

**CE 586: Modeling Transportation Network Supply and Demand**

**Units: 4**

**Spring, 2022**

**Friday 9:00 AM – 12:20 PM**

**Location:** TBD, including 100 minute/Week of supervised work in the SAL computer lab.

**Instructor: Fatemeh Ranaiefar**

**Office:** KAP 2\*\* (CEE Adjunct Faculty Office)

**Office Hours:** by appointment

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**Teaching Assistant: N/A**

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[consult@usc.edu](mailto:consult@usc.edu), 0-5555 for ITS

**Catalogue Course Description**

Theories and applications of transportation network demand and supply models and simulation techniques. Hands‐on opportunities to work with simulation software to solve problems.

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**Detailed Course Description**

This course presents theories and applications of transportation network demand and supply models and simulation techniques. The course provides a firm grounding in modeling and optimization of transportation networks. A review of discrete optimization and static transportation network analysis will be provided in the first few lectures. The course will discuss representation, modeling and algorithms for solving different network problems. Both analytical and simulation‐based network assignment models and vehicle routing problems will be discussed. In addition, strategic issues such as network design, congestion pricing and lane management models will be discussed in the later sections of the course. The emphasis in this course is on practical applications, analysis of algorithms and the ability to solve such problems. Students will learn about four-step travel demand model process through lab sessions and get hands-on experience with current software tools. They will practice transportation network design and editing, implementing various network assignment algorithms, network optimization strategies and reporting various network performance measures such as Vehicle Miles Travelled (VMT), delay and Volume to Capacity Ratio (V/C). Basic undergraduate engineering knowledge of programming, operations research, and optimization models may be required for the problems sets and the final Project.

**Learning Objectives**

By the end of this course, students will be able to:

1. relate the overall purpose of Transportation Network Analysis (TNA) to the transportation planning process;
2. identify different optimization techniques standard for modeling flows in transportation networks such as user equilibrium and stochastic optimization techniques, and apply them;
3. understand different transportation network management policies such congestion pricing and lane management, and apply them in a class project;
4. analyze and solve models used to make better network management decisions and to improve system performance;
5. understand the overall input and output data types and sources, procedures, and models for each stage of a four-step, large-scale travel demand model;
6. produce valid results and interpret these results with respect to each of the four components of a large-scale travel demand model;
7. apply the travel demand procedures to a sample transportation network using modeling software, with focus on network analysis; and
8. implement basic models and analysis in one of the transportation network modeling software packages.

**Prerequisite(s):** None

**Co-Requisite(s):** None

**Concurrent Enrollment:** None

**Recommended Preparation**: Students should have basic knowledge of one programing language such as Python, VBA, C, Java, or R; a prior introduction to transportation modeling at the level of CE 471 or PPD/CE 633; basic statistics at the level of ISE 225, CE 408, or EE 364; and linear programing and basic optimization concepts at the level of ISE 330.

**Technological Proficiency and Hardware/Software Required**

The USC Viterbi School will provide students with free access to one of the leading transportation demand modeling software packages available in the market. Students need not have prior experience with this software, but are expected to be familiar with using USC Viterbi virtual machines and basics of one programing language.

**Course Notes**

Selected course lectures and lab exercises will be posted on the class Blackboard website.

Students are expected to routinely attend the class and take notes for study and review.

**Required Readings**

* Sheffi, Y. Urban Transportation Networks: Equilibrium Analysis with Mathematical programming methods. Prentice‐Hall Inc., Englewood Cliffs, NJ, 1985. [The best introductory textbook to transportation network analysis, although it is a bit dated.] Available online for free at

http://web.mit.edu/sheffi/www/selectedMedia/sheffi\_urban\_trans\_networks.pdf

* Ahuja, R.K., Magnanti, T.L. and Orlin, J.B. Network Flows: Theory, Algorithms and Applications. Prentice‐Hall Inc., 1993. [Very good textbook on computer implementation of network algorithms, and applications beyond the transportation domain]
* Available at the USC Bookstore or online at

http://dspace.mit.edu/bitstream/handle/1721.1/49424/networkflows00ahuj.pdf

* Selected Articles will be distributed during the class via Blackboard
* Transportation modeling Software tutorials

