Via Department of Civil & Environmental Engineering

TRANSPORTATION INFRASTRUCTURE AND SYSTEMS ENGINEERING (TISE)

INFORMATION, DEGREE REQUIREMENTS, AND ADVISING MANUAL

Spring 2020

COLLEGE OF ENGINEERING
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

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PREFACE

This handbook is designed to assist graduate students and faculty in the Transportation Infrastructure and Systems Engineering Program. It contains the following types of information:

- General information about the TISE program, key personnel and faculty in the Charles E. Via Department of Civil and Environmental Engineering (CEE) and the Transportation Infrastructure and Systems Engineering (TISE) Program;
- Degree requirements, advising procedures, and Program requirements.

If questions remain after reading this handbook, please see your advisor or any transportation engineering faculty member. Additional information can be found on the CEE Web Site at http://www.cee.vt.edu/.

1. GENERAL INFORMATION

The Transportation Infrastructure and Systems Engineering Program is a graduate program within the Charles E. Via Department of Civil and Environmental Engineering (CEE) and provides educational and research opportunities in Blacksburg.

Two degrees, offered and administered by the CEE Department, may be pursued by eligible TISE students: Master of Science in Civil Engineering (MSCE), and Doctorate in Civil Engineering (PhD). Specific requirements for each degree are described in later sections of this manual, the Graduate Policies and Procedures Manual, the Virginia Tech Course Catalog, and in the Civil and Environmental Engineering Graduate Handbook. A third degree at the masters level, the Master of Engineering, is available to students interested in broadening their general knowledge of Civil Engineering rather than specialize in a single area. More information on this option is available in the CEE Departmental Graduate Policies and Procedures Manual.

1.1. Mission

The mission of the TISE program is to: (1) provide the highest quality education in one of many fields within transportation engineering; (2) create an inclusive environment for students to learn transportation engineering and systems concepts and to develop critical thinking; (3) advance knowledge about transportation infrastructure and systems that sustains our global leadership in research and technology development; and (4) conduct outreach and service activities to disseminate knowledge and actualize practical positive transportation changes.

The curriculum of the TISE Program has been developed to enable students to plan, design, construct, maintain, rehabilitate, manage, operate, and predict service life of transportation infrastructure and systems. In addition, courses are designed to allow students to master the analytical, experimental, and problem-solving skills needed to excel in their professional careers. We provide a dynamic program which adapts to the current and future needs of a very dynamic profession.

To best meet the needs and interests of our students, we have established two graduate study tracks, (1) *Infrastructure* and (2) *Systems Engineering*. The *Infrastructure* track targets pavement design; civil engineering materials; and transportation infrastructure assessment, maintenance, and management as areas of teaching and research concentration. The *Systems Engineering* track focuses on traffic operations and engineering; transportation planning; safety and human factors; goods movement; and public and air transportation as fields of study and research.

The TISE Program recognizes the need for engineering planning, design, evaluation, and renewable engineering. Therefore, the program provides a balance between these areas and allows students to design individual course curricula to meet their unique interests. Graduate study within TISE is built on student objectives and mutual agreement between each student and faculty advisor. Specific guidelines are provided later in this document.

1.2. CEE Personnel

The Via Department of Civil and Environmental Engineering offices are located on the second floor of Patton Hall in room 200. During their time at Virginia Tech, students may interact with the following individuals:

The Department Head of Civil and Environmental Engineering, 200 Patton Hall, (540) 231-6635
Ms. Sarah Martin, Graduate Student Coordinator, 200 Patton Hall (540) 231-6069, shmartin@vt.edu

Ms. Breanna Farmer, TISE Program Support, 221C Patton Hall (540) 231-6635, breannaf@vt.edu

1.3. Transportation Engineering Faculty

Faculty in the TISE Program include:

Montasir Abbas, PE, Professor, PhD Purdue University, abbas@vt.edu. Dr. Abbas' research interests include traffic management and control, traffic flow theory, ITS, agent-based modeling and simulation, traffic safety, artificial intelligence, and systems optimization.

Alexander Brand, Assistant Professor, PhD University of Illinois Urbana-Champaign, asbrand@vt.edu. Dr. Brand's research interests include: Materials science of civil infrastructure materials; Advanced characterization techniques to study the micro- and nanostructure development in cementitious materials; Use of recycled and by-product materials in concrete (reclaimed asphalt pavement aggregates, recycled concrete aggregates, steel furnace slag aggregates, and supplementary cementitious materials); Concrete pavement engineering; Fiber-reinforced concrete.

