Engineering Programs?

What many believe to be the first engineering school in the world, the Ecole Nationale des Ponts et Chaussées, was founded in 1747 with the objective of improving transportation in France (Turner et al. 1992). In the United States, civil engineering education developed through two parallel paths in the late 1700s and 1800s; one path was through apprenticeship training, the other through formal education (Turner et al. 1992). The areas of transportation facility design and construction (roadways, canals, and railways) represented the primary tasks of these early civil engineers (Turner et al. 1992; Sinha et al. 2002). The subdiscipline of traffic engineering first became recognized in the United States in the early 1920s, with the first course in traffic engineering in the United States being offered in 1926 (Hurd 1969). From these early beginnings, the primary pipeline for transportation professionals in this country has remained engineering. A survey of Institute of Transportation Engineers (ITE) members in 1989 found that over 90% of its members had at least one engineering degree (Lipinski and Wilson 1992). More recently, that percentage was found to have decreased to 77%, with 93.5% of the engineering degrees identified as being civil engineering degrees (Lipinski 2005).

Debate on whether the transportation engineering profession is best served by traditional civil engineering programs has been ongoing for decades. In 1969, Hurd characterized the tradeoffs between programs with highly specialized coursework that leads to greater technical proficiency in a relatively narrow area versus programs that appreciate the problem-solving approaches and methods of other disciplines that come from a broad, multidisciplinary degree (Hurd 1969). This debate was echoed in a follow-up article on traffic engineering education in Germany (Retzko 1970).

European higher education has recognized the need to increase the preparation time for specialty professions, which led to the signing of the Bologna Declaration in 1999 to harmonize higher education across Europe (Perkins 2009). This resulted in the requirement for engineers to complete 3 years of basic engineering coursework to attain a bachelor's degree, followed by 2 years of specialized coursework that culminates in a master's degree (Perkins 2009). This is somewhat similar to the ASCE Policy 465 adopted in 2001 that supports a master's degree or equivalent as a prerequisite of licensure and the practice of civil engineering (Lipinski 2005). An article by Hurd in 1971 indicated that there was a trend to increase engineering undergraduate programs from 4 to 5 years but that this trend was viewed as unpopular by the profession because it delayed students' entry into the workforce (Hurd 1971). Also in 1971, Juanzems published an article detailing the development of the first graduate transportation engineering program in Brazil. The development of the program, which was focused on air and highway transportation, was motivated by a concern that all of the requisite courses for a transportation engineering focus could not be incorporated into existing undergraduate programs (Juanzems 1971).

In 2006, the National Council of Examiners for Engineering and Surveying (NCEES) added language to its Model Law and Model Rules requiring a master's degree or equivalent for initial engineering licensure based on the council's belief that significant revisions were needed to engineering education (NCEES 2014). Currently, no state engineering licensing board has adopted the additional education requirement, and in August 2014, NCEES removed the language from the Model Law and Model Rules over concerns that it was confusing to engineering students and educators since it had not been adopted by any state board. NCEES is in the process of developing a position statement on the need for additional education prior to professional practice to replace the Model Law and Model Rule text that was recently removed.

A millennium paper from the Transportation Research Board's Committee on Transportation Education and Training characterized the history of professional transportation education as beginning as nonformal, apprenticeship training and moving to college-based engineering programs, to a new era of stand-alone transportation degree programs (Manning 2000). People working in the transportation subdiscipline of travel behavior modeling recognized the growing divide between the education and required skills of transportation modelers and held a workshop at a major international conference to determine what a multidisciplinary degree would look like for that field (Chow et al. 2013). Morgan State University offers a transportation-specific Bachelor of Science degree that is accredited by the Applied Science Commission of ABET (2014). At this time, the move to stand-alone transportation degrees has not been as widespread as predicted at the turn of the century.

University-based certificate programs are becoming increasingly popular for the transportation profession, with over 20 identified programs in the United States (Joh and Li 2015). Most of these programs use traditional face-to-face delivery methods, but four of the certificate programs have online delivery as an option or are fully online. At the University of Sao Paulo at Sao Carlos in Brazil, undergraduate civil engineering students can receive a certificate of special studies from the Department of Transportation Engineering if they focus their elective courses in the transportation area (Prado da Silva et al. 2014). The University of Wisconsin-Madison developed an interdisciplinary Transportation Management and Policy graduate certificate program that requires 17 credit hours aimed at creating more well-rounded transportation professionals (Waidley and Bittner 2008).

