Indian Institute of Technology Kanpur

Proposal for a New Course

1. Course No.

2. Course Title: Analysis of Transportation Systems

3. Per Week Lectures: 3 (L), Tutorial: 0 (T), Laboratory: 0 (P), Additional Hours [0-2]: 0 (A),
   Credits: 9 Duration of Course: Full semester

4. Proposing Department/IDP: Civil Engineering
   Other Departments/IDPs which may be interested in the proposed course: DoMS, CSE
   Other faculty members interested in teaching the proposed course: N/A

5. Proposing Instructor(s): Hemant Gehlot and Aditya Medury

6. Course Description:

   A) Objectives: This PG course aims to cover mathematical foundations for analysis of transportation systems. In the beginning, basics of optimization will be covered and after that important combinatorial optimization problems with transportation applications will be discussed. Finally, there will be focus towards traffic assignment or infrastructure management problems.

   B) Contents:

   Module 1 (Compulsory): 20 lectures

S. No.	Broad Title	Topics	No. of Lectures