Gerardo Flintsch, PE, Professor, PhD Arizona State University, flintsch@vt.edu. Dr. Flintsch's research interests include infrastructure condition assessment and performance prediction; pavement evaluation, design and management; application of soft computing, geographic information systems and other emerging technologies to support infrastructure data management, analysis and decision-making; non-destructive evaluation; and life-cycle-cost analysis.

Kathleen Hancock, PE, Associate Professor, PhD Vanderbilt University, hancockk@vt.edu. Dr. Hancock's research interests include freight operations and planning, highway safety, and geospatially enabled decision making for transportation.

Kevin Heaslip, PE, Associate Professor and TISE Coordinator, PhD University of Massachusetts Amherst, kheaslip@vt.edu, Dr. Heaslip's research interests include: Transportation Operations, Critical Infrastructure & Transportation Cybersecurity, Public Transportation, Transportation Automation and Electrification, and Transportation Resilience.

Susan Hotle, Assistant Professor, PhD Georgia Institute of Technology, shotle3@vt.edu. Dr. Hotle's research interests include travel demand modeling, aviation economics and operational analysis, and benchmarking.

Bryan Katz, PE, Associate Professor of Practice, PhD Virginia Polytechnic Institute and State University, bkatz@vt.edu. His research interests include Traffic Engineering, Transportation Safety, Traffic Control Devices, and Transportation Human Factors

Hesham Rakha, PEng, Professor and Director for Sustainable Mobility VTTI, PhD Queens University, hrakha@vt.edu. His research interests include traffic flow theory and control, traffic modeling, dynamic traffic assignment, optimization, Intelligent Transportation Systems, environmental modeling, and safety modeling.

Antonio Trani, Professor, PhD Virginia Tech, vuela@vt.edu. His research interests include air transportation, simulation and modeling, airport engineering, systems engineering, infrastructure systems.

Linbing Wang, Professor, PhD Georgia Tech, wangle@vt.edu. His research interests include multiple-scale microstructure characterization, modeling, simulation and visualization of infrastructure materials; simulative pavement testing and mechanistic pavement design; application of imaging techniques to pavement materials; and remote sensing.

Adjunct faculty include:

Sam Tignor, PE, FASCE, retired Federal Highway Administration. His research interests include driver needs and highway safety, freeway management and incident detection, freeway merging control systems, railroad-highway grade-crossing safety, visibility of changeable message signs, condition-

responsive work-zone traffic control, and truck overturn-warning systems. He is located in the National Capital Region.

1.4. Professional Organizations

Several professional organizations are available to transportation engineering students and all graduate students are encouraged to become involved. Listed below are two of the more active organizations at Virginia Tech. There are also many other organizations or societies that students may find beneficial and can be found on the University web page at http://www.vt.edu/student_life/.

In addition to organization activities, a variety of journals which contain transportation engineering and human factors material are available through these organizations. The reduced student memberships to most organizations provide students with an excellent opportunity to join these professional societies or to purchase the journals.

VIRGINIA TECH ALLIANCE OF TRANSPORTATION ENGINEERING STUDENTS (ATES) - is the umbrella under which three student chapters (ITE, ASHE & ARTBA) perform. The major goal of the alliance is to promote the dissemination of knowledge and information related to transportation infrastructure and systems issues, problems and solutions. Information about VTATES can be found at https://www.cee.vt.edu/tise/ates/.

Institute of Transportation Engineers (ITE) - a national professional organization for transportation systems and operations. ITE publishes the ITE Journal and other books and periodicals. (http://www.ite.org).

American Society of Highway Engineers (ASHE) - The mission of the American Society of Highway Engineers is to provide a forum for members and partners of the highway industry to promote a safe, efficient and sustainable transportation system through education, innovation and fellowship. (http://www.ashe.pro)

American Road and Transportation Builders Association (ARTBA) – a national professional organization for the design and construction of physical transportation infrastructure and facilities. (http://www.artba.org).

AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE) – includes the Transportation and Development Institute (T&DI) which has a number of technical committees and the Aerospace Division. ASCE publishes the Civil Engineering Magazine and Transportation Engineering Journal. Information about the Virginia Tech student chapter can be found at http://www.asce.cee.vt.edu/.

2. DEGREE REQUIREMENTS

2.1.1. General

The material presented below is provided for the information and guidance of graduate students and their faculty advisors and committee members. Regulations governing the degrees come from three levels: the Graduate School, the Department of Civil and Environmental Engineering, and the Transportation Infrastructure and Systems Engineering Program. Faculty advisors (see Advising section in this manual) assist students in planning their graduate degree programs. **However, ultimate responsibility lies with the student**.