How Does Transportation Engineering Fit within Civil Engineering Programs?

Lipinski (2005) looked at transportation education and recruitment issues with respect to changes in accreditation and credit hour reductions in civil engineering programs as well as the proposed change to make a master's degree the entry-level degree for the civil engineering profession. This article reported that the number of credit hours in the typical civil engineering program decreased from a range of 150 to 155 credit hours in the 1940s to 133 h or fewer in current programs. Much of the content that has been removed from the curriculum is engineering content since the number of math and science credits has remained unchanged, and general education and nontechnical skills within programs have increased (Lipinski 2005). In recent years, the number of credit hours has been relatively constant, with the average number of credit hours for undergraduate civil engineering programs being 130.4 in 2002, 130.8 in 2004, and 130.0 in 2011 (Russell and Stouffer 2005; Turochy 2006; Fridley 2011).

Tooley (1996) discussed the expected impacts of the ABET 2000 Criteria on transportation engineering preparation and noted anecdotally that graduate students who had participated in a curriculum under the (at that time proposed) ABET 2000 Criteria were better prepared than their counterparts who had not participated in such a curriculum.

A 2005 study using data collected from 90 of the 218 accredited civil engineering programs in 2002 found that 81% of the programs required at least one transportation engineering course (Russell and Stouffer 2005). Of those that required a transportation course, 9% required a second course, and 9% required a laboratory experience in transportation. A similar study of Canadian universities found that 62% of their 26 civil engineering programs required one course or fewer in transportation (Perkins 2009). A study conducted in 2012 found that 88% of the U.S. accredited civil engineering programs taught an introductory transportation course and that 79% required this course (Turochy et al. 2013). This study found that 25% of the introductory courses had a laboratory component. A 1994 civil engineering alumni survey at Southern Polytechnic State University found that over 50% of its graduates were employed in transportation or transportation-related fields (Currin 2001). The survey also found that these students felt that the one required course they took in the transportation area did not adequately prepare them for their current employment. The alumni survey results led the university to expand its transportation course offerings within the undergraduate civil engineering program.

The study conducted in 2012 also explored the background of the instructors of the introductory class and found that 14% of the courses were being taught by adjunct faculty (Turochy et al. 2013). The study also found that 85% of the faculty teaching the introductory transportation course had a background in transportation, indicating that 15% of the faculty had a background in a field other than transportation.

With the majority of transportation professionals coming from a civil engineering background, questions arise as to (1) how to compete with the other disciplines within civil engineering for workforce recruitment, and (2) how to incorporate the specialized skills that transportation employers want from a degree programs with such a breadth of content (ITE Technical Council Committee 2-32 1990; Lipinski and Wilson 1992; Agrawal and Dill 2008). Currently there are 233 ABET-accredited, undergraduate civil engineering programs in the United States (ABET 2014) that awarded over 12,000 civil engineering bachelor degrees in 2013 (ASEE 2014), which represents a substantial pipeline for recruiting transportation professionals. Recruiting from the civil engineering pipeline requires that a potential student first be attracted to civil engineering and then to a specialization in transportation (ITE Technical Council Committee 2-32 1990).

While the different civil engineering programs offer varying degrees of specialization in transportation, currently there are no ABET accredited transportation engineering programs (ABET 2014). As previously noted, there is a specialized transportation program at Morgan State University that is accredited by ABET through its Applied Science Commission (as opposed to the Engineering Commission).

A 1986 study on career guidance in engineering looked at influencing factors for career selection and found that there was no single method of obtaining career information that was independently effective (ITE Technical Council Committee 2-32 1990). An information report published by ITE used the results from this study along with survey results to characterize three areas needing improvement in transportation workforce recruitment: (1) the image of the civil engineering and transportation engineering professions, (2) average beginning salaries for civil/transportation engineers compared with other engineering disciplines, and (3) the professional and social status of civil/transportation engineers (ITE Technical Council Committee 2-32 1990).

In a 2008 study looking at a similar issue, Agrawal and Dill surveyed 1,852 undergraduate students in civil engineering from 56 different U.S. universities to determine the factors those students used to select a specialization area within civil engineering (Agrawal and Dill 2008). The survey included questions relating to personal interests and values as well as factors influencing their choice of specialization. The most popular specialization selected by the survey respondents was structures (23%), and transportation was the second highest choice at 12%. The study went on to conclude that there was a potential for a higher percentage of undergraduate students to choose the transportation profession. Two main recommendations resulted from this study. The first was to show freshman and sophomore students that transportation engineering provides dynamic and varied career options. The second recommendation was to increase the number of and better publicize transportation internship programs.