• Patriksson, M. (1994). The Traffic Assignment Problem — Models and Methods. VSP International Science. Very comprehensive (> 1000 references). Provides an excellent history of the topic and is a great jumping-off place for a literature review on a specific topic, but not always aimed at those new to the field

**Supplementary Materials**

* Ortuzar & Willumsen (2011). Modeling Transport (4th) Wiley. Available at the USCBookstore (optional)
* Bell, M.G.H., and Iida, Y. Transportation Network Analysis. John Wiley & Sons, 1997. ISBN 0471 96493 X. [More recent than Sheffi’s text, but not as detailed in its explanations.] Available at the USC Bookstore.
* Patriksson, M. (1994). The Traffic Assignment Problem — Models and Methods. VSP International Science. [Very comprehensive (> 1000 references). Provides an excellent history of the topic, great starting point for literature review, but not always aimed at those new to the field.]

**Description of Assignments**

* Midterm exams are written tests and will be graded out of 100 points for each exam.
* Lab and homework assignments require students to use a transportation modeling software package, Microsoft Excel, online search, or excute simple programing in any language.
* The final project consists of building a case study model in the identified transportation modeling software. Students will work on teams of two on the final project. The project is due the day the final examination would otherwise be scheduled.
* Students are expected to have two, 15‐minute presentations during the course to show their progress, and a final written report of their case study model scenario analysis.
* Students may do field work in their study area to collect network operational and characteristic information such as number of lanes, speed, intersection geometry or signal timing. The field work is recommended but not required.

**Assignment Rubrics**

Each homework assignment will be posted on class blackboard page as indicated in the Course Schedule. The instructions for lab exercises will also be posted prior to each lab session.

**Assignment Submission Policy**

* Each student is expected to submit his/her assignment via the class blackboard pages.
* Submissions should conform to the course schedule.
* Students can work together on lab exercises, but they need to submit their work individually.

**Grading Timeline**

* Grades will be posted on class web page within two weeks after each assignment submission.

**Additional Policies**

* Attendance is not graded, but routine attendance is highly recommended.

**Grading Breakdown**

The following weights apply.

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| --- | --- | --- |
| **Assignment** | **Points** | **% of Course Grade** |
| **Homework/ Lab exercise** | 4 sets of 100 points each | 20 |
| **Midterm Exam** | 100 | 40 |
| **Final Project & Presentations** | 100 | 40 |

**Extra credit worth up to 10%:** A research paper on a topic related to the course material.

The subject of the paper must be submitted to the instructor for approval no later than week 4. The paper is a voluntary extra credit opportunity accounted for after draft letter grades are computed. Students are not disadvantaged if they do not elect to submit a paper.

**Grading Scale**

Course final grades will be determined using the following scale:

A 95-100

A- 90-94

B+ 87-89

B 83-86

B- 80-82

C+ 77-79

C 73-76

C- 70-72

D+ 67-69

D 63-66

D- 60-62

F 59 and below

**Course Project Description**

The class project is designed for students to learn how to use state‐of‐the‐art transportation network analysis tools to develop real‐world network improvement Strategies. A group of two students should form a team and pick one project. Most of the final project requires application of transportation modeling software and Microsoft Excel data analysis. There are two options for projects:

1. The instructor will provide a general, semi‐complete transportation model. Each team has to complete and validate their model. During the lectures we will review various policies to improve transportation network performance metrics such as lane management policies, congestion pricing, signal improvements, and multi modal network assignment solutions. Students are expected to define and analyze three scenarios to improve their model transportation network’s performance. An improvement scenario can be defined based on policies and solutions discussed in the class, or can be a creative new policy.
2. The students may propose their own transportation modeling project, but need to convince the instructor that their project is appropriate with respect to scope, that the workload is reasonable, and that they can follow all the required steps and exercises with their proposed model

