Investigating the Future of Transportation Engineering Education

Thesis

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Abstract

The transportation engineering field has a history of rapid change that coincides with the evolution of technology. As such, it is essential to prepare the transportation engineering students of today for the careers that will be available to them in the future. While there are numerous graduate transportation engineering programs in the United States, there has been little research conducted on the education given at this level. Currently, the majority of research on transportation engineering education has been focused on the undergraduate level, specifically, on introductory courses and capstone design courses. The investigation presented here therefore concentrated on transportation engineering graduate curricula at the master's level. The aim of this research was to answer the following questions:

- How will employment opportunities for transportation engineers evolve in the coming 5-10 years?
- How will the work that transportation engineers perform on a day-to-day basis evolve in the coming 5-10 years, both in private-sector and public-sector organizations?
- What topics should graduate-level transportation engineering curricula include now, such that the students develop the skills to be successful in the transportation sector of the next 5-10 years?

The investigation consisted of in-depth one-on-one interviews with a range of academics involved in the teaching of graduate level transportation engineering courses as well as practitioners working in the field who have participated in the hiring of transportation engineers. The interviews consisted of questions concerning the current and future needs of the field and the professionals within it. The responses were then analyzed using thematic analysis methods. From the results, recommendations were made for changes to established transportation engineering master's programs and to lay the groundwork for the creation of future programs.

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Chapter 1. Introduction

As the population of the United States grows, there will be increasing demand for urban and interurban travel, resulting in a need for improved transportation services and facilities (Sinha et al., 2002; Transportation Research Board, 2003). Transportation engineers are responsible for helping society meet these needs by providing new transportation infrastructure and improving the infrastructure already in place. In 2016, 303,500 civil engineers were employed in the United States. This number is slated to increase by 10.6% by 2026 (U.S. Bureau of Labor Statistics, 2018). Unfortunately, the Bureau of Labor Statistics does not track how many of those civil engineers worked in the transportation domain. In addition to society's growing need for effective infrastructure, a myriad of changes, as originally described by the Transportation Research Board in 2003, are and will continue to impact the roles and responsibilities of transportation engineers. These changes include new transportation modes, materials, and technologies, and broader technical and environmental challenges (Transportation Research Board, 2003). As such changes continue to impact the field, the educators responsible for transportation engineering programs at U.S. universities must determine whether their program design has been keeping up with the skills needed to address these new challenges, and whether they are adequately preparing students for the future of the profession.

The research presented in this thesis consists of a qualitative study, employing a small number of expert interviews. The aim of the study was to collect the views of a balanced panel of experts from academia, the private sector, and the public sector. The interviews focused on anticipated developments in the transportation sector and on the competencies and skills that future transportation engineers will require. Based on the experts' responses during the interviews, an analysis of the anticipated competencies of a successful transportation engineer in the future was performed. In addition, an analysis of their current and potential future employment opportunities, as described by the interviewees, was completed. Based on this analysis, recommendations for transportation engineering master's programs were derived, to assist faculty in developing programs to better prepare the transportation engineering students for their future careers.

Chapter 2. Literature Review

The growth of the Internet and increasing availability of large amounts of data have created new business, engineering, and policy opportunities, but also new challenges for transportation systems (Grazia Speranza, 2018). In the coming years, new employment opportunities will emerge for transportation engineers as transportation systems technologies evolve. Of course, technological change has been a constant element throughout the history of the transportation engineering discipline. With the creation of trains came the need for interconnected railroad systems, and similarly, with private automobiles came the need for paved roadways and eventually an interstate freeway system. Historically, the education of transportation engineers has closely paralleled the needs of the transportation systems in place (Hoel, 1982; Sinha et al., 2002). In more recent decades, the education of transportation engineers has shifted to support the development of urban public transportation systems with a focus on areas such as safety, system operations, and Intelligent Transportation Systems (ITS) applications (Hoel, 1982; Turochy, 2006). As technology continues to evolve, the education provided to transportation engineers will need to evolve as well. The following sections, 2.1 and 2.2, contain an investigation into the current literature on transportation engineering education research. This investigation was used to determine the scope of the study presented in this thesis. Since part of this thesis relates to curriculum development, pertinent literature on curriculum development theory is also reviewed.

2.1 Undergraduate Transportation Engineering Education

The current literature on transportation engineering education is mainly focused on undergraduate curricula. It ranges from discussions of the balance between breadth and depth in introductory transportation engineering courses to best practices for capstone or senior design courses. Turochy (2006) completed a study to determine the needs of the transportation engineering profession by surveying practicing transportation engineers and comparing his results to the results of a similar survey conducted in 1985 (Khisty, 1986). In both surveys, practicing transportation engineers were asked to score the importance of topics on a Likert scale from 1 to 5, where 1 was a topic of the lowest priority and 5 was a topic of the highest priority. Then, respondents ranked each topic based on its relative importance compared to others (Turochy, 2006). Between the two studies in 1985 and 2006, there was little change in the relative importance of many topics, such as the geometric design of highways, highway capacity studies, and long-range transportation planning. However, there were other topics that significantly grew or declined in importance: Topics related to traffic management, mobility, safety, and ITS applications grew more important between 1985 and 2006, while topics with contract-related issues declined in importance. These findings could be related to increasing traffic congestion problems in the time between the two surveys and to the idea that contracts can be covered in an optional construction management course or later transportation courses taken by students for whom the topic is relevant (Turochy, 2006).

Several past conferences have been dedicated to improving transportation engineering education at the undergraduate level. In June 2009, a Transportation

Engineering Educators Conference was held to enable collaboration between university faculty and transportation practitioners on the design of introductory transportation engineering courses (Young et al., 2011). Over 60 participants took part, with presentations about innovations in the area of transportation engineering education and workshops on how to create active learning environments and how to define the learning domain for the introductory course (Young et al., 2011). The outcomes of the conference were described by Bertini & Kyte (2009) as follows:

- It is critical that the one or two required undergraduate transportation engineering course(s) address a minimum set of core competencies (“learning domains”).
- There should be a common set of knowledge tables that map out the learning domains. These could be used by instructors across universities as the basis of the required course(s).
- There is a need for effective strategies that provide contextual active learning environments for students in these courses.
- There is a need to develop collaborative tools for sharing transportation engineering curricular materials between instructors and institutions.

In response to these outcomes, 20 transportation engineering educators created the Curriculum Subcommittee of the Institute of Transportation Engineers (ITE) Education Council. The subcommittee’s goal was to build upon the work done at the conference and to review efforts to develop bodies of knowledge and learning outcomes that included various methodologies and approaches (Young et al., 2011). This culminated in the

creation of the National Transportation Curriculum Project (NTCP) (Sanford Bernhardt et al., 2013). The NTCP created learning outcomes, knowledge tables (including concepts, processes, tools, and contexts), and desired ways of being for transportation engineers and their lifelong skills that could form part of an introductory transportation engineering course (Young et al., 2011). The skills were defined as cognitive, social, or affective. In addition, the NTCP educated faculty on the importance of active learning techniques and facilitated the development of learning and assessment activities for transportation engineering courses. A repository of content created has been made available online in the hopes of encouraging awareness and adoption (Sanford Bernhardt et al., 2013).

The 2012 Transportation Engineering Educators Conference and Workshop focused on educators' level of comfort with active learning as a pedagogical approach and on promoting the further development, sharing and adoption of materials through the formation of collegial networks (Sanford Bernhardt et al., 2013). While all conference participants cared about workforce development and the future of the profession, they lacked collaborative networks between institutions that would allow for significant change. The conference let participants share best practices and learn new approaches to improve student learning in an introductory transportation engineering course. The creation of the NTCP and the work done at both the 2009 and 2012 conferences show a strong motivation within the community of transportation engineering educators to address the challenges of educating, recruiting, and retaining students in the profession.

Research on the effectiveness of the NTCP creations has been performed to validate the work done. Young et al. (2011) piloted the NTCP learning outcomes and

knowledge tables in their revision of an introductory transportation engineering course. As an introductory course, it may be the only occasion on which students are exposed to the transportation engineering profession, and in turn, it may be the only opportunity to draw their attention to this field. With this in mind, Young et al. (2011) asked the question, “What is the impact on students of designing/revising a course based on these learning outcomes and knowledge tables?” The course instructor redeveloped the course to include further depth on the most critical topics and reduce breadth by using the knowledge tables and course outcomes created by the NTCP. Due to the changes made, student comprehension of material increased while memorization became less important (Young et al., 2011). A pre and post survey of the students’ perceptions of the transportation engineering field indicated improvements in the level of interest in transportation as a potential profession. Overall, the NTCP knowledge tables and course outcomes helped the instructor implement changes in the introductory transportation engineering course that positively affected student learning and perceptions.