A comprehensive study on transportation workforce issues in 2003 identified the dual challenges of expanded technical skills required of transportation professionals and anticipated workforce shortages (TRB 2003). Ten years earlier, a study by the Institute of Transportation Engineers also highlighted challenges with recruitment of transportation professionals and pointed out that the supply from the traditional civil engineering pool would be inadequate to meet the anticipated demand, and that more focus on underrepresented groups, including ethnic minorities and women, would be needed (Mason and Lostival 1993).

What Topics Are Addressed within Transportation Engineering Courses?

Several issues pertaining to transportation engineering curricula have been well documented. The content of transportation engineering coursework, particularly the first or introductory course, has been examined from the perspectives of educators and employers. The fields of transportation planning, intelligent transportation systems, and facilities for pedestrians and bicyclists are among the subspecialties to which significant attention has been devoted. Alignment of coursework with knowledge expectations in the workplace and within the overall civil engineering curriculum has been studied extensively. Sinha et al. (2002) provide a history of transportation education and categorize the profession into three main components: (1) design, construction, and maintenance of facilities; (2) planning, project development, and financing and management; and (3) operations and logistics. Similarly, in 1971, Hurd described the evolution of the transportation profession in five distinct steps: (1) the design and construction of highways, (2) addressing the rising problems of traffic safety and congestion as more highways were being constructed, (3) the need for advanced planning of facilities to meet future demand, (4) the realization that travel could likely not be accommodated purely by single-occupant vehicles, and (5) final recognition of the impacts that transportation systems have on society and the environment (Hurd 1971).

The first course in transportation engineering is a critical step in the development of future transportation professionals because it is the first exposure for many students to the dynamic and varied range of career choices within this field (Agrawal and Dill 2008). This course serves as a general survey as well as a preparatory course for more specialized electives in transportation engineering subspecialties. Factors to consider in selecting topics to address in this course range from relationship to other coursework and the overall civil engineering curriculum, to institutional setting and constituencies, to coverage of material that may appear on the Fundamentals of Engineering Examination (Currin 2000; Turochy 2006). The priorities of the profession and of educators regarding course topics have been measured many times; for most topics the priority level has changed little over time (ITE Technical Council Committee 2-15 1979; Khisty 1986; Turochy 2006, 2013). For example, an examination of the ranks of 34 potential course topics from a survey of 43 educators and a survey of 108 practicing transportation engineers reveals that 9 of the top 10 topics in each stakeholder group priority list are the same (although the order is different), and a rank correlation coefficient of 0.93 exists between the two rank-ordered lists (Turochy 2013). Key core topics, such as roadway geometric design, highway capacity analysis, transportation planning, and traffic control devices, have been near the top of each list across time and both stakeholder groups. However, a few topics hold quite different positions in each list (for example, educators placed a much higher priority on driver behavior than did practitioners, and the reverse was true for transportation economics) (Turochy 2013).

One question that arises when considering candidate topics for inclusion in the course pertains to an optimal tradeoff point between breadth of topics addressed and depth within each topic. Several efforts to address basic questions of content and, more deeply, an approach to identifying core concepts, knowledge tables, and learning outcomes have been undertaken in recent years. A 2007 survey of instructors for the first course found that 65% of instructors focus mainly on the highway traffic mode, while 24% use a multimodal perspective (Kyte 2009). The three most frequently cited course topics in that survey correspond to three of the main phases of the transportation facility life cycle: transportation planning, geometric design, and traffic operations. A review of syllabi from several institutions found that a course structure focused on these three areas is a typical structure for the first course. A conference held in 2009 focused primarily on the 40 or so contact hours this course provides; the objectives of the conference were to map the learning domain for transportation engineering, foster development of active learning environments, and provide an impetus for the sharing of curricular materials (Kyte et al. 2010). A group of educators then used a learning taxonomy-driven approach to develop a set of core concepts and desired learning outcomes for the first course (Sanford Bernhardt et al. 2010). A set of knowledge tables was developed for seven candidate course content areas: traffic operations, transportation planning, geometric design, transportation finance, transportation economics, traffic safety, and transit and nonmotorized modes (Bill et al. 2011). Pilot studies of the implementation of this approach to course design were carried out at three different institutions, and strengths and opportunities for improvements to this approach were identified (Young et al. 2011, 2012).