**Project Timeline:**

* 3nd week: Instructor introduces projects.
* 4rd week: Project proposal, students decide teams and projects
* 6th week: Prepare the project contract (1 page)
* 8th week: Midterm progress report (10 min presentation)
* 15th week: Project presentation
* Finals week: Final report submission

**Grading breakdown for the course project:**

* A base credit (50%) will be given if basic features of the project are implemented in a timely way (model 30%, reports 10%, presentations 5%, schedule 5%)
* Credit for GUI/usability design: 15%
* Credit for creativity, new ideas, adding good features, problem solving: 20%
* Presentation to the class: 15%

| **Week** | **Topics/ Activities** | **Reading, Assignment, Lab** |
| --- | --- | --- |
| w1 | Overview   * Transportation planning Process * Transportation system analysis   + Introduction to concepts/ components /data requirements in transportation modeling with focus on the network aspects | Read Ortuzar Ch 1  Skim Ortuzar 2‐3 |
| W2 | Fundamentals of Network Models   * Structure * Graphical Representation * Network Characteristics   + Link Flows   + Link Costs   + Link Bounds   + External Flows * Conservation of Flow * Algebraic Structure   + Primal/ Dual Formulation | Skim Ahuja Ch 1  Read Ahuja Ch 2  Lab: Introduction to the modeling software  Identify your team partner |
| W3 | Fundamentals of Network Models -Graph Theory   * Connectivity, constraint, tree, path, tour, degree,… * Minimum Spanning Tree * Edge Covering: Chinese Postman Problem * Euler tours and paths * Node Covering: Travelling Salesman problem * Heuristics Multi-route Node Covering Problem | Read related sections  from Ahuja Ch 3‐ 5.  Read Ortuzar Ch 1, 4.1  HW#1 will be posted  Lab: Introduction to 4-step demand model Software terminologies , zoning, Land Use , trip generation |
| W4 | Transportation Network problems   * The Hitchcock Problem, … * Transshipment Problems * General Network Optimization Algorithms | Read related sections from Ahuja Ch 3‐5  Read Ortuzar Ch 5.1, 5.2  Lab: Continue on 4‐step model discussion.   * # 1 Trip Generat * # 2‐Trips Distribution /Gravity Model   Review projects descriptions |
| W5 | Transportation Network problems- continue   * Minimum Path Algorithms * Label Correcting and Label Setting Algorithms * All Nodes to All Nodes Algorithms * K-Shortest Path Algorithm | Read related sections from Ahuja Ch 3‐5  HW#2 will be posted  Lab : Network coding , setup geometry, attributes, direction, functional class, connectors, Network visualization, GIS application |
| W6 | Network Trip Assignment   * Conceptual Formulations * Wardrop's Principle I - User Equilibrium * Wardrop's Principle II - System Optimal * Multipath Assignment (Dial's Algorithm)   Network Trip Assignment – continue   * Equivalency of Beckmann and Wardrop Formulations. | Read Sheffi Ch 1-3 (skim 2)  Lab: Continue on 4‐step model discussion.   * #3‐Mode split * # 4- Network assignment |
| W7 | Non-Equilibrium (Heuristic) Methods   * All-or-Nothing Loading * Capacity Restraint Assignment * Incremental Assignment * Iterative Assignment * Multipath / Probabilistic Assignment | Read Sheffi Ch 4-5 (skim 4)  Read Ortuzar Ch 10.1 ‐10.5, 10.7  HW#3 will be posted  Lab: Trip Assignment methods:   * Multiclass * Stochastic * AON |
| W8 | Review Assignment 1 and 2 ,  Review Sample Problems for Midterm | Lab: Review progress with each group, Q&A |
| W9 | Origin- Destination Matrix Estimation using Big Data as seed  Other Transportation Networks   * Supply chain/freight Network * Transit Network * Ride sharing Network * Multi modal networks   Special applications/ case studies/ research papers- presentation by students | Slides/ articles will be  provided  Lab: Big Data Platform (provide access to the cell phone/Connected vehicle data through one of the data vendors)  Review interim project report , Student presentations |
| W10 | Mid term  Project presentation | Student presentations |
| W11 | Network improvements   * Resiliency * Bottlenecks * Performance measures (PMs)   o Average and marginal cost  o VMT, VHT, V/C/ delay | Slides will be provided in advance.  Class notes.  Lab: Model Calibration and Validation (FHWA Guidelines), Exporting PMs |
| W12 | Overview of Travel Forecasting   * Sensitivity and Scenario analysis   Dynamic Traffic Assignment part 1: Elastic Demand | Slides will be provided  HW#4 will be posted  Lab: band width, select zone/link, Turning movement reports. |
| W13 | Dynamic Traffic Assignment part 2   * Variable Demand; Joint Travel Decisions; Link Interactions * Stochastic User Equilibrium | Class notes, Research articles  Read Sheffi Ch. 6, 11-12 (skim 10)  Lab: Scenario analysis, forecasting future year , final project troubleshooting |
| W14 | Dynamic Traffic Assignment part 3  Optional student presentations | Class notes, Research articles  Lab: Project’s QA , DTA in Cube  Project Report Due: last Friday |
| W15 | Review – Sample Problem solving | Lab: Project presentation |
| W16 | Final project due. |  |