Students should also be familiar with these documents:

- Graduate Policies and Procedures and Course Catalog http://graduateschool.vt.edu/graduate_catalog/
- The CEE Departmental Graduate Policies and Procedures Manual https://www.cee.vt.edu/wp-content/uploads/2019/07/Graduate-Policies-and-Procedures-Manual-Departmental.pdf

These documents provide information about Graduate School regulations, registration, due dates, thesis and dissertation requirements, etc. and about specific Departmental and University requirements. Information in the this document is intended to reinforce and supplement requirements from the other sources, not to replace those requirements.

2.1.2. Admission Requirements

Admission is contingent on meeting all requirements as specified by the graduate school and in the CEE Departmental Graduate Policies and Procedures Manual. Students must have either received an earned Bachelor of Science degree in civil engineering or a closely related field, or demonstrate competency in the field through completion of undergraduate courses identified in Appendix A and/or documented and approved professional experience.[1] Students without a civil engineering baccalaureate must make up coursework at the basic level of undergraduate engineering as identified in Appendix A to be accepted into the Masters program in TISE. No graduate credit is granted for this basic level work and students are not part of the graduate program during this time.

Recommended minimum scores for acceptance to the TISE graduate program are:

GPA (undergraduate): 3.0 or equivalent

GPA (graduate): 3.5 or equivalent

TOEFL: International students who have not earned (or will earn within 6 months) a baccalaureate or master's degree from a higher education institution with English as the language of instruction will be admitted only after satisfactory completion of the TOEFL Examination (or meet TOEFL waiver requirements as set by the VT Graduate School). It is the responsibility of the international student to provide proof of English instruction to the Graduate School office if their undergraduate institution is outside of the United States. International applicants must provide a TOEFL score of at least 90 iBT with 20 or better in each subsection to be considered for admission. International students, like all applicants, must also submit GRE scores. In some cases, the Graduate School will approve other English tests as proof of language proficiency such as IELTS with a minimum of 6.5 (this score is subject to change- check the VT Graduate School website for updates).

GRE: All applicants seeking regular admission to a degree-seeking program in CEE must take the Graduate Record Examination (GRE) and submit their GRE scores as part of their application. The recommended minimum GRE score for the quantitative section is 155. However, decisions to admit are based on a prospective student's entire application package.

2.1.3. Graduate Programs

The TISE Program offers the following degree options:

Master of Science: This degree has two options: Thesis Option and Non-thesis Option. Students who choose the MS Thesis Option are required to conduct research in a specific area and register for at least 22 credits of coursework and a minimum of six semester credit hours of CE 5994 "Research and Thesis". The Non-thesis Option can be completed in three ways: graduate students take at least 25 credit hours of coursework and 6 credit hours of CEE 5904 "Project and Report"; graduate students take at least 28 credit hours of coursework and 3 credit hours of CEE 5904 "Project and Report", or students complete a course-only option by completing 31 credit hours of course work and passing a final exam.

[1] Students who anticipate applying their graduate degree toward professional engineering registration requirements must have an earned Bachelor of Science degree from an accredited undergraduate civil engineering program.

***PhD Program**:* The PhD requirements have been adopted by the Graduate Faculty of the TISE Program to supplement the graduate degree requirements stated in the Graduate Degree Programs Bulletin. **Complying with graduate school and departmental requirements is the responsibility of each student.**

2.1.4. Curriculum Tracks

The TISE curriculum consists of two tracks: (1) *Infrastructure* and (2) *Systems Engineering*. *Infrastructure* graduate students are required to take three core courses and a minimum of one elective course from the Infrastructure cluster and any one course from the Systems Engineering cluster. *Systems Engineering* graduate students are required to take three out of six core courses and a minimum of one elective or additional core course from the Systems Engineering cluster and any one course from the Infrastructure cluster. Table 1 lists the core and elective courses in each cluster. Appendix B gives a detailed description of courses in the TISE program.

Based on the plan of study prepared by the student and his/her main advisor, courses from other program areas and departments may be taken. It is suggested that at least one course is taken from other program areas. Courses from other departments (Statistics, Industrial Engineering, Engineering Mechanics, Materials Engineering, Electrical Engineering, Computer Science, etc.) are determined based on each student's thesis/project and his/her interests.