In addition to the efforts focused on the general transportation engineering course content described earlier, documentation of educational efforts within selected subspecialties has occurred as well. Perhaps the most activity has occurred in the transportation planning area. A review of transportation planning coverage in both urban planning and civil engineering programs found generally adequate coverage of topics and that the largest gap between topic importance and coverage was not in highly technical topics but instead in communication skills and public relations (Handy et al. 2002). The case for incorporation of skills associated with intermodal transportation, public involvement, ethics, and communications in urban transportation planning courses was made so that graduates would be better prepared upon entering the workforce (Khisty and Kikuchi 2003). A graduate-level course in urban transportation planning was revised accordingly. A subsequent nationwide survey of transportation planning courses that examined the breadth and depth of topics covered found a wide variety in coverage and extent but contended that a generalized syllabus, which could then be adjusted as needed at each institution, could be developed (Zhou and Soot 2006). Such a syllabus was subsequently developed (Zhou and Schweitzer 2009).

Other subspecialties that tend not to be in the top group of candidate course topics in past surveys have also received some attention. The relatively young field of intelligent transportation systems (ITSs) has been the focus of several curriculum reviews and proposals. In the early days of ITS, a paradigm for educating the so-called new transportation professional was proposed (Sussman 1995). An evaluation of the then emerging field of ITS included a survey of ITS-focused organizations, and the need for an interdisciplinary approach to preparing engineers for employment in the ITS field was identified (Boile et al. 1997). This study also noted that only a broad overview of ITS could be incorporated into the undergraduate civil engineering curriculum and that most relevant coursework would take place at the master's degree level. A strong role for continuing education in this rapidly evolving field was also identified (Boile et al. 1997). More often, the ITS subspecialty has been described as a component of transportation systems management and operations (TSMO). The skills required by this field were discussed by Humphrey, who concluded that there was a need for technology-based skills and continuous education (Humphrey 2000).

More recently, an effort to document the extent of coverage of bicycle and pedestrian issues was undertaken (Dill and Weigand 2010). This study found that just over half of introductory transportation engineering courses explicitly include bicycle and pedestrian topics; in about half of these cases only 2 h or less were devoted to the topic. Among bicycle and pedestrian topics, safety for these vulnerable users ranked as the most important topic to address. An effort to redesign a transit systems planning course to maximize the usefulness of the immense volume of data available to such systems was recently undertaken (Lorion et al. 2014). The researchers noted a lack of advanced data-driven modeling in current transit planning education as well as challenges in moving research results into practice were identified. Other studies have examined the extent of coverage of railroad engineering and asset management topics (Lautala and Sproule 2009; Bittner 2006; Smadi and Akili 2006).

Meeting Stakeholder Needs

A survey of public- and private-sector transportation engineering employers' expectations of student knowledge upon entering the workforce with a BSCE or an MSCE was conducted in 2005 by the ITE Transportation Education Council (Thomas 2006). Highway capacity and geometric design were identified as the more important topics for undergraduate proficiency, while highway capacity and the use of transportation publications were the most important topics for graduate students (Thomas 2006).

Ultimately the goal of educating transportation engineering students is to prepare them for the transition into the workplace, which leads to employer expectations about the skills and knowledge students should have at the time of graduation. As mentioned previously, the differences between faculty and practitioners in their perceptions of the relative importance of transportation topics covered in the introductory course has been studied and found to be quite similar, particularly in the importance of key core topics (ITE Technical Council Committee 2-15 1979; Khisty 1986; Turochy 2006, 2013). Also mentioned in an earlier section was the desire by the profession for specialized transportation degrees, transportation certificate programs, or the requirement for additional education, all of which are driven by a need employers have for additional technical skills in recent graduates.

A novel example of developing an introduction to transportation engineering class based on a highly specified workplace expectation can be found in the preparation of civil engineers for military service. Melin et al. (2010) developed a required undergraduate introduction to transportation engineering class with experienced-based learning to better prepare civil engineering students for practicing as members of the Army Corps of Engineers in a deployed environment. Some of the unique factors associated with the design and construction of a road in a deployed environment can include security concerns, cultural and social considerations, and lack of material availability.