ABET has created criteria for various undergraduate engineering programs, including civil engineering. As of 2016, ABET accreditation requires civil engineering programs to create opportunities for students to “design a system, component, or process in more than one civil engineering context” (ABET, 2016). This requirement of a design experience has led to the necessity for a senior-level design course or capstone project within civil engineering programs. Since there is a wide range of focus areas available within civil engineering, many programs offer transportation engineering design project options as part of the larger civil engineering capstone course. Because of this, existing

literature does not focus specifically on design courses in transportation engineering but rather on capstone courses. Since those may also include transportation topics, the findings are still applicable to transportation engineering education.

In the early 1990s, North Dakota State University disseminated information about their organization of a civil engineering capstone design project with topics that covered many aspects of civil engineering, including transportation (Andersen, 1992). The course was meant to be an accumulation of previous curricular components in addition to being an engineering design experience. Each civil engineering faculty member acted as a mentor and a resource in their particular area of expertise, which included conducting an hour-long weekly lecture covering technical topics (Andersen, 1992). Much like in the real world, student groups gave oral reports on their progress and were asked to produce written documentation. As reported by Andersen (1992), “an important benefit of the project was an appreciation for working together as a group to accomplish an overall goal.” These aspects of the course helped students develop soft skills, communication skills, and social skills needed to be a successful engineer (De Graaff & Ravesteijn, 2001). Like the students of today, Andersen’s (1992) students were frustrated by the lack of direction and information given at the outset of the capstone project. However, this experience provided a glimpse into the reality of being a civil engineer.

Gavin (2011) reviews project-based learning in a capstone design course, with a focus on structural engineering, but the pedagogical approaches described can be easily transferred to transportation engineering design courses. Project-based learning allows students to take control of what needs to be learned and how it should be learned, but also

provides an opportunity to develop teamwork, problem solving and leadership skills (De Graaff & Ravesteijn, 2001). While there is definite support for project-based learning in the literature, few authors illustrate how it can be implemented within civil engineering education. In the hopes of filling this gap in the literature, Gavin (2011) suggests that “project-based learning should be used as a partial solution to develop professional problem-solving skills through the application rather than the acquisition of knowledge”. He reports on the use of such project-based learning in his capstone design course, where learning is directed by the problem itself and students are required to guide themselves toward a solution. In project-based learning applications, self-reflection through questions such as ‘What did I learn?’ and ‘What further knowledge do I need?’ can help guide students throughout the design process (Kolmos et al., 2007). This method requires less scaffolding and support, as students are applying knowledge previously obtained and can be overseen by a floating facilitator (Gavin, 2011). The support given by the faculty has the ability to gradually introduce students to real-world design aspects and to positively affect the outcomes of the course. Overall, project-based learning is an effective approach to teaching design and to introducing the necessary skills for success in the field.

2.2 Graduate Transportation Engineering Education

The available literature on transportation engineering education at the graduate level is very limited in both quantity and scope. Only two articles were found that focus on graduate-level transportation engineering programs and curricula. The first is an

investigation of best practices in logistics and transportation education at the graduate level, and was conducted by Sarder (2015). It attempted to derive program-level best practices from a review of program descriptions on university websites. The derived best practices were organized into four categories, namely program content, program delivery, experimental and active learning, and career placement. The article does not explain the methods that were used to create the best practices. While many of the best practices made sense, this omission lowers the usefulness and generalizability of the findings in the article.

The second study, by Waidley and Bittner (2008), looked at the effectiveness of an interdisciplinary, graduate-level certificate program called “Transportation Management and Policy”. The program was a series of 17 credit hours focusing on technology and engineering, economics, policy and management, and environmental studies. The program recruited students with an interest in transportation from any graduate program within the university. The study consisted of a survey of employers of some of the graduates of the program, asking them to rate their employee’s understanding of transportation-related topics compared to others hired in the same or similar positions. These topics included the transportation decision-making process, transportation policy, transportation economics and funding, environmental issues, organizational structure, and the ability to communicate with others outside of their degree field (Waidley & Bittner, 2008). The results of the survey revealed that the competence of program alumni was rated the highest in the areas of transportation policy, environmental issues, and the ability to communicate with other outsiders of their degree field. Waidley and Bittner

believe these results were a function of the specific course topics embedded in the program and the interdisciplinary nature of it. The investigation into current transportation engineering education research yielded a limited amount of research at the graduate level. This gap in the literature informed the scope of the presented thesis, transportation engineering education at the graduate level.

2.3 Curriculum Development

When developing a curriculum, educators classify the intended student accomplishments as objectives. The use of instructional objectives is highly encouraged because of their ability to “provide explicit descriptions of the post-instruction behavior desired of learners” (Popham, 2009, p. 95). There are a variety of methods that educators use to derive objectives, including studies of contemporary life. This method uses a similar logic to that of job analysis, or to the creation of training for particular activities performed by worker in a certain field by using an in-depth analysis of those activities (Tyler, 2009). This method is akin to the search for objectives in the “knowledge needed to ‘live in the modern world’, in the skills required for success in a trade or vocation” as described by Schwab (2009, p. 127). An argument for the use of studies of contemporary life to inform educational objectives is the fact that contemporary life is complex and continually changing. It is necessary to continuously adapt by educating students on the critical aspects of life and not dedicating time to learning things that have become insignificant. However, there has also been criticism of this method. Critics argue that seeing a large amount of people engaged in a certain activity does not necessarily mean

that such activities should be taught to students. Also, it is thought that if life is continually changing, then students prepared to handle today's problems will not necessarily be prepared to handle the problems of the future (Tyler, 2009).

As an answer to this particular criticism of the approach of determining educational objectives by studying *contemporary* life, it would make sense to instead study expert predictions of the near future to inform objectives. While there is a chance that predictions of the future could be incorrect, using the predictions of experts in a certain field, who are aware of its history and current trends, would increase the probability of those predictions being accurate. In summary, the method of interviewing experts to gather their predictions of the future appears to be a promising approach for deriving curricular outcomes and has therefore been selected as the overarching methodology of this study.

This study aimed to evaluate the current status of transportation engineering curricula at the graduate level and to make suggestions for improvements such that students are adequately prepared to tackle the transportation problems of the future. In order to perform this evaluation, the following research questions were formulated:

1. How will employment opportunities for transportation engineers evolve in the coming 5-10 years?
2. How will the work that transportation engineers perform on a day-to-day basis evolve in the coming 5-10 years?

3. What topics should graduate-level transportation engineering curricula include now, such that students develop the skills to be successful in the transportation sector of the next 5-10 years?

The following chapter describes the methods used to answer the research questions posed.

Chapter 3. Methods

The purpose of this study was to investigate how the skills taught by transportation engineering programs at the master's degree level may need to evolve in order to keep pace with recent and anticipated developments in the field. It focuses on universities and transportation-oriented companies in the United States. The sample was small and cannot be considered representative but contains a broad range of universities and companies that represent several important actors in the transportation engineering field.

In order to address the research questions outlined in section 2.3, a qualitative, interview-based study was designed to collect and analyze the opinions of current transportation engineering professionals and academics regarding future developments in the transportation sector and the skills required to be successful in the sector in the future. Interviews were chosen to answer the research questions because of their ability to provide more in-depth information than a survey. Also, due to the open-ended nature of interview questions, participants could bring up aspects not thought about by the researcher and that might have been missed in a survey design. A total of 16 interviews were conducted, transcribed, and systematically analyzed. The analysis of the interview content was then distilled into a series of findings that informed recommendations on the design of curricula for master's degree programs. The subjects of the interviews were a series of transportation engineering professionals from academia and industry. The participating professionals from academia, henceforth referred to as academics, were faculty from various transportation engineering programs at universities within the

United States. The participating professionals from industry were classified into two categories, traditional and non-traditional practitioners, based upon their employers. Reasoning behind the classification of the participants and explicit definitions for each classification are outlined in section 3.1. The content of the interviews was focused on anticipated developments in the transportation sector and on the competencies and skills that future transportation engineers will need. More details on the interview protocol will be discussed in section 3.3.