Table 1. Transportation Courses by Track

INFRASTRUCTURE CLUSTER	SYSTEMS ENGINEERING CLUSTER
Core	Core
CEE 4634 Infrastructure Condition Assessment	CEE 5600 Analysis of Civil Infrastructure Systems
CEE 4664 Pavement Design	CEE 5604 Traffic Characteristics and Flow
	CEE 5624 Transportation and Land Use
	CEE 5614 Analysis of Air Transportation Systems
CEE 5674 Advanced Pavement Design	CEE 5634 Analysis & Planning of Mass Transit Systems
or	CEE 5650 Freight Operations and Planning
CEE 5754 Pavement & Bridge Infrastructure Mgmt. Systems	Elective
	CEE 4604 Traffic Engineering
Elective	CEE 4654 Geometric Design of Highways
CEE 4614 Advanced Structural Concretes	CEE 4674 Airport Planning and Design
CEE 5684 Rehabilitation of Transportation Structures	CEE 4684 Transportation Safety
CEE 5764 Asphalt Technology	CEE 5204 GIS Applications in CEE
CEE 5984 Mech. of Asphalt Concrete & Pavement Modeling	CEE 5620 Transportation Networks Analysis
	CEE 5640 Highway Transportation Safety
	CEE 5650 Advanced Signal System Control
	CEE 5654 Critical Issues in Transportation
	CEE 5670 Applied Traffic Engineering Analysis
	CEE 5694 Traffic Signal System Operation and Control

2.2. Masters of Science Degree

2.2.1. Master of Science Options

Two options are available: the thesis option for students that are supported by research projects and/or teaching assistantships, and the non-thesis option for part-time students or students pursuing a terminal masters for the purpose of expanding professional expertise within the transportation field. In addition to the information provided below, all graduate students are required to complete the departmental ethics requirement.

> ***Thesis Option.*** Students are required to successfully complete a minimum of 21 credit hours of course work, one credit hour of seminar, and six to nine credit hours of CEE 5994 "Research and Thesis" for a total of a minimum of 31 credit hours. They are required to conduct work involving researching a particular subject in depth to produce findings which are not readily apparent at the commencement of the work. Upon completion of the proposed work, the student prepares a written thesis. The thesis is a complete document that describes the student's work. A draft of the thesis is submitted to the Advisory committee at least one week prior to the oral thesis defense. The draft is reviewed and approved by the major advisor prior to distribution to the advisory committee. The student then defends the thesis during the oral defense. The thesis is modified based on comments from the defense and the final thesis is approved by the advisory committee and submitted electronically by the student to the Graduate School (http://etd.vt.edu/etdsubmn.html).
>
> ***Non-Thesis Option.*** Students are required to successfully complete a minimum of 31 credit hours, of which, up to 6 credit hours can be CEE 5904 Project and Report, and 1 credit of seminar. A presentation of the project and report will be made to complete the requirements for CEE 5904. If the student opts for completing 31 credits of course work only (including the 1 credit seminar), an oral examination will be administered to complete the requirements for graduation.

2.2.2. Course Requirements

A total of 31 credit-hours must be completed to satisfy the M.S. degree requirement. A minimum of 15 credit hours of 5000-level or higher coursework must be completed. A maximum of 6 credit hours of 4000-level courses approved for graduate credit can count toward this requirement. A 1 one-credit hour of seminar is required.

The seminar (CEE 5944) focuses on computational tools used in the remainder of the student's graduate career and in transportation professional practice and should be taken as soon as possible.

2.2.3. MS Degree Committee

Prior to the completion of 15 credit hours of coursework, a chairperson and an M.S. committee (chosen by the student with the agreement of the chairperson) will be recommended by the Department to the Graduate School as part of the plan of study. The chairperson of the M.S. committee will become the student's academic advisor and shall, along with the committee, provide overall guidance for the candidate's M.S. program. The M.S. committee shall consist of two or more members of the Graduate Faculty in the major field.

2.2.4. Program of Study

In the second semester and/or prior to completion of 15 credit hours of coursework, the student, in conjunction with the M.S. committee advisor, will formulate a Plan of Study (http://www.cee.vt.edu/graduate-information-and-forms/). The plan shall reflect the student's probable area of research or professional expertise and the coursework needed to accomplish the degree. Any subsequent revisions to the program of study shall be approved by the M.S. committee and Department representative using the Plan of Study Change Form (http://graduateschool.vt.edu/academics/what-you-need-to-graduate/forms.html).