Kyte et al. (2003) described the development of a traffic signal summer workshop in response to the needs of the transportation profession, specifically by identifying competencies required by today's transportation professional that are not currently addressed in traditional transportation engineering classrooms. Those skills included using traffic signal equipment, using and programing traffic controllers, and developing signal timing plans for fixed time and actuated signal controllers, among others (Kyte et al. 2003). These skills were packaged into a 5-day summer workshop.

Discussion

The first research question looked to the literature to determine where transportation engineering fits within undergraduate engineering programs and found that, while this question has been asked for over a century, there does not appear to be a definitive answer. The main issue around this question seems to be the tradeoff between the broad, multidisciplinary, problem-solving skills developed in a civil engineering degree program versus the specialized technical skills that come from a transportation-specific degree program. For early career transportation professionals this tradeoff was viewed as the difference between apprenticeship training versus formal engineering education. At times in the literature it has been argued that the trend was toward 5-year degrees, with at least a portion of these years spent in specialized transportation coursework, but that trend was never fully realized. The main concern expressed in the literature with longer duration undergraduate degrees is the impact on the profession of delaying students' entrance to the workforce. If undergraduate degrees transitioned to a 5-year timeline, the profession would lose one cohort of students for 1 year, after which students presumably would graduate at similar rates. However, concerns about whether students would choose to pursue a 5-year degree (rather than another field of engineering that offers 4-year degree) remain.

The primary concern with specialized transportation degrees is the loss of student recruitment from the civil engineering pipeline. If students have to self-identify with transportation engineering too early in their career, many future transportation professionals may be lost. For students within civil engineering, one possible approach to counteracting this effect would be to position a required course in transportation engineering earlier in the curriculum than the junior year, as is most typical. The current trend to address the tradeoff between broad versus focused education appears to be in the use of certificate programs to provide additional specialization.

The second research question investigated how transportation engineering should fit into civil engineering programs. The majority of ABET-accredited civil engineering programs require at least one class in transportation engineering; however, considering the fact that a significant proportion of civil engineering graduates find employment in transportation or transportation-related fields, it can be argued that the current allocation of classwork at the undergraduate level does not adequately reflect employment outcomes. One possible approach to resolving this apparent imbalance would be to increase the number of required transportation classes at the undergraduate level from one to two since it is not uncommon to see a two-course requirement in subdisciplines, such as structures or geotechnical engineering. Another opportunity is to encourage instructors in other disciplines to be more intentional about drawing clearer connections between other civil engineering sub-disciplines and transportation engineering.

The content of transportation engineering courses was the focus of the third research question. The experiences of students in these courses have been found to be critical to students' decisions on transportation engineering as a career path. In about two-thirds of the institutions offering transportation engineering courses, the first course is focused on the highway mode, while in other transportation engineering programs, the class is conducted using a multimodal approach. No best practice was argued for in the literature; however, two factors could be considered in making the decision regarding which approach to adopt: (1) the context of the home institution—for example, is the institution situated in a large urban region with significant public transit, or is the institution located in a small college town? (2) the anticipated career market for the institution's graduates. Over the years, a high degree of consistency regarding the topics to be addressed in the first course has been expressed by transportation engineers. A recent survey of educators found strong agreement with practicing engineers regarding course topic priorities. A desire for coverage of transportation planning, intelligent transportation systems, and bicycle and pedestrian facilities in transportation engineering courses has also been documented.

The literature pertaining to the fourth and final research question, how well the university education system is meeting transportation engineering stakeholder needs, is diverse, ranging from surveying employer expectations and professional beliefs on the importance of different transportation topics being covered in the classroom to workplace training through specialized workshops and internship experiences. Similar to the first research question, there does not appear to be consensus on what best serves the profession, nor is there a clear path forward to addressing the identified issues and professional needs.