3.1 Sample Selection

The desired number of participants for the study was identified as being between 15 and 20 due to the use of semi-structured interviews to answer the research questions. The potential participants were classified by their current positions within academia and industry. A meaningful effort was made to capture a broad and diverse set of respondents, representing many major types of employers in the transportation engineering field. The list of academics contacted for the purposes of this study included university faculty with at least three years of teaching experience in transportation engineering at the graduate level. The academic participants were required to have three years or more experience because of the necessity for them to be able to comment on the current and future state of transportation engineering programs and the field in general. Also, requiring only three years of experience would allow for the perspective of the younger generation of engineering faculty. After a discussion with The Ohio State University faculty, it was determined that industry practitioners, and the companies they work for, who were

contacted for this study could be roughly divided into two categories - traditional practitioners and non-traditional practitioners. Traditional practitioners consisted of those who work for transportation engineering public-sector organizations, such as federal and state departments of transportation, and those who work for companies that provide transportation design services (which have historically saturated the market for transportation engineers). Examples of such companies include Woolpert and Gresham Smith. Non-traditional practitioners consisted of those who work for companies that are relatively new, are active in transportation related areas that did not exist until the recent 10 to 15 years and are typically technology-driven. Examples of such companies include Uber and Lime. For both types of practitioners, participation was limited to those who had worked in the field for at least 5 years such that they were able to comment on the history of the field and the most recent developments. Practitioners that were in a position active in their company's hiring decisions were targeted to provide information on the number of current transportation engineers within their company and the likelihood of hiring more in the future.

Potential participants were identified through a variety of methods. An initial sample of practitioners was identified through the professional network of OSU transportation engineering faculty, in many cases via LinkedIn. To identify an initial sample of academics a list of well know transportation engineering master's degree programs within the United States was identified with the aid of OSU transportation engineering faculty. An online search of the program's faculty yielded a list of potential academic participants. An additional academic participant was identified through their

publication record within transportation engineering education research. For all types of participants, snowball sampling (Goodman, 1961) was then conducted as part of the interview protocol, where participants were asked to identify additional potential participants that the research team could contact. The recruitment based on the initial samples yielded 15 affirmative responses and the snowball sampling yielded 1 additional affirmative response from a potential participant not identified in the initial samples.

3.2 Data Collection

Once identified, participants were recruited through an email giving a brief description of the study and asking for their participation. A sample recruitment email from the graduate student researcher can be found in Appendix B. If an affirmative response was given, the phone interview was scheduled, and the participant was given an informed consent document as well as the interview questions for review. It was found that affirmative responses were more likely to come when the email was sent by an OSU transportation engineering faculty member, rather than a graduate student. A total of 39 people was contacted with 24 being from academia and the remaining from industry. Of those, 16 participants were interviewed, including 6 academics, 7 traditional practitioners, and 3 non-traditional practitioners. Demographic data for the participants can be found in Figures A1 through A6 in Appendix A. Out of the 16 participants, 50 percent were female and 11 received a doctorate degree. Graduate institutions attended by participants included University of California, Berkeley, University of Virginia, MIT, and University of Texas at Austin, among others. Of the participants, seven were located on the west

coast of the United States, five were located in the south, and four were located on the east coast at the time of the study. The study consisted of semi-structured interviews conducted over the phone. The interviews lasted approximately 30 minutes and followed a written interview protocol, found in Appendix C, consisting of an introduction to the purpose of the study, affirmation of consent, main questions, probing questions, and a thank you for participation statement. All interviews were recorded by the researcher. After the interviews were finalized, they were submitted to a transcription service, Rev.com. All interview procedures were approved by an Institutional Review Board (IRB). The IRB approval letter can be found in Appendix D.

3.3 Interview Protocol Development

The interview protocol development began with the creation of the main interview questions. An outline of the question topics was derived from the research questions. The topics included the participant's connection to and their thoughts about the transportation engineering field at present and in the future, the skillsets that are needed to be a successful transportation engineer, and what topics master's level transportation engineering programs should emphasize and/or add in order to best prepare students for the future. From the topics, questions were developed in multiple iterations so that they would each evoke an answer that had the opportunity to aid in answering one or more of the research questions. As the participant responses were a function of the question asked, specificity in the questions were avoided to minimize bias results. Certain questions were worded differently depending on the category of participants (i.e.

academic, traditional practitioner, non-traditional practitioner) such that their unique perspectives would be captured. An additional catch-all question was added to capture any final participant thoughts. The final set of main interview questions, used for academics, and the order in which they were asked can be seen in Appendix C.

Once the main interview questions were developed, probing questions for individual main questions were created to aid the interviewer in clarifying the main questions and getting responses from the participants that would aid in answering the research questions. A snowball sampling question, used to identify additional participants, was also created and included in the protocol. Finally, an introduction to the interview containing background information on the study, including its purpose, goals, and a statement of consent, was written and used at the beginning of the interview. The interview questions and protocol went through many iterations with input from OSU transportation engineering faculty and an OSU engineering education research group with experience in interview question creation. The iterative writing process aided in the development of questions that would elicit genuine and detailed participant responses. All of the described questions and interview introduction can be found in the interview protocol in Appendix C.

3.4 Data Analysis

The transcribed interviews were analyzed using theoretical thematic analysis, a process for identifying themes that is driven by the research questions. Thematic analysis is a qualitative method of identifying and reporting patterns, referred to as themes, within

data (Braun & Clarke, 2006) used by social science researchers that is not bound by any theory. Identifying themes is considered to be a general skill across qualitative methods but thematic analysis began to be acknowledged as a method in its own right in the mid-2000s. A summary and practical guide to thematic analysis can be found in Maguire and Delahunt (2017), which in turn is based on Braun and Clarke (2006). The former guide was used for the design of the present analysis. For the purpose of this analysis, only the first five of six steps were used because the final step consists of dissemination of the results and is inherent in the creation of a thesis. They are as follows:

1. *Become familiar with the data:* Read all of the transcripts and take note of early impressions.
2. *Generate initial codes:* Code each segment of data that is relevant using open coding, a process of developing and modifying codes while going through the coding process.
3. *Search for themes:* Examine the codes for ways in which they can fit together to form a theme. A theme captures something important about the data with respect to the research questions and is a representation of a pattern found within the data set.
4. *Review themes:* Review and modify the initially generated themes such that they are coherent and distinct from each other while ensuring they fit the original data.
5. *Define themes:* Define the specific meaning of each theme and identify how they interact with each other.

Like most qualitative analysis methods, thematic analysis uses coding, the process of creating codes which are words or short phrases that symbolizes portions of data (Saldana, 2016), and assigning them to passages to interpret meaning from the data. For this study, the researcher created codes while reading the interview transcripts as a response to what was being read, adding new codes when necessary and applying existing codes to transcript passages when appropriate. During the coding process, some codes were found to be either too broad or too specific and were modified to more accurately represent the data passages by either creating sub-codes from the broader codes or combining specific codes to create a more inclusive parent code. From the analysis, a final codebook consisting of 24 codes with corresponding definitions was developed. While each of the codes were distinct, some excerpts were co-coded using multiple codes such that the ideas expressed were fully captured. Once all transcripts were coded, themes were formed based on significant patterns within the data set. Patterns were identified by organizing the codes by their relevance to the research questions. The themes were then derived from the patterns and the associated transcript excerpts such that they each were able to answer 1 or more of the research questions. A total of seven themes were derived from the excerpts and are defined in the following chapter. The excerpts displayed in the following chapter are reproduced verbatim when possible, but in a small number of cases, minimal editing was performed to improve clarity.

3.5 Research Quality and Researcher Positionality

Based on Walther, Sochacka, and Kellam's (2013) quantitative research quality framework, consisting of validation and reliability constructs, the following aspects of the research are identified as positively contributing to the trustworthiness of the study outcomes. To address theoretical validation, a sample consisting of transportation engineering field experts was used to predict future trends in the field so that there was an increased likelihood that the predictions are accurate. To address pragmatic validation, the minimum experience requirements for participation and the diversity of participant employers and demographics are compatible with the field in that most transportation engineers work for traditional employers and academia while fewer work for non-traditional employers. In addition, the outcome of the study is meaningful in the context under investigation because the recommendations derived from the results were directed toward transportation engineering master's programs. To address process reliability, the data was collected using the pre-constructed interview protocol for each interview. The interview protocol went through many iterations with input from transportation engineering faculty at OSU and an engineering education research group with experience in collecting data through interviews. To address procedural validation, the data was minimally altered after collection to remove identifying information and for clarity such that the participants' ideas were not misconstrued. Finally, to address communicative validation, the results were connected to previous literature such that the findings were represented in accordance with the existing knowledge within the research community.

My position as a graduate student studying both transportation engineering and engineering education has played a part in the research process. These two foci guided the development of the research questions and the methods used to answer them. As a master's student within a transportation engineering program I have personal insights into a current transportation engineering curriculum which may affect my perspective. Additionally, as an engineering education student, I have learned about curriculum develop and bring that perspective to this work.

3.6 Limitations

It is recognized that the study completed has limitations. All of the interview responses were aggregated making the results of the analysis dependent upon the sample composition and therefore made the discussion of the results sensitive to the sample. This sensitivity may impact the ability of the results to be transferred to other settings. Only one person completed the analysis which provided consistency across the analysis. However, this may limit the variety of interpretations of the data that could be possible. To overcome this limitation, the results were discussed extensively with the committee of this thesis to minimize the effects. Finally, the small sample size could be seen as a limitation however, due to the qualitative nature of the research and its scope, a small sample size is considered acceptable as discussed by Borrego, Douglas, and Amelink (2009).