2.3. PhD Degree

2.3.1. Admission to the Doctoral Program

Prior to admission, the TISE Program faculty will review the applicant's records. Applicants with non-civil engineering undergraduate degrees will be advised, at the time of acceptance, of any undergraduate coursework that must be fulfilled as part of the doctoral program. Upon admission to the doctoral program, the student will be assigned an academic advisor selected from the student's specialty area. The student has the option to choose an advisor after being enrolled in the program. The following PhD degree requirements must be satisfied:

- Maintain a grade point average of 3.0 or above to remain a degree candidate.
- Satisfy the associated research skills requirement.
- Satisfy the communication skills requirement.
- Successfully complete the preliminary examination prior to the dissertation proposal.
- Successfully prepare and present a proposal for dissertation research prior to the dissertation.
- Prepare and orally defend the PhD dissertation.

2.3.2. Credit Hour Requirements

A minimum of 90 post-baccalaureate credit-hours are required to satisfy the PhD degree requirement. The program must include at least 27 credit hours of 5000-level and higher coursework. A limit of 6 credits of 4000-level courses can be approved for graduate credit. In addition, all TISE students are required to take 1 one-credit-hour seminar (CEE 5944). The seminar focuses on computational tools used in the remainder of the student's graduate career and in transportation professional practice and should be completed as soon as possible. Between 30 and 63 hours of CEE 7994, Dissertation Research must be included in the program. The number of research and dissertation credits for which the candidate registers should reflect the time that is spent by the candidate in the laboratory or in the field, in analyzing data, writing the dissertation, or other activities specific to the dissertation. The candidate is expected to maintain continuous registration throughout the program.

2.3.3. Competencies

Research Skills. Since the Doctoral degree is a research degree and candidates are expected to continue research activities after graduation, the candidate should demonstrate competence in research skills. Specific skills should be commensurate with the candidate's specialty area and career goals and should be identified jointly by the candidate and his/her Doctoral committee chairperson and dissertation advisor.

Communications Skills. The doctoral committee will evaluate the candidate's ability to use written and oral forms of the English Language correctly. International students may be required to take remedial courses in oral or written English.

2.3.4. Doctoral Advisory Committee

Every PhD student must select a Major Advisor who will be the chairperson of the Advisory Committee. The student and Major Advisor will establish the PhD Advisory Committee consisting of a minimum of four members of the graduate faculty, two of which must be full-time tenure or tenure-track CEE faculty members. The chairperson and the committee will provide overall guidance for the candidate's doctoral program. At least one member should be from outside the Department of Civil and Environmental Engineering. The student may choose one committee member as a dissertation advisor, usually although not necessarily, the chairperson. The dissertation advisor will guide the candidate in the preparation of the research proposal and in the development and defense of the dissertation.

2.3.5. Plan of Study

After the establishment of the PhD Advisory Committee and before the completion of 15 credit hours at Virginia Tech beyond the MS degree, the candidate, in conjunction with the doctoral committee chairperson will prepare a plan of study (http://www.cee.vt.edu/graduate-information-and-forms/). The course plan shall reflect the candidate's probable area of research and any coursework recommendations made by the doctoral committee.

The candidate shall meet with the Doctoral Committee as soon as practical to review the candidate's course plan and plan for satisfying the degree requirements. Any subsequent revisions to the program of study shall be approved by the Advisory Committee and Department representative using the Plan of Study Change Form (http://graduateschool.vt.edu/academics/what-you-need-to-graduate/forms.html).

2.3.6. Preliminary Examination

The purpose of the examination is to evaluate the potential of the candidate to conduct independent scholarly research with technical proficiency. The candidate is expected to be competent in technical skills and be able to apply these skills to the analysis of complex engineering problems. The examination should specifically test the candidate's ability to (1) demonstrate proficiency in the candidate's research area of expertise, (2) identify and characterize a problem, (3) select proper analytical strategies, and (4) apply appropriate research methodologies.

The exam is usually taken when the student is nearing completion of required coursework, and must be passed at least nine months before graduation. In addition, at least 24 credit hours, including work for which the student is currently enrolled, must be completed after the preliminary examination is passed. The student must be registered when the examination is taken. The student must schedule the oral portion of the preliminary examination at least two (2) weeks before the date requested.

The areas of competence shall be determined by the chairperson of the Doctoral Committee and should be consistent with the candidate's planned dissertation research. The examination shall include at least three but no more than five technical areas of competence. The chairperson should advise the candidate of these areas at least eight weeks before the examination. The candidate has the right, and is so encouraged, to discuss the material upon which the candidate will be examined with individual committee members.

The preliminary examination shall consist of both a written and an oral component.