Recent visions for engineering education advocate breadth at the undergraduate level, followed by depth at the graduate and professional levels. For example, the National Academy of Engineering's *Engineer of 2020* and the American Society of Civil Engineers' (ASCE) *Vision for Civil Engineering in 2025* and *Civil Engineering Body of Knowledge for the 21st Century* suggest that engineers in the coming decades will require skills that typically are acquired during an undergraduate education that includes coursework in the liberal arts as well as science and engineering (NAE 2004; ASCE 2007, 2008). Thus, these organizations seem to support the view that more specialized degrees at the undergraduate level, such as in transportation engineering, may not be desirable. Further, ASCE's *Policy 465: Academic Prerequisites for Licensure and Professional Practice* promotes the idea that formal education beyond the undergraduate degree should be required before someone becomes eligible for licensure (ASCE 2015). While there appears to be consistent support for the provision of specialization in transportation engineering at the graduate level, it is less clear what level of specialization should be provided at the undergraduate level. There is, however, an opportunity to promote additional connections to and content in transportation engineering while recognizing that undergraduate civil engineering education is significantly constrained by numerous factors.

Conclusions

There is a need for analytic literature reviews in transportation engineering education; few have been conducted, though they can provide immense value to educators and researchers alike.

These metalevel evaluations are critical to understanding the body of knowledge that has already been produced in transportation engineering education. They serve to inform educators about the state of the practice in a more effective way and aid researchers in the establishment of new research directions.

For this analytic review, literature was collected and interpreted by a group of four academicians who are subject matter experts, and as such it may not be representative of the entire population of academics or all stakeholders involved in transportation engineering curriculum issues at the undergraduate level. By establishing exclusion criteria for non-peer-reviewed publications, thought-provoking ideas that are taking place either offline or in other venues may have been overlooked.

Opportunities for additional work in the area of curriculum development include the following:

- Development of materials that will support civil engineering faculty members in connecting transportation concepts across the civil engineering subdisciplines;
- Reinvestigation of questions last addressed more than one or two decades ago in the context of changes in education and engineering practice;
- Reassessment at regular intervals of transportation educator and practitioner priorities for essential skills and knowledge for new graduates; and
- Evaluation of civil engineering skills upon graduation and their relation to employer expectations.

This paper documented the literature relevant to transportation engineering curricula at the undergraduate level. Specifically, four research subquestions were considered through the analysis of 51 unique peer-reviewed journal articles and conference papers. The findings of this paper inform practitioners and researchers in transportation engineering education of the state of the practice in the transportation engineering curriculum and identify opportunities for further research and dialogue. This paper provides a unique model arguing for the importance of analytic literature reviews to promote the advancement of research in transportation engineering education.

References

ABET. (2014). "Find accredited programs." ⟨http://main.abet.org/aps/Accredited programsearch.aspx⟩ (Jul. 13, 2014).

Agrawal, A. W., and Dill, J. (2008). "To be a transportation engineer or not?: How civil engineering students choose a specialization." *Transp. Res. Rec.*, 2046, 76–84.

ASCE. (2007). "The vision for civil engineering in 2015." Reston, VA.

ASCE. (2008). "Civil engineering body of knowledge for the 21st century preparing the civil engineer for the future." Reston, VA.

ASCE. (2015). "Policy statement 465—Academic prerequisites for licensure and professional practice." Reston, VA.

ASEE (American Society of Engineering Education). (2014). "Engineering data management system." ⟨http://edms.asee.org/session/new⟩ (Jul. 13, 2014).

Bill, A., et al. (2011). "Development of knowledge tables and learning outcomes for an introductory course in transportation engineering." *Transp. Res. Rec.*, 2211, 27–35.

Bittner, J. (2006). "Transportation asset management in for-credit higher education course offerings." *Transp. Res. Rec.*, 1957, 19–22.

Boile, M. P., Spasovic, L. N., and Pignataro, L. J. (1997). "Developing a market-sensitive intelligent transportation systems educational program." *Transp. Res. Rec.*, 1588, 120–129.

Borrego, M., Foster, M. J., and Froyd, J. E. (2014). "Systematic literature reviews in engineering education and other developing interdisciplinary fields." *J. Eng. Educ.*, 103(1), 45–76.

Chow, J. Y. J., Jayakrishnan, R., and Mahmassani, H. S. (2013). "Is transport modeling education too multidisciplinary? A manifesto on the search for its evolving identity." *Travel behavior research: Current foundations, future prospects*, Lulu, Raleigh, NC.

Currin, T. R. (2000). "Filling the void of transportation engineering education at the baccalaureate level." *Proc., ITE Annual Meeting*, Institute of Transportation Engineers (ITE), Washington, DC.

Currin, T. R. (2001). "Transportation engineering and its role in the undergraduate civil engineering." *Proc., ASEE Annual Conf.*, American Society for Engineering Education (ASEE), Washington, DC.

