CE 597-071: Dynamic Transportation Models

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Credits: 3 units

Prerequisites:
Undergraduate level knowledge of probability and statistics. College level linear algebra and discrete optimization. Interest in Networks.

Texts:
There is no required text book for this class. The course is primarily based on the instructors notes and research articles published in peer-reviewed journals. A set of relevant articles will be provided at the beginning of each block and the corresponding articles will be available in the online journals of the library or will be provided by the instructor.

Main References:

- Ahuja, R.K., Magnanti, T.L. and Orlin, J.B. *Network Flows: Theory, Algorithms and Applications*. Prentice-Hall Inc., 1993.
- Bell, M.G.H., and Iida, Y. *Transportation Network Analysis*. John Wiley & Sons, 1997. ISBN 0471 96493 X
- Cascetta, E. *Transportation systems engineering: theory and methods*. Dordrecht ; Boston, MA : Kluwer Academic, 2001.
- Sheffi, Y. *Urban Transportation Networks: Equilibrium Analysis with Mathematical programming methods*. Prentice-Hall Inc., Englewood Cliffs, NJ, 1985. [Out of print]. Available online for free.

Journal References:
Networks and Spatial Economics
Operations Research
Transportation Research – Part B (Methodology)
Transportation Science
Transportation Research Record

Course Description:

This course provides a firm grounding in modeling and optimization of dynamic transportation networks. A review of discrete optimization and static transportation network analysis will be provided in the first few lectures for the students to come up to speed. The course will discuss representation, modeling and algorithms for dynamic transportation networks including dynamic shortest paths and dynamic network equilibrium (game theory). Both analytical and simulation based network assignment models will be discussed. In addition, strategic issues such as network design and congestion pricing models will be discussed in the later sections of the course. The emphasis in this course is primarily on mathematical rigor, precise analysis of algorithms and the ability to solve such problems. Wherever relevant, practical issues related to the applications of dynamic network assignment will be discussed with real case studies. Some basic programming knowledge will be required for the problems sets and the paper.

Course Objectives:

A student completing this course is expected to be able to:

1. Rigorously formulate transportation systems evolving with time as dynamic network flow based problems.
2. Identify the importance of stochasticity in transportation networks and apply stochastic optimization techniques specialized for such transportation problems.
3. Ability to analyze and solve models to make better decision making under time dependency/uncertainty for improved system performance.
4. To understand how transportation networks research is done.

Tentative Course Outline:

Block 1 *Fundamental Concepts*

- Review of discrete optimization – Network Terminology, Network Representation, Complexity, shortest paths, Dijkstra's Algorithm (1.5 class)
- Fundamentals of Transportation Network Analysis – Deterministic user equilibrium, stochastic user equilibrium (1 class)
- Overview of modeling approaches in transportation systems (1 class)

Block 2 *Dynamic Network Modeling*

- Dynamic Network Representation (0.5 class)
- Time dependent shortest paths – algorithms, complexity and extensions (2 classes)
- Instantaneous and Predictive Dynamic Traffic Assignment – Analytical Formulations – mathematical programming formulation, Optimal control formulations and VI based formulations (7 classes)
- Dynamic Traffic Assignment – Simulation based approaches (4 classes)
- Overview of available DTA software – design issues and differences (1 class)

Block 3 *Transportation Systems evaluation under uncertainty – Stochastic Optimization Methods*

- Representation of uncertainty (0.5 class)
- Analytical approaches for capturing uncertainty in transportation networks (1 class)
- Notion of Robustness and Network Reliability in Transportation Systems (1 class)
- Stochastic Linear programming based network design problems (4 classes)
    1. Review of network design
    2. Hydrodynamic traffic flow models
    3. Cell Transmission Model (CTM) – Properties, advantages and limitations
    4. Development of CTM embedded DTA models
    5. Extension to Network design problems – analysis of the dual program, multi-stage stochastic programming approach.

Block 4 *Additional Topics*

- Modeling Approaches for Congestion Pricing (3 class)
- Approximation methods for stochastic network analysis – Monte Carlo simulation, sampling based approaches, output analysis of network data, bounds. (2 classes)
- Introduction to Network Science – Introduction to relationship with other domains such as Internet routing, telecommunication design, power systems and social networks. (1 classes)
- Paradoxes and Networks!

Format: Classes will be in a combination of lecture and discussion. Students are expected to participate actively in class discussions.

Homework:

- Four problem sets will be given, and the analysis of these assignments will be the basis for some class discussion
- Problem sets are due at the beginning of class on designated days; late problem sets will not be accepted.

Grading Policy:

Problem Sets	20%
Scribe Notes	10% (Approximately 3 lectures per student)
Exam	30%
Paper + Presentation	(35 + 5)%

For the problem sets, you may (are encouraged to) discuss with other students but the final written solution should be your own work. The exam is in class, open book and open class notes.

Paper:

The paper must be original and, if possible, related to your research. The paper should be prepared according to the guidelines of Transportation Research Record and should be of a comparable quality (lower bound). You will be assigned a peer reviewer (from the class) that will be following your progress in every step. He should read everything before you turn it in; with every progress report please attach the copy edited by your peer reviewer with all corrections/changes suggested. Additional information on the paper and list of possible topics will be provided by the instructor in the fourth week of the semester.

Student Feedback:

Throughout the semester, students are especially encouraged to bring attention of the professor any difficulties/issues encountered during the lectures. The primary purpose of this is to provide the instructor with continuous feedback on how to improve the classroom learning environment.

Student Conduct:

Students are expected to abide by the Purdue University Student Conduct Code. Further, it is assumed that each and every student subscribes to a personal code of ethics based on a value system that is adheres to the highest standards of academic integrity. Any breach of academic honesty or disruptive classroom behavior will be handled in accordance with established university procedures.