> ***Written Examination****:* Each committee member will prepare one or more questions covering a given area of competence. These will be forwarded to the chairperson who will select the questions that will be given to the candidate. The written examination will be open-book and shall be completed within seven consecutive days. Following the examination, the Chairperson will forward the candidate's responses to the respective committee members for evaluation. The committee members shall evaluate the candidate's response to their respective questions and report their evaluation to the chairperson prior to the oral examination.
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> ***Oral Examination****:* The oral examination shall be conducted after completion of the written examination, preferably within the same semester. A 2-hour examination period is recommended. The oral examination is a continuation of the written examination and allows the candidate to amplify and clarify the written responses. However, questions will not necessarily be confined to the subject matter covered on the written examination. Note: The Graduate School must be notified in advance of the scheduled date of the oral examination.

Unsatisfactory Performance on Written or Oral Examination: A vote by all members of the committee will determine satisfactory performance on both the oral and written parts of the preliminary examination where

"satisfactory performance" is defined as up to one negative vote. Unsatisfactory performance will result in one of the following:

- A requirement for additional coursework and/or reexamination. One full semester must lapse (a minimum of 15 weeks) before the administration of a second examination. The preliminary examination cannot be attempted more than twice.
- Dismissal from the PhD program. Appeals shall be submitted in writing to the Department representative who, together with the committee chairperson, shall render a decision regarding the candidate's continuation in the program.

Upon successful completion of the preliminary exam, the student officially becomes a candidate for the PhD Degree.

2.3.7. Dissertation Proposal

The candidate shall develop a formal written research proposal that independently details the proposed doctoral research at a very early stage of the candidate's work on the dissertation and at least six months prior to completion of the dissertation. The purpose of this written and oral presentation is to determine the feasibility and originality of the proposed research, to examine the student's familiarity with the literature and background materials involved, and to offer suggestions to the student regarding the proposed research. Development of the proposal normally follows the preliminary examination. In certain circumstances, especially when the candidate's research is funded by an external agency, it may be appropriate for the candidate to prepare the proposal in advance of, or in conjunction with the preliminary examination. If the proposal and the oral portion of the preliminary exam are taken together, the student must follow the paperwork procedures for an official preliminary exam scheduled with the Graduate School.

The research proposal shall consist of the following parts:

- Background and detailed literature review that justify the problem statement.
- Statement of the problem and the hypothesis to be tested.
- Objective and Scope.
- Work plan, including proposed scheme for data collection, data analysis, and hypothesis testing.
- Anticipated results.
- Engineering significance.
- Gantt chart showing the key activities and time schedule.
- List of References.

The proposal must be submitted to each member of the dissertation committee for his or her review no later than two weeks before the oral presentation and defense. The proposal will be judged by the committee on its technical merit as well as the adequacy with which the bulleted items are addressed.

Once accepted by the committee, a copy of the proposal, along with any corrections or additions requested by the committee, will become a permanent part of the candidate's record. Approval of the proposal, by vote of the entire committee, will be recorded by completing the CEE approval and transmittal form (http://www.cee.vt.edu/wp-content/uploads/2014/09/departmental-phd-proposal-form.pdf). The original signed version of this form must be given to the Graduate Student Coordinator to be added to the students online file.

2.3.8. Progress Reports

The student must periodically communicate with the Advisory committee to keep it informed of his/her progress. Periodic oral reports should be scheduled in consultation with the student's advisor. A written progress report

must be submitted before the end of the spring semester every academic year during the time the student is enrolled in the program and should be submitted canvas.

2.3.9. PhD Dissertation

The dissertation should be an original contribution to the literature in an area of Transportation Engineering. It should describe the execution and results of the research effort in detail. The format of the dissertation should be either in the traditional detailed written presentation or as a series of Journal Articles (see the Graduate School dissertation requirements). Electronic dissertation submission should be completed within two weeks following the final defense. Committee approved dissertations are submitted electronically to the Graduate School (http://etd.vt.edu/etdsubmn.html). A delay in the submission of the dissertation may cause a delay in awarding of the degree, and the student may incur fees for late submission.

2.3.10. PhD Final Exam: Dissertation Defense

The final examination shall be an oral defense of the candidate's doctoral dissertation. The dissertation must be submitted to and approved by the committee members at least two weeks prior to the date of the examination. The candidate's doctoral committee will conduct the examination in accordance with Graduate School requirements. Requirements for successful completion of the final examination are the same as for the preliminary examination. The student must be registered when the examination is taken. **The "Request to Admit Candidate to Final Exam" must be submitted online to the Graduate School at least two (2) weeks before the date requested. (https://ess.graduateschool.vt.edu/pages/login.php) The Graduate School will generate a packet that will be emailed to the major advisor. (Application for degree should already have been submitted).**

Major revisions to the dissertation should be completed before the oral examination. The dissertation should be in final draft form, with appropriate notes, references, bibliography, tables, etc., at the time of the oral examination; both the content and style should be correct and polished by the time this final draft is submitted to the committee.