Chapter 4. Results

Based on the methods described in the previous chapter, a codebook consisting of 24 codes was created. The following sections describe the codebook and themes developed by the researcher. The presentation of codes and themes is supported with excerpts from the transcribed interviews.

4.1 Codebook

The code definitions, which were developed while reading the transcripts, are shown in appendix D. Each of the codes were assigned to statements in the interview transcripts. The individual codes are discussed in the remainder of this section. Throughout this thesis, all code names will be in italics to distinguish them from surrounding text. In the example excerpts, bolded text was used to emphasize portions of the passage. When creating codes, most were neutral in nature, meaning the code was used regardless of the opinion about the topic discussed. However, the code *modeling software* was divided into two different sub-codes that highlight the different opinions, positive and negative, about the inclusion of specific modeling software in the curriculum.

Many of the excerpts contained discussions that would fall under many of the code descriptions and were therefore co-coded. Additionally, many of the codes play into one another, such as the following codes: *additional skills needed*, *change of transportation field*, and *traditional employers*. The first code, *additional skills needed*, was used to capture specific skills that were identified by the participants as ones that

would be needed to be successful in the transportation engineering field in the coming years. This code often appeared with the *change of transportation field* code, which captured the projected changes in the field. The participants identified various changes to the transportation field, but a majority spoke about the new companies that are entering it. Nonetheless, all felt that the traditional transportation engineering companies and public agencies that have traditionally been the primary employers of transportation engineers, referred to here as *traditional employers*, will continue to play a large role in the field. An example of such a response from a non-traditional practitioner was:

“There's just a lot of emerging transportation, these big tech companies who are trying to get in the space so, like I said, ride sharing, so **Lyfts, and Ubers, and scooters and bikes**. So, I can feel a lot more of these companies coming up because they're trying to figure out how can we move people in more innovative methods. And I think that those are **opportunities for jobs for new grads**, but I also still think that **firms and the public agencies will still be here**. I think that they'll still be doing, some of the work they do today, but also maybe some additional work as well.”

This excerpt was co-coded with three additional codes: *multi-modal emphasis*, *non-traditional employer*, and *diversity*. The code *multi-modal emphasis* was used because the excerpt mentions a variety of emerging transportation modes that are available. Other usages of the code included discussion of the need to teach more about design for modes other than motor vehicles because of their current and future prevalence in urban areas. It was also co-coded using *non-traditional employer* because of the companies, Lyft and

Uber, that were identified as being job opportunities for new transportation engineering graduates. The field was identified as growing in *diversity*, specifically of the types of employers that have traditionally been active in the field and ones that are now joining it.

As participants were discussing changes to the field, they also identified potential *change in the transportation engineering work* in both the public and private sectors – i.e., the actual activities carried out by transportation engineers. One participant tied the amount of work that required transportation engineers to current priorities of the federal administration, as captured by the code *policy and government relations*. For both public and private entities, an increase in the availability of data was identified by many interviewees as a factor that will change the nature of work done by transportation engineers. One non-traditional practitioner stated:

“I think that the **biggest change is going to be driven by the data**, and the data availability and the analysis that is enabled by that. I think that to a certain point some of the work may have been more focused on design aspects or operational aspects, without having such a stark data-driven component, and this is something that is bound to change as more and more data becomes available. I think that is definitely going to have a **big impact on the type of work and analysis that transportation engineers are able to conduct** in the future.”

The frequent discussions mentioning the impact of available data warranted the creation of several separate codes, including *data management and analysis, modeling software: positive, modeling software: negative, and data visualization skills.*, These

were used to designate sentences describing the need for data related skills in future transportation engineers. The code, *data management and analysis*, was applied to excerpts that discussed the need for more advanced data management and analysis skills along with those mentioning the current state of data management and analysis courses available at the master's level. When asked about such courses, one academic participant said:

“I think they are being **taught at a lot of places but to a more limited extent** and then students are opting into them. A lot of programs require you to have some sort of computing requirement. At least when I got my master's degree at [university], we had to take one. It was actually a generic database, internet, and programming class at a minimum. Many at the undergraduate level have one computer programming class, but I think it would be beneficial to have more and **more diverse types of data mining, big data analysis, networks**, that sort of thing.”

When asked to discuss data analysis tools, some participants considered learning about specific software while studying toward a master's degree to be useful, coded with *modeling software: positive*. Others considered this aspect not to be as important, because engineers have the ability to learn such software on the job. This was coded as *modeling software: negative*. In addition to the management and analysis of data, the ability to create data visualizations and interpret data visually was mentioned as another skill that is important for transportation engineers. This was captured with the *data visualization skills* code. Participants spoke about the need to be able use visuals to convey ideas and

information to not only other engineers but also to the public. Below is an example of a traditional practitioner explaining this:

“So, if you're trying to explain a concept, I think it's really important that they be able to present the information that they're visualizing **for clarity, and for the public**. Especially if you're trying to explain like street typologies or something like that. So, **visualizing information**, being able to do hand-drawings, I think, is critical.”

Two codes that were found to play into each other were *city planning as a benefit* and *new transportation engineering role*. Participants identified a firm understanding of *city planning as a benefit* to future transportation engineers such that they can better communicate their ideas visually. This was related to other participants' views of the *new transportation engineering role* as being a bridge between very technical groups, such as software engineers, and more system-oriented workers, such as planners and policy makers. An example of such a view from an academic is:

“If programs evolve and we train our students and the future generations of transportation engineers appropriately, I see an **increase in opportunity** for them in these newer companies and what are today startup companies, that are focused on mobility services and I think the roles that people are hired into can be things like data science roles at companies like that. Where they're not necessarily doing traditional transportation engineering work, and they're not really data scientists, but again they're occupying this kind of niche where they can **communicate**

effectively with the engineers on the technical side but also bridge over to connect that work to the operation of the broader transportation system.”

This interviewee referred to the transportation engineering students filling a role that is capable of communicating with other engineers, like software engineers, and those that are system-oriented.

Other skills that were specifically identified as being important to have as a transportation engineer can be grouped under the *professional skills* and *project management skills* codes. The *professional skills* code encompasses communication and teamwork/interpersonal skills, also known as “soft skills”. The nature of transportation engineering requires such skills, due to the different stakeholders that are involved in the creation, funding, and operation of transportation designs and solutions. One academic participant stated:

“The ability to communicate verbally, with written communication skills, the ability to make an impactful presentation, being able to **find the right words for the right audience** will be really, really important for people with careers in transportation going forward because it is such an **interdisciplinary field.**”

A separate code, *project management skills*, was used for discussions about time management, scheduling, and leadership as being important skills for transportation engineers. Both codes, *professional skills* and *project management skills*, were applied to statements mentioning a lack of explicit training or development of such skills in the *current curriculum* at the master’s level. The *current curriculum* code was used when

interviewees mentioned aspects of what is currently being taught to transportation engineering master's students.

One portion of the interview consisted of questions about what changes participants would make to the current curriculum. The responses to these questions generated the *keep currently taught skills*, *less emphasis*, and *beyond specifications and fundamentals codes*. When participants were asked what, if any, skill sets they would deemphasize in current transportation engineering master's curricula, many had difficulties thinking of any. The code of *keep currently taught skills* encompasses this inability to identify any currently taught skills that should be deemphasized. This implies that the interviewee believed that all skills taught at the master's level in transportation engineering programs were still relevant and of value in the field. On the other hand, if an interviewee identified skills to deemphasize, the code of *less emphasis* was applied. An example of such a statement was the desire to have fewer homework problem sets without prompts or ties related to real-world problems. In a set of related statements, some participants called for curricula to go *beyond specifications and fundamentals* and to focus more on teaching engineering design.

Participants were asked to reflect upon their own graduate student experiences in order to uncover which skills that they learned in graduate school were most useful to them in their current careers. This was also an opportunity for them to reflect on whether they thought there was anything missing that could have aided them in their careers. From these reflections, the following codes were created: *extra-curricular activities*, *missing from participants' graduate experiences*, *flexibility in course choices*, and *more*

specialization. Some of the participants identified *extra-curricular activities*, such as research and internships, as being some of the most useful experiences to them because of skills they gained through them that were not taught in the regular curriculum. One example of such a response from a traditional practitioner is:

“In my master's education, we had a couple of different things. Every [week] we had a **research meeting**, but it was the entire group or what we call the transit lab, so it was 20, 25 people who were working in transit. You had to **present your work** and you had your peers and your professors essentially asking you questions and critiquing it. You had to **make a convincing argument**. It wasn't just a quantitative argument, it was a qualitative argument, it was a social, economic argument, it was an equity argument.”