**Statement on Academic Conduct and Support Systems**

**Academic Conduct:**

Plagiarism – presenting someone else’s ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Part B, Section 11, “Behavior Violating University Standards” [policy.usc.edu/scampus-part-b](https://policy.usc.edu/scampus-part-b/). Other forms of academic dishonesty are equally unacceptable.  See additional information in *SCampus*and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct.

**Support Systems:**

*Student Counseling Services (SCS) – (213) 740-7711 – 24/7 on call*

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention. [engemannshc.usc.edu/counseling](https://engemannshc.usc.edu/counseling)

*National Suicide Prevention Lifeline – 1 (800) 273-8255*

Provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week. [www.suicidepreventionlifeline.org](http://www.suicidepreventionlifeline.org/)

*Relationship and Sexual Violence Prevention Services (RSVP) – (213) 740-4900 – 24/7 on call*

Free and confidential therapy services, workshops, and training for situations related to gender-based harm. [engemannshc.usc.edu/rsvp](https://engemannshc.usc.edu/rsvp/)

*Sexual Assault Resource Center*

For more information about how to get help or help a survivor, rights, reporting options, and additional resources, visit the website: [sarc.usc.edu](http://sarc.usc.edu/)

*Office of Equity and Diversity (OED)/Title IX Compliance – (213) 740-5086*

Works with faculty, staff, visitors, applicants, and students around issues of protected class. [equity.usc.edu](http://equity.usc.edu/)

*Bias Assessment Response and Support*

Incidents of bias, hate crimes and microaggressions need to be reported allowing for appropriate investigation and response. [studentaffairs.usc.edu/bias-assessment-response-support](https://studentaffairs.usc.edu/bias-assessment-response-support/)

*The Office of Disability Services and Programs*

Provides certification for students with disabilities and helps arrange relevant accommodations. [dsp.usc.edu](http://dsp.usc.edu/)

*Student Support and Advocacy – (213) 821-4710*

Assists students and families in resolving complex issues adversely affecting their success as a student EX: personal, financial, and academic. [studentaffairs.usc.edu/ssa](https://studentaffairs.usc.edu/ssa/)

*Diversity at USC*

Information on events, programs and training, the Diversity Task Force (including representatives for each school), chronology, participation, and various resources for students. [diversity.usc.edu](https://diversity.usc.edu/)

*USC Emergency Information*

Provides safety and other updates, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible. [emergency.usc.edu](http://emergency.usc.edu)

*USC Department of Public Safety – UPC: (213) 740-4321 – HSC: (323) 442-1000 – 24-hour emergency or to report a crime.*

Provides overall safety to USC community. [dps.usc.edu](http://dps.usc.edu/)