CUTC (Council of University Transportation Centers). (2012). "National transportation workforce summit summary of results." Washington, DC.

Dill, J., and Weigand, L. (2010). "Incorporating bicycle and pedestrian topics in university transportation courses." *Transp. Res. Rec.*, 2198, 1–7.

Fridley, K. J. (2011). "Today's BSCE: A survey of credit hour requirements." *Proc., ASEE Annual Conf.*, American Society for Engineering Education (ASEE), Washington, DC.

Handy, S., Weston, L., Song, J., and Lane, K. M. D. (2002). "Education of transportation planning professionals." *Transp. Res. Rec.*, 1812, 151–160.

Humphrey, T. F. (2000). "Educational expectations of transportation engineering employers." *Proc., ITE Annual Meeting*, Institute of Transportation Engineers (ITE), Washington, DC.

Hurd, F. W. (1969). "Trends in traffic engineering education." *Traffic Eng.*, 13–16.

Hurd, F. W. (1971). "Highway engineering education in the United States." *Inst. Transp. Eng. J.*, 26–36.

Hurwitz, D., Sanford Bernhardt, K. L., Turochy, R., and Young, R. (2015). "Transportation engineering instructional practices: An analytic review of the literature." *Transp. Res. Rec.*, 2480, 45–54.

ITE Technical Council Committee 2-15. (1979). "Evaluation of education resources for a select group of transportation subjects." *Inst. Transp. Eng. J.*, 49, 30–31.

ITE Technical Council Committee 2-32. (1990). "An informational report: Attracting students to a professional career in transportation engineering." *Inst. Transp. Eng. J.*, 60, 42–48.

Joh, K., and Li, W. (2015). "Developing and interdisciplinary transportation certificate program for today's transportation workforce." *Proc., 94th Annual Meeting*, Transportation Research Board, Washington, DC.

Juanzems, P. J. (1971). "Graduate transportation engineering education in Brazil." *Inst. Transp. Eng. J.*, 41, 36–40.

Khisty, C. J. (1986). "Undergraduate transportation education." *Transp. Res. Rec.*, 1101, 1–3.

Khisty, C. J., and Kikuchi, S. (2003). "Urban transportation planning education revisited: Reading the dials and steering the ship." *Transp. Res. Rec.*, 1848, 57–63.

Kyte, M. (2009). "What should undergraduate civil engineering students know about transportation engineering?" *Inst. Transp. Eng. J.*, 79(5), 26–29.

Kyte, M., Abdel-Rahim, A., and Lines, M. (2003). "Traffic signal operations education through hands-on experience lessons learned from a workshop prototype." *Transp. Res. Rec.*, 1848, 50–56.

Kyte, M., Bill, A., and Young, R. (2010). "Everything you need to know about transportation engineering in 40 hours." *Inst. Transp. Eng. J.*, 80(10), 40–43.

Lautala, P. T., and Sproule, W. J. (2009). "Rebuilding railroad engineering education in the United States with industry-university partnerships." *Transp. Res. Rec.*, 2109, 37–44.

Lipinski, M. E. (2005). "ASCE Policy 465: Impact on transportation engineering workforce development." *Inst. Transp. Eng. J.*, 75(12), 24–27.

Lipinski, M. E., and Wilson, E. M. (1992). "Undergraduate transportation education: Who is responsible?" *Inst. Transp. Eng. J.*, 62(8), 29–32.

Lorion, A., Harvey, M. J., and Chow, J. C. Y. (2014). "Redesign of curricula in transit systems planning to meet data-driven challenges." *J. Prof. Issues Eng. Educ. Pract.*, 10.1061/(ASCE)EI.1943-5541.0000223, 05014007.

Manning, P. A. (2000). "Transportation education." Transportation Research Board, Washington, DC.

Mason, J. M., and Lostival, L. M. (1993). “Transportation engineering careers: Awareness, retention, and curriculum.” *Proc., ITE Annual Meeting*, Institute of Transportation Engineers (ITE), Washington, DC.

Melin, N., Hallon, R., and Hanus, J. (2010). “Development of an introduction to transportation engineering course using experience based learning to bring Afghanistan into the classroom.” *Proc., ASEE Annual Conf.*, American Society for Engineering Education (ASEE), Washington, DC.

NAE (National Academy of Engineering). (2004). “The engineer of 2020: Visions of engineering in the new century.” Washington, DC.