Anything that the interviewee felt was lacking in their master's curriculum was coded as *missing from participants' graduate experiences*. Examples of missing elements mentioned by interviewees were a lack of development of professional skills and programming skills that they considered essential to their current positions. Some called for more *flexibility in course choices*, such that students are able to gain additional skills either within, or through courses and activities outside of their program. It was suggested that some program structures make it difficult for students to take all of the courses that the program offers. An academic participant described it as:

“Sometimes a student comes through and there's a class, for example, in traffic simulation software. And if somebody's working on a master's degree in a traffic area that would be a good skill set to have, but if the **resources are only**

available to offer that class once every two years, sometimes students will come through with a master's and not get that. So, I think the biggest control on if students don't get all the skill development they need while they're working on their master's in the transportation area, I think the biggest control on that is the availability to offer the courses.”

A potential solution to this issue was mentioned by some interviewees as *more specialization*, i.e., having students choose a specification early in their degree.

4.2 Themes

The codes and their associated excerpts were used to derive seven overarching themes from the interviews. The themes were organized into three categories: Future Opportunities, Highlighted Skills, and Program Structure Observations, that interact with each other as seen in Figure 1. This section describes the different categories and the themes housed within each.

Figure 1: Relationship between theme categories and theme category composition

4.2.1 Future Opportunities

The “Future Opportunities” themes describe developments within the field that are the interviewees perceived as already having an impact and that are predicted to continue. The first theme included in this category was related to the observation that new mobility options are creating new design problems. This may change designs of existing infrastructure, such as roadway intersections. The rapid technological changes that have taken place over the last few decades will continue in the future; with them come rapid changes in mobility services available to the public. Many if not all of these new mobility services are for-profit products, such as ride-sharing services provided by Uber and Lyft, electric scooters, and bike-share systems. A non-traditional practitioner expressed this by saying, “these new modalities have been one of the recent changes and I can definitely see this trend continue on for the next few years, with new modes of transportation, new ideas coming into the scene and requiring transportation knowledge.”

As a consequence of these changes, transportation users have more choices and control over their modes of transportation than ever before. Nonetheless, all of these new modes require infrastructure, the design and construction of which has been the traditional backbone of the transportation engineering profession. Therefore, “traditional” transportation engineering jobs and projects are not anticipated to go away, but they will have to be adapted to meet the needs generated by the emerging technologies.

The second theme was about technology and data-driven companies joining the transportation engineering ecosystem and taking advantage of the plethora of data

available. Many participants noted an increase in the use of sensors across technology such as cell phones and motor vehicles. This has increased the amount of transportation-related data that are and will be available. One interviewee said, “now we have sensors on all sorts of things, everyone has a smartphone, there's tons of data being generated, so this could be just mining the backend systems, so the cloud-based systems that are generating tons of data as part of the just basic operations of companies.” Technology and data-driven companies that created transportation-related services and apps, including Google and Uber, were named by several respondents as new entrants into the transportation engineering ecosystem. They were seen as creating a place where “there are going to be [job] opportunities in these certain new mobility companies in the future” by an academic participant.

The third theme in this category was focused on the idea that transportation engineers will have a new role of being the bridge between data scientists, software engineers, and urban planners in the transportation field. Participants articulated the need for a method of communicating conclusions drawn from transportation data to those who make decisions about urban development. Within the transportation ecosystem, transportation engineers were identified as the ones responsible for this communication. As one academic participant stated, “transportation engineers have a unique role to play in connecting those areas and helping to develop services, apps, businesses, and business models.” These future opportunities for transportation engineers inform the themes that are grouped within the “Highlighted Skills” category.

4.2.2 Highlighted Skills

The themes in this category describe the skills that were highlighted by the interviewed transportation professionals as being of growing importance for transportation engineers to master. While these skills are not necessarily core competencies taught by a transportation engineering graduate program, they are still very important for master's students to learn, as they enable a successful career in the field.

First, the interviews showed that the future of the field requires transportation engineering master's students to have more advanced skills in data management, analysis, and visualization. As previously described, the abundance of data is changing the field, and as such, an ability to manage large data sets and turn raw data into meaningful insights and conclusions is sought after in new hires. One non-traditional practitioner directly stated, "data management, programming, eventually statistics and analytics, version control, those are the types of things that would be really important to getting hired." The ability to choose the best methods of data representation, based on audience and purpose, is also important. This was noted by one participant who said, "to communicate effectively with data, it needs to be intuitive and understandable to the people you're presenting it to, telling a clear story, with pictures, with data is key." However, it was identified by the participants that available courses have limited coverage on these skills.

The other theme in this category was that of professional skills, including communication, interpersonal/teamwork, and project management skills. Several interviews showed that these skills were highly valued, and interviewees stated that

teaching these skills should be a more explicit portion of the master's curriculum. It was clearly explained by participants that both verbal and written communication is necessary, with both technical audiences as well as those outside of the technical engineering community. One traditional participant discussed "being asked to not just think critically, but how to communicate in more complex ways and to different audiences and in different types of communications." The fact that transportation engineers routinely work on interdisciplinary teams and must be able to navigate a variety of interpersonal situations was highlighted by participants. One non-traditional practitioner said, "being able to have a data-heavy background and then the ability to collaborate in a multi-disciplinary sort of environment, I think that's something that's super relevant." Project management skills, including leadership, scheduling, communication, and teamwork, were said to be ones that transportation engineers lack as they start in project management roles. It was also mentioned by a traditional practitioner that "these skills are being taught implicitly, but not explicitly" in transportation engineering graduate programs.

The third and last theme category, "Program Structure Observations", contains themes that have the ability to both help and hinder the development of the skills outlined by the "Highlighted Skills" themes.

4.2.3 Program Structure Observations

The themes grouped in "Program Structure Observations" included general statements about the structure of transportation engineering graduate programs. They are

not new concepts, but it is important to acknowledge them in order to strive to provide the best education to students. Furthermore, these themes may hold clues as to what the most effective ways of imparting new skills, such as those described in the “Identified Skills” themes, may be.

The first theme in this category was about how transportation engineering master’s programs are limited in their ability to offer all courses to all students during their time in the program. Interviewees expressed that programs should aspire to create as much flexibility in course selection as possible. Ideally, all courses would be available for all students, but the number of students and faculty are limitations that make doing so difficult. However, respondents also identified a potential strategy to aid in providing students with what they need. They proposed to increase student awareness of the courses available outside of the program that could be useful or of interest to them based on their career goals. An example of this being mentioned in an interview was said by an academic: “encouraging our transportation students to seek these classes that I had mentioned, potentially thinking about taking classes in statistics or computer science or industrial engineering in terms of optimization.”

The final theme was focused on extracurricular experiences such as research and internships. These were seen as highly valuable additions to the academic experience of transportation engineering master’s students. In statements related to this theme, interviewees commented on the need to supplement programs’ curricula with experiences that were considered as enhancing critical thinking and communication skills by participants. One academic commented, “I think that going through having to write a

master's thesis taught me a lot about having to structure a problem that you don't know the answer to, per se, and then have to write about it in a clear, coherent, and easy to understand way.” Extracurricular experiences can also provide greater exposure to professionals and opportunities within the field, thus helping build the student’s network and allowing the student to develop a better understanding of possible future career paths.

Chapter 5. Discussion

5.1 Summary of Findings

An analysis of the transcribed interviews of transportation engineering professionals yielded a codebook of 24 codes and seven overall themes. The themes defined the patterns found within the data with respect to the research questions presented in chapter 2. They were then organized into three categories, “Future Opportunities”, “Highlighted Skills”, and “Program Structure Observations”. The “Future Opportunities” category housed themes that describe developments within the transportation engineering field that the interviewees perceived as already having an impact and that are predicted to continue. These “Future opportunities” themes informed the themes that are grouped within the “Highlighted Skills” category. The “Highlighted Skills” themes described the skills that were highlighted by the interviewee as being of growing importance for transportation engineers to master. Finally, the “Program Structure Observations” themes included general statements about the structure of transportation engineering graduate programs. These themes have the ability to both help and hinder the development of the skills outlined by the “Highlighted Skills” themes. The following sections connect these findings to previous literature and present recommendations for transportation engineering master’s programs.

5.2 Connection of Findings to Previous Literature

The results presented in Chapter 4 are consistent with several previously published findings in the engineering education literature. For instance, this research is

not the first to identify the themes that were grouped in the “Identified Skills” and “Program Structure Observation” categories presented in section 4.2. The requirement for graduates to have more advanced skills in data management, analysis, and visualization, which was mentioned by a number of the transportation engineers interviewed, was previously identified by Grigg (2000) for the civil engineering field as a whole. Of course, since the beginning of the 21st century the availability and volume of data has accelerated. This will continue to increase the importance of modeling and analysis capabilities in civil engineering applications, including the analysis of transportation systems (Grigg, 2000). Additionally, the high emphasis placed on professional skills, including communication, teamwork, and project management, has previously been identified by industry practitioners and academics as a set of skills necessary “for engineers to function effectively in a multidisciplinary environment” (Nguyen, 1998, p. 66). The present research clearly shows that this remains important. A study in 2001 found that 64% of an engineer’s overall worktime was spent on some form of communication, and identified technical communication skills as being key to promotion and advancement (Sageev & Romanowski, 2001). Since the publication of that study, communication technology has significantly improved and become a much more important component of daily life in many professions. So it can be assumed that the percentage reported by Sageev and Romanowski (2001) is still quite plausible, and may even have increased.

The fact that it is difficult for transportation engineering master’s programs to offer all courses to all students and in all academic year’s mirrors similar challenges in 4-

year undergraduate engineering programs. Therefore, educators must decide what topics to omit or include in any given year, a question which has been described as one of the most difficult problems facing engineering educators (Nguyen, 1998). The problem is even more pronounced at the master's level, as the majority of students spend at most two years working toward their degree; some programs are even 1-year programs.

The value of professional experiences such as internships and research has previously been acknowledged in the literature treating engineering education at the undergraduate level. A study of alumni perceptions of their undergraduate engineering research experiences found that alumni considered their experiences to have been a 'very important' or 'extremely important' component of their education. This was especially true for those who performed research for a longer period of time (Zydney, Bennett, Shahid, & Bauer, 2002). Among the benefits that alumni described were significant enhancements of cognitive and personal skills, such as the ability to understand scientific findings, the ability to speak effectively, and the development of clear career goals. Even though Zydney et al. (2002) focused on undergraduate-level research, their findings were similar to the remarks made by participants in the current study concerning the value of their graduate research experiences.

5.3 Recommendations

Jamieson and Lohmann's (2009) innovation cycle of educational practice and research models a continuous flow between research and practice and vice versa. It describes engineering education as resulting in insights that should be used to improve

educational practice. Based on this cycle, the following outlines results from the study described in this thesis and my recommendations for transportation engineering master's programs that were derived from the results. Given the focus of this research on the United States context, the recommendations also primarily apply to programs within the United States.

Result #1

Very few topics were mentioned that the interviewees felt should be emphasized less, suggesting that the material taught is still very much relevant and necessary to learn in order to be successful in the field.

Recommendation #1

I recommend that programs do not remove topics they are currently teaching but consider a reorganization of the material taught such that there is room for additional topics that were identified as important for future success. These topics include the ones described in the “Highlighted Skills” themes (i.e., professional skills and data management, analysis, and visualization).

Result #2

The “Highlighted Skills” themes described topics that were identified as important for future success (i.e., professional skills and data management, analysis, and visualization) by the participants. [no suggestions for how to integrate them into the

curriculum] While the participants did not provided suggestions for how to integrate these topics into the curriculum, they did indicate that their experiences conducting research and having internships allowed them to expand their professional skill level and their knowledge of data management and analysis.

Recommendation #2

One method that could be used to integrate the “Highlighted Skills” into transportation engineering master’s programs is through student research and/or internships. I recommend that master’s programs capitalize on the learning opportunities afforded by both student research and internships by being deliberate in aiding their students to find the right experiences for them. One way in which this could be done in the case of student research is by defining learning objectives for a typical transportation engineering master’s thesis research experience at the university, and sharing them explicitly with students, along with an explanation of the benefits to them if they meet those objectives. Similarly, programs should consider what internship opportunities are available to their students and provide support in finding and applying to companies with open internship positions that in the transportation engineering field.

Result #3

Participants identified transportation engineering master’s programs as being limited in their ability to offer all courses to all students during their time in the program. They expressed that programs should aspire to create as much flexibility in course

selection as possible. The participants proposed to increase student awareness of the courses available outside of the program that could be useful or of interest to them based on their career goals.

Recommendation #3

Taking the participant suggestion on how to meet the goal of offering more flexibility in course selection one step further, I recommend collaboration and coordination between thematically related master's programs within the university. This would allow the coordinated offering of relevant courses from multiple programs to transportation engineering students. A possible example of this could be a machine learning course that is offered to both transportation engineering students and students in related disciplines with applications drawn from the fields of all targeted audiences. Students would thus have the opportunity to work in a multidisciplinary environment, mimicking multidisciplinary work in industry. Moreover, this would provide them with additional courses to choose from that would not only aid them in their career path but also count toward graduation. While such a collaboration and coordination could prove to be time-intensive for faculty at the outset, once established, there would be evident benefits to the programs: they would be able to offer students a greater number of course choices without the transportation engineering faculty being the sole responsible party for creating and teaching said courses.

Chapter 6. Conclusions

Continued rapid technological changes are affecting the transportation engineering field, and by extension, the work that transportation engineers do every day. It is important for the education of transportation engineers to keep pace with the changes happening in the field. Published research on transportation engineering education has been mainly conducted with a focus on the undergraduate level, and as such, there is a gap in the literature when it comes to graduate education. The present thesis addresses this gap for transportation engineering education at the master's level. The established methodology of using studies of contemporary life as a method of informing curricular development guided the present study. An investigation of current and potential future changes in the transportation engineering field was conducted with the goal of informing transportation engineering education at the master's level. A thematic analysis of semi-structured interviews with academics, practitioners working for "traditional" employers of transportation engineers, and practitioners working for emerging ("non-traditional") employers resulted in a codebook of 24 codes that led to the derivation of 7 themes. The themes were organized into 3 categories: Future Opportunities, Identified Skills, and Program Structure Observations.

The distinct theme categories are not independent; they interact with one another, and these interactions hold information to answer the research questions that were presented in section 2.3. The "Future Opportunities" category included themes concerning the effect of new mobility services on the design of future infrastructure and the re-design of existing infrastructure, technology companies joining the transportation

engineering ecosystem, and new roles for transportation engineers in the future. These themes directly address the first two research questions, which were focused on the employment opportunities and the nature of day-to-day work that transportation engineers will encounter in the next 5 to 10 years. The “Identified Skills” category focused on themes identifying skills that were identified as being critical to a successful career in the future. These themes echoed a broad call among the interviewed transportation professionals for more advanced data manipulation and professional skills. Together with the “Future Opportunities” themes, this answers the second research question regarding the future day-to-day work environment of transportation engineers. Additionally, it helps to address the third research question, which was focused on the topics that should be taught in transportation engineering at the master’s level. The themes housed in the “Program Structure Observations” category addressed programs’ limitations in course offerings and the value of research and internships. Interestingly, while many of the comments in this last category are not new per se (for instance, the value of internships has been recognized for some time), this category also holds valuable clues about how some of the additional skills needed can be imparted to students without designing entirely new courses within the transportation engineering program. This provides another answer to the third research question.

Based on these results, recommendations for transportation engineering master’s programs were provided, with the purpose of improving programs such that students will be well prepared for their future careers. The recommendations included the continued inclusion of current core topics in transportation engineering while making organizational

changes to include the teaching of professional skills and data management skills as a larger part of the curriculum. The continued and expanded use of current elements of many transportation engineering programs, including student research and internships, and possible new collaborations with other graduate programs have the potential to add a component of the student learning experience that will provide new skills and enhance students' future success in this ever-evolving field.

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Appendix A. Participant Demographics

Figure 2 A: Distribution of male and female participants

Figure 3 A: Distribution of participants' current position classification

Figure 4 A: Distribution of participants' highest earned degree

Figure 5 A: Distribution of participants' master's degree field of study

Figure 6 A: Distribution of participants' doctoral degree field of study (if earned)

Figure 7 A: Distribution of participants' relative location within the United States

Appendix B. Sample Recruitment Email

Dear [NAME],

My name is Meg West, and I am a second-year master's student at the Ohio State University. For my master's thesis, I'm interested in how transportation engineering students are being prepared for the future. To explore this space, I'm conducting a series of interviews and wondered if you could be interested in being a participant.

I am searching for participants who identify as having either of the following roles:

- Practitioners, employed in the private or public sector, who have worked in the transportation engineering or planning field for at least 5 years and who are currently in leadership (management) roles, at any level.
- University faculty with at least 3 years of teaching experience in transportation engineering at the master's degree level.

If you are in one of these roles, would you be willing to participate in a 30-minute, telephone or in-person, interview? The interview will focus on skill requirements for transportation engineers and your opinions regarding the future direction of the field.

If you are willing to participate, please let me know, preferably by [DATE]. The interview will be scheduled between [DATE] and [DATE], at a time that is convenient for you. If you agree to be interviewed, I will email you the consent form which you will acknowledge verbally in the interview.

If you know of someone else that would be willing to participate in this study, I would appreciate any recommendations.

Please let me know whether you have any questions and thank you for considering this request!

Sincerely,
Meg West

Appendix C. Interview Protocol

Semi-structured script to be read by interviewer:

Hello! Thank you for agreeing to participate in this interview! I'm Meg West, a master's student at the Ohio State University studying transportation engineering... Before we start, due to general university regulations about interview studies I must ask for your consent as noted in my email. Please state now whether or not you consent to taking part in this study. This interview will be audio recorded for later transcription and analysis. May I turn on the recorder?

Through this interview, I would like to understand your opinions on the future of transportation engineering education. For that purpose, I will discuss how you see the transportation engineering field evolving, and what the most important skills are that students will need to acquire in order to be successful in the coming years. The focus will be master's-level programs and students, so please keep that in mind during our conversation.

I am conducting a series of interviews such as this one with industry experts and academics. I will then distil the insights from them in order to derive recommendations for the curriculum development in transportation engineering programs in the U.S. I am interested in your personal opinions, but if your organization or institution has an official stance on some questions, please indicate that. Your identity will only be known to the research team and our results will only be published in a de-identified and aggregated form.

Please state your name.

I am going to start with some questions about you and your thoughts about the transportation engineering field.

* Indicates a question aimed toward traditional practitioners.

** Indicates a question aimed toward traditional practitioners.

Main Question	Probing Question	Notes
What is your connection to the transportation engineering field?	What is your current position title? What is the type of work you do?	

** Approximately how many transportation engineers with master's degrees has your organization hired in the last year?		
<p>What organizations do you know of that hire your master's students?</p> <p>*What other organizations do you know of that hire students with master's degrees in transportation engineering?</p> <p>** [if their organization hired no transportation engineers] What organizations do you know of that hire students with master's degrees in transportation engineering?</p>		
How do you see the ecosystem of companies and agencies within the transportation engineering field changing in the next 5-10 years?	** Do you foresee any changes that are not strictly within the transportation engineering <i>field</i> , but that will affect companies that work in transportation engineering? For example, due to emerging transportation-related companies or industries?	
Within those companies, how do you see the type of transportation-related work changing in the next 5-10 years?	Within the types of emerging transportation-related companies mentioned, how do you see the type	

	of transportation-related work developing in the next 5-10 years?	
In your opinion, how will those changes impact who hires transportation engineers, and what roles they are hired into?		
<p>**Could you see your company hiring transportation engineers in the future?</p> <p>If so, what sort of roles can or could be filled by them?</p>		
<i>Thank you! Now we are going to switch gears and focus on skillsets of transportation engineers.</i>		
What skillset will be needed to be a successful transportation engineer for the types of employers and projects you mentioned?	E.g. data analysis, communication skills, specific software skills, modeling, GPS, etc.	
Which of these skills are currently being taught? Which are not?	<p>Is your program teaching them? Are programs across the country teaching them?</p> <p>*Do your new hires have these skills when they come to you? If not, what are they lacking? **These should be overarching</p>	

	skills not specific tool skills**	
What were the most useful skills you learned from your master's degree?	What aspects of your graduate education helped you be successful in the field?	
Are there any skills you wished you had obtained during your master's degree?		
<i>We will now be moving into questions focused on what programs should emphasize and/or add in order to best prepare students for the future.</i>		
<p>What skillsets that are currently taught in (enter school name here) your program's curriculum do you think should be emphasized more in order to prepare your students for the transportation field in the future?</p> <p>* Of the skillsets that you know your new hires have been taught during their master's program, which do you think should be emphasized more in the future?</p> <p>** What skillsets that transportation engineers are currently taught in their master's programs should be emphasized more in the future in order to make them more likely to be hired by companies like yours?</p>	*What should transportation engineering master's programs emphasize?	

<p>What skillsets, if any, that are currently taught in (enter school name here) your program's curriculum should be emphasized less? (in order to prepare your students for the transportation field in the future)</p> <p>* Of the skillsets that you know your new hires have been taught during their master's program, which do you think can be emphasized less in the future?</p> <p>** What skillsets that transportation engineers are currently taught in their master's programs are less critical for companies like yours?</p>	<p>*Are there any skillsets that transportation engineering master's programs should emphasize less?</p>	
<p>What additional skillsets should be taught in (enter school name here) your program that are currently not taught? (in order to prepare your students for the transportation field in the future)</p> <p>*What skillsets do you think your new hires should have in the future that they do not currently have?</p> <p>** What new or additional skillsets that are currently not being taught in master's programs should transportation engineers be taught in order to make them more likely to be hired by companies like yours?</p>	<p>What topics would you add to the curriculum to prepare students?</p>	
<p><i>Thank you very much! Now we are going to wrap it up with a couple of closing questions.</i></p>		

<p>Do you have any further thoughts about the future of transportation engineering education?</p>		
<p><i>I am still actively looking for additional participants and would be grateful for recommendations of others that you think would be good participants for this study. I am looking for contacts in industry and academia. You can tell me now or send the information at a later time.</i></p>		

Thank you again for participating in this interview! I will share the results of the study with you once it is complete. I will turn off the recorder once you hang up the phone.

Appendix D: Codebook

Table 1 D: Code definitions, example application, and frequency

Code Name	Description	Example Application	Application Frequency
<i>Additional skills needed</i>	Identified an additional skill that will be needed to be successful in the transportation engineering field in the future	“The second thing is that we are not explicitly teaching the students' curriculum with regards to things like certain types of business models and these type things, because traditionally these students have more or less worked in the public sector. And that is perhaps something that, I don't know if we need to be teaching it as a class, but there probably could be other things we're doing to enhance the student's knowledge of those.”	36
<i>Change of transportation engineering field</i>	Identified a projected change in the transportation engineering field	“There's other smaller, niche industries, that also leverage transportation engineering talent, like some software developers who develop simulation tools or data high-ends, like boutique firms that provide consultant services specializing on these areas that have also come into the space.”	48
<i>Traditional employer</i>	Identification of a traditional employer of transportation engineering master's students such as departments of transportation and transportation engineering consulting firms	“I mean you have public agencies, state and local governments, NPOs, state DOTs. They need a lot of designers and the transportation engineering program that the students are coming out of is more design based. With knowing the METCD and the highway safety manual and all that good stuff. I think a lot of those students end up going to either design or for governments in different levels, state agencies. They work for obviously private companies, big design groups.”	30
<i>Multi-modal emphasis</i>	Identification of multi-modal design and analysis, including bicycles, pedestrians,	“In my current job, I interview a lot of recent graduates from engineering programs. I think that there are a subset of schools where students are taught about the multi-model transportation system, all aspects of it and all modes of it. I think there is still a majority of	3

	electric scooters, etc.	schools where transportation engineering is largely roadways, highways, vehicle-driven approach where the transit and pedestrian bike modes are not considered engineering, they're considered planning. So that's one part of it."	
<i>Non-traditional employer</i>	Identification of a non-traditional employer of transportation engineering master's students; includes all employers other than traditional employers and academia	"Other faculty in the program have students go on to Tony Bike, NREX and IDAX so again street born data-oriented companies. We did see this a gross area in the transportation engineering field. We, to date, have not placed a lot of our students there, but we see that this is where there are going to be opportunities for people who are interested in this type of work. In a faux short study Transportation Engineering, there are going to be opportunities in this certain new mobility companies in the future."	37
<i>Diversity</i>	Identification of the diversity of employers and people within the transportation field	"I'd love to see a little bit more diversity of people in the teaching of transportation engineering education. At least on the academic side, the people teaching the classes tend to look very similar. I think having a diverse workforce is a very positive thing, and if you have a diverse faculty and a diverse set of teachers, that can make that... it's a good example and I think could facilitate that."	4
<i>Change in transportation engineering work</i>	Identified a projected change in the type of work performed by transportation engineers	"I think that the biggest change is going to be driven by the data, and the data availability and the analysis that is enabled by that. I think that to a certain point some of the work may have been more focused on design aspects or operational aspects, without having such a stark data-driven component, and this is something that is bound to change as more and more data becomes available. I think that is definitely going to have a big impact on the type of work and analysis that transportation engineers are able to conduct in the future."	35
<i>Policy and government relations</i>	Identification of topics dealing with the relationship	"I wouldn't say that that is a new thing. One thing that I see among a lot of engineers, or a lot of engineering students I should say, is	13

	between transportation engineering and policy/government	perhaps a lack of or a weak understanding of policy and a very weak understanding of business. I think that if people are going to be going into the private sector, some understanding of the business world and how it works is something that will be increasingly important. That's more like a mindset than a skill set, I guess ... that's one area.”	
<i>Data management and analysis</i>	Identified the need for large amounts of transportation-related data to be managed and analyzed; includes mentions of "Big Data"	“More data management, programming, eventually statistics and analytics, version control. Those are the types of things, to my own knowledge aren't emphasized in current transportation engineering programs that would be really important to getting hired. In roles like mine, and in other roles at a company like mine.”	28
<i>Modeling software: positive</i>	Suggestion that learning specific modeling software is useful	“Again, I really think computers, technology, GIS, is huge. So much of the stuff that we do, GIS skills are really valuable. I don't really do like traffic engineering per se or stuff like that, but there are people that do it. I think familiarity with stuff like all those technology things I was mentioning and GIS and data sources like INRIX, modeling things like microsimulation software, VSM. Those are things a lot that our consultants are working with to get the kind of, you know, process the kind of data and information that we're looking for, for a job like mine in public transit.”	15
<i>Modeling software: negative</i>	Suggestion that learning a specific modeling software is seen as not as important	“I think time spent on learning modeling software. That was another area that I think was very much encouraged to me. I don't, it's tricky because yes, I think it's valuable as a skill to put on your resume, but long term, it's probably not. Only because if you don't happen to get a job that requires that skill right out of college or right out of your master's program, having learned it five years ago is not going to help you further a job. Right? Things change so quickly that I think that learning more foundational skills and more.”	3

<i>Data visualization skills</i>	Identified transportation engineers as needing to have strong data visualization skills	“I very much value data visualization and big data processing, all of that. And that's a thing that I see that new hires, some of them have, that I did not have. Maybe this is just a generational thing, that this is now a much more common and a much more buzz worthy concept. This whole data visualization topic and processing large datasets and to some extent, statistical modeling.”	6
<i>City planning as a benefit</i>	Identified city planning skills can be useful to transportation engineers	“The skill sets emphasized in the future for Transportation Engineering should be city planning, transportation planning, station, sustainable. How to build, yeah, city planning goes along with sustainability of cities and lighter levels. Regional planning, regionalism, so maybe some skill sets in understanding how projects are conceived at the very high levels.”	6
<i>New transportation engineering role</i>	Identified a new role or job type for transportation engineers	“We also are positive as a discipline we bring some context to bear by being able to kinda bridge between the engineers and data scientists and the urban planners. That Transportation Engineers kinda have a unique role to play and kinda connecting those seals and helping to develop services, apps, businesses, business models. They're responses to the needs of communities and kinda connect with the..., I don't know, the ways planners view this. I think we have the unique bridging role to play.”	16
<i>Professional skills</i>	Identification of communication skills as a necessary part of a transportation engineer's job; includes other "soft skills" including teamwork; also known as "power skills"	“So I still think that the ability to communicate verbally, with written communication skills, the ability to make an impactful presentation, being able to find the right words for the right audience will be really, really important for people with careers in transportation going forward because it is such an interdisciplinary field. You find yourself having to converse with people with different expertise backgrounds, you have to be able to communicate your vision and your message, not getting too down with the jargon the specific	46

		transportation area jargon, I think that's going to be very important.”	
<i>Project management skills</i>	Suggestion of addition of project management skills as valuable	“I think a lot of transportation engineers find themselves as project managers before they learn those skills. So I think that learning about project management and estimating and construction management in a graduate program is useful. I know some universities do that, some don't. It just depends. I don't know.”	10
<i>Current curriculum</i>	Identified an aspect of what is currently being taught to transportation engineering master's students	“I would say that probably CAD is being taught a lot, and sometimes like SYNCHRO and those programs. And, obviously the transportation demand modeling programs.”	25
<i>Keep currently taught skills</i>	Inability to identify currently taught skills to deemphasize due to their still relevant value	“I mean, this is a hard question because I think that sometimes curriculums require students to have certain classes even though the student may not want to ever work in that field. So those types of things, obviously, can be nixed, but I don't think that there are, fundamentally, any skill sets that aren't relevant anymore. Because I think they are relevant for some type of career. I, none of our new hires do any type of drafting, right? It's just, that's not what we need. Yeah, so I don't, I can't really think of any.”	2
<i>Less emphasis</i>	Topics identified that could be emphasized less in graduate transportation engineering curriculum	“One thing that... I feel like we spent a lot of time on when I was in the master's where techniques that were related to traffic operations, things like traditional traffic frailty. These get used nowhere, as far as for-profit companies, even in places where you might expect them to. For instance, we could use a lot of traffic flow to predict how long it would... like what's the speed of a vehicle making its way to a road race. This is directly trying to say, hey what's the ETA for the vehicle, given a six distance. Traffic flow approaches have never proven accurate at all when we even track them, even with data. Things like that I feel they took up time, two	13

		semesters in third grade master's program. If you imagine a basic traffic full class, and we had one more elective related to either highway operations or transit operations but all from a traffic focus record.”	
<i>Beyond specifications and fundamentals</i>	Identified a need to design/think beyond the specifications; focus less on the in-depth understanding of transportation engineering fundamentals	“I think that innovation and thinking outside of traditional guidelines and specifications and following these design specs or models, I think, is going to be more and more valued in the future. Those are going to be, I think the students that excel at thinking that way, are going to be the ones that excel in the career. Because I think increasingly, we can automate a lot of this standard design stuff and we're just pulling standard designs off the table. There's not a lot of leg work being done on them.”	7
<i>Extra-curricular activities</i>	Identified activities outside of required curriculum that could benefit the pursuit of a successful transportation engineering career	“The second thing was that all of us had to do a summer internship in our... in the gap summer between the first and second year, with the transit agency. We learned the workings of an agency, how the mechanics of transit worked, or transportation worked. Then we were seen by the agency as a resource who was helping them solve their real-world problems.”	10
<i>Missing from participants' graduate experiences</i>	Concepts, topics, methods of teaching that were identified as missing from the participant's graduate experience	“Yes, I wish I had some of the skills that I mentioned. We did analytics techniques, so some of the techniques that are being used currently. I mentioned about data science and data analytics but there was some industries skills operations, like some of the operations that transportation engineers will soon need, about scalable algorithms, design scalable implementation of algorithms, so our transportation systems, there's a lot of data but we really don't have a way to implement some scalable algorithms from those data sets. So some of the big data analytics models are the data instructions that I wish I knew when I was a graduate student.”	21
<i>Flexibility in course choices</i>	Suggestion of offering more course choices	“Well they are being taught; I don't know if they're required. I think we're encouraging our transportation students to seek these	9

	such that students can learn topics they are interested in or that will be useful for the job they desire	classes that I had mentioned, potentially thinking about taking classes in statistics or computer science or industrial engineering in terms of optimization. So those courses are available, but right now they are probably not part of the required curriculum for a master student in transportation.”	
<i>More specialization</i>	Suggestion of having students choose a specialization within transportation engineering, make the choice early	“The ability to hone in faster on a specific area of engineering, I think, is great. Yes, this might limit a student's ability to branch out in the future, but when I think back on a lot of the classes that I took, that have nothing to do with any of the work that I do, I wasn't interested in, that I took because you need one 400 level or 600 level class and that's all that was being offered.”	

Appendix E: IRB Approval Letter

THE OHIO STATE UNIVERSITY

Office of Responsible Research Practices

300 Research Administration building
1960 Kenny Road
Columbus, OH 43210-1063

orrp.osu.edu

01/13/2019

Study Number: 2018E0808

Study Title: Investigating the Future of Transportation Engineering Education

Principal investigator: Andre Carrel

Date of determination: 01/13/2019

Qualifying exempt category: #2

Dear Andre Carrel,

The Office of Responsible Research Practices has determined the above referenced project exempt from IRB review.

Please note the following about this determination:

- Retain a copy of this correspondence for your records.
- Only the Ohio State staff and students named on the application are approved as Ohio State investigators and/or key personnel for this study.
- Simple changes to personnel that do not require changes to materials can be submitted for review and approval through Buck-IRB.
- No other changes may be made to exempt research (e.g., to recruitment procedures, advertisements, instruments, protocol, etc.). If changes are needed, a new application for exemption must be submitted for review and approval prior to implementing the changes.
- Records relating to the research (including signed consent forms) must be retained and available for audit for at least 5 years after the study is closed. For more information, see university policies, [Institutional Data](#) and [Research Data](#).
- It is the responsibility of the investigators to promptly report events that may represent unanticipated problems involving risks to subjects or others.

This determination is issued under The Ohio State University's OHRP Federalwide Assurance #00006378. Human research protection program policies, procedures, and guidance can be found on the [ORRP website](#).

Please feel free to contact the Office of Responsible Research Practices with any questions or concerns.

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