Wherever a committee vote is required, a dissenting vote from no more than one member of the committee represents a passing vote.

APPENDIX A. Required Background Courses for Non-Civil Engineering Undergraduate Degrees

	CREDIT HRS	CONSTRUCT	EWR	GEOTECH	STRUCTURES	TISE
Chemistry 1074	3		X	X		
Chemistry Lab 1084	1		X	X		
Math 1205 (Calculus)	3	X	X	X	X	X
Math 1206 (Calculus)	3	X	X	X	X	X
Math 2224 (Calculus)	3	X	X	X	X	X
Math 2214 (Differential Equations)	3		X	X	X	X
Physics 2305	4	X	X	X	X	X
Physics 2306	4	X	X	X	X	
Geology 2104	3	X	X(3)	X		
ISE 2014 (Engineering Economics)	2	X	X		X	X
ESM 2104 (Statics)	3	X	X	X	X	X(1)
ESM 2204 (Deform. Bodies)	3	X	X(4)	X	X	
ESM 2304 (Dynamics)	3		X(4)			
CEE 2814 (CEE Measurements)	4				X	
CEE 3014 (Construction Mgmt)	3	X				
CEE 3104 (Environmental Engineering)	3	X(5)	X			
CEE 3304 (Fluid Mechanics)	3		X	X		
CEE 3314 (Water Resources)	3		X			
CEE 3404 (Theory of Structures)	3	X		X	X	X(1)
CEE 3424 (Reinforced Concrete)	3	X			X	X(1)
CEE 3434 (Steel Structures I)	3				X	
CEE 3514 (Soil Mechanics)	4	X	X(3)	X	X	X(1)
CEE 3604 (Transportation)	3					X
CEE 3684 (CEE Materials)	3	X		X	X	X(1)
CEE 3804 (Computer Applications)	3	X			X	X(2)
CEE 4554 (Hazards)	3	X(5)				
CEE 4804 (Professional & Legal Problems)	3	X				
CS 1044 or 1054 (Programming)	3		X			
STAT 4604 (Statistical Methods for Engr)	3		X			X

(1) Required if the student specializes in the transportation infrastructure area.
(2) Or demonstrated experience.
(3) EWR requires either GEOL 2104 or CEE 3514.
(4) EWR requires either ESM 2204 or 2304.
(5) Construction requires either CEE 3104 or 4554.

APPENDIX B. List of Transportation Courses

Graduate Level Courses

5600: CIVIL INFRASTRUCTURE SYSTEMS ANALYSIS

Systems analysis, modeling infrastructure systems by mathematical programming, measuring infrastructure systems performances, probabilistic analysis of infrastructure systems, multiple attribute decision making in infrastructure systems. Graduate standing in engineering required. (3H,3C).

5604: TRAFFIC CHARACTERISTICS & FLOW

Driver, vehicle, and roadway characteristics; stochastic modeling of traffic processes including queuing theory, headway distributions, and gap acceptance; stream flow characteristics including car-following and multilane traffic models, roadway capacity and bottleneck analysis, network operations, and fuel consumption models. Pre: 4604. (2H,3L,3C).

5614: ANALYSIS OF AIR TRANSPORTATION SYSTEMS

Planning, design and operation of aviation systems with computer aided design tools and computer simulation models. Airline airport operations and practices and their effect in airport planning and design. Air cargo facilities planning and modeling. State-of-the-art computer simulation models used in aviation environmental planning and airspace modeling. Graduate standing in CE required. (3H,3C).

5620: TRANSPORTATION NETWORKS ANALYSIS

Optimal paths in transportation networks, transportation network design, vehicle routing and scheduling, facility location problems, traffic flows on networks, traffic assignment problems. Graduate standing in engineering required. (3H,3C).

5624: TRANSPORTATION & LAND USE

Interaction between transportation and land use variables, including modeling requirements, impacts, and data needs within the context of good community planning and economic development; elements of transportation and land use that shape the quality of life in urban areas. Pre: 3604. (3H,3C).

5634: ANALYSIS & PLANNING OF MASS TRANSIT SYSTEMS

An overview of mass transit systems; transit system planning including demand and cost analysis and evaluation; transit system design including route design, scheduling, and fare policy; transit networks and marketing; para transit systems; future trends in mass transit. Pre: 3604. (3H,3C).