NCEES (National Council of Examiners for Engineering and Surveying). (2014). “Engineering education initiative.” ⟨http://ncees.org/about-ncees/engineering-education-initiative/⟩ (Jul. 13, 2014).

Perkins, S. A. (2009). “A comparative analysis of civil engineering program standards in Canada, the United States and Europe.” *Inst. Transp. Eng. J.*, 79(5), 44–45.

Prado da Silva, C., Jr., Fontenele, H. B., and Rodrigues da Silva, A (2014). “Transportation engineering education for undergraduate students: Competencies, skills, teaching-learning, and evaluation.” *J. Prof. Issues Eng. Educ. Pract.*, 10.1061/(ASCE)EI.1943-5541.0000220, 05014006.

Retzko, H. G. (1970). “Traffic engineering education in the Federal Republic of Germany.” *Inst. Transp. Eng. J.*, 40, 50–51.

Russell, J. S., and Stouffer, W. B. (2005). “Survey of the National Civil Engineering curriculum.” *J. Prof. Issues Eng. Educ. Pract.*, 10.1061/(ASCE)1052-3928(2005)131:2(118), 118–128.

Sanford Bernhardt, K. L., et al. (2010). “Development of core concepts and learning outcomes for the introductory transportation course.” *Proc., ASEE Annual Conf.*, American Society for Engineering Education (ASEE), Washington, DC.

Sinha, K., et al. (2002). “Development of transportation engineering research, education, and practice in a changing civil engineering world.” *J. Transp. Eng.*, 10.1061/(ASCE)0733-947X(2002)128:4(301), 301–313.

Smadi, O., and Akili, W. (2006). “Intrastructure asset management education active learning and engagement-based practices.” *Transp. Res. Rec.*, 1957, 16–18.

Sussman, J. M. (1995). “Educating the new transportation professional.” *Intelligent Transportation Society Quarterly*, 89–99.

Thomas, G. B. (2006). “Educational expectations of transportation engineering employers.” *Proc., ITE Annual Meeting*, Institute of Transportation Engineers (ITE), Washington, DC.

Thomson Reuters. (2015). “Journal citation reports ®.” New York.

Tooley, M. S. (1996). “A student’s perspective on transportation education and curriculum.” *Proc., ITE Annual Meeting*, Institute of Transportation Engineers (ITE), Washington, DC.

TRB (Transportation Research Board). (2003). “The workforce challenge: Recruiting, training, and retaining qualified workers for transportation and transit agencies.” Washington, DC.

Turner, D. J., Campbell, B. S., and Turner, D. S. (1992). “History of engineering education: How we got here.” *Proc., ITE Annual Meeting*, Institute of Transportation Engineers (ITE), Washington, DC.

Turochy, R. E. (2006). “Determining the content of the first course in transportation engineering.” *J. Prof. Issues Eng. Educ. Pract.*, 10.1061/(ASCE)1052-3928(2006)132:3(200), 200–203.

Turochy, R. E., et al. (2013). “Assessment of introductory transportation engineering course and general transportation engineering curriculum.” *Transp. Res. Rec.*, 2328, 9–15.

Turochy, R. E. (2013). “Structuring the content of the first course in transportation engineering: Perspectives of engineers and educators.” *J. Prof. Issues Eng. Educ. Pract.*, 10.1061/(ASCE)EI.1943-5541.0000149, 206–210.

Waidley, G., and Bittner, J. (2008). “An interdisciplinary approach to transportation education.” *Proc., ASEE Annual Conf.*, American Society for Engineering Education (ASEE), Washington, DC.

Young, R., et al. (2011). “A nationwide effort to improve transportation engineering education.” *Proc., ASEE Annual Conf.*, American Society for Engineering Education (ASEE), Washington, DC.

Young, R., Sanford Bernhardt, K. L., and Nambisan, S. (2012). “Core concepts and learning outcomes in an introductory transportation engineering course: An evaluation of pilot implementations.” *Proc., ASEE Annual Conf.*, American Society for Engineering Education (ASEE), Washington, DC.

Zhou, J., and Schweitzer, L. (2009). “Transportation planning education in the United States.” *Transp. Res. Rec.*, 2109, 1–11.

Zhou, J., and Soot, S. (2006). “Nationwide survey of transportation planning courses: Introduction, findings, and recommendations.” *Transp. Res. Rec.*, 1956, 175–183.