5640: HIGHWAY TRANSPORTATION SAFETY

Emphasis is placed on identifying highway safety problems and the discussion of remedial solutions and countermeasures needed to eliminate highway crashes and the associated fatalities and injuries. The course addresses the history of highway safety, the remedial steps that have been taken to improve safety, current research, and the challenge remaining to eliminate all highway crashes. Pre: 4984. (3H, 3C).

5650: FREIGHT OPERATIONS AND PLANNING

Introduction to the operation of modal and intermodal freight facilities. Types of freight movement and handling equipment, freight planning methods, and research. Freight as a multi-modal transportation system. Role of privately owned and operated freight movement on public sector transportation operations and decision making. Communication of impacts of freight movement. Pre: 3604. (3H, 3C).

5654: CRITICAL ISSUES IN TRANSPORTATION:

Technological, societal, economic, political, environmental, health and energy effects on planning, design, operation, and management of the transportation system. Problem identification, objectives identification, alternatives generation and evaluation, and reasoning process for transportation investment.

5674: ADVANCED PAVEMENT DESIGN
Methods used to characterize, stabilize, and specify pavement materials. Methods for rigid and flexible highway and airport pavement design and analysis. Load equivalence factor and specific design considerations related to environment and traffic characteristics. Pavement overlay design. Software for pavement design and analysis using various models. Pre: 3684, 4664. (3H,3C).

5684: REHABILITATION OF TRANSPORTATION STRUCTURES
Identification of maintenance and rehabilitation needs for transportation structures such as bridges and pavements. Cost effective maintenance and rehabilitation methods. Consideration of bridge and pavement management systems. (3H,3C).

5754: PAVEMENT & BRIDGE INFRASTRUCTURE MANAGEMENT SYSTEMS
Management concepts used in civil infrastructure; planning, design, construction, maintenance, and rehabilitation of bridge and highway systems. Prioritization, optimization, and decision-making techniques. Life-cycle-cost prediction. Pre: 3684, 4664. (3H,3C).

5764: ASPHALT TECHNOLOGY
Origin, types and properties of bituminous materials and their use in civil engineering. Asphalt rheology. Theory behind technological processes and procedures for hot-mix asphalt including design philosophy, performance, and durability. Modern construction with bituminous materials; special mixtures, recycling, and additives. Pre: 4614. (2H,3L,3C).

Advanced Undergraduate Courses

4604: TRAFFIC ENGINEERING
Study of traffic and parking characteristics; application of traffic control devices; principles and techniques used to improve the efficiency and safety of traffic flow systems. Pre: CEE 3604. (3H,3C).

4614: ADVANCED STRUCTURAL CONCRETES
Fundamental properties and the physical and chemical aspects of the structure of Portland cement concretes. Emphasis placed on environmental performance aspects and the application of studies of concrete performance under various exposure conditions. Co/Pre: 3684. (3H,3C).

4624: PLANNING TRANSPORTATION FACILITIES
Transportation planning process; urban and regional studies, surveys, data analysis, model development and testing; transportation management, administration, finance, system evaluation, implementation, and integration. Pre: 3604. (3H,3C).

4634: INFRASTRUCTURE CONDITION ASSESSMENT
Infrastructure components and assessment needs; physical and chemical properties of construction materials; deterioration causes, assessment methods, nondestructive evaluation techniques, infrastructure management systems, performance models, service-life-cycle estimates. Pre: 3684. (3H,3C).

4654: GEOMETRIC DESIGN OF HIGHWAYS
Functional design of highways; curves, intersections, interchanges, drainage, and other features involved in highway safety and traffic efficiency. Pre: 3604. (3H,3C).

4664: PAVEMENT DESIGN
Principles underlying methods for the design of various elements of flexible and rigid pavements for highways and airports; climate and traffic effects; pavement management systems. Pre: 3604. (3H,3C).

4674: AIRPORT PLANNING AND DESIGN

Airport planning and economic justification, site selection, configuration, development and design of terminal areas, demand forecasting, access, traffic control. Pre: 3604. (3H,3C).

4684: TRANSPORTATION SAFETY

Analyses and decision making that affect public safety as part of the transportation system. Pre: 3604. (3H,3C).

4694: FREIGHT OPERATIONS

Modal and intermodal freight facilities, their operation, and types of freight movement and handling equipment in context of a multi-modal transportation system; role of privately owned and operated freight movement within public sector operations and management. Pre: 3604. (3H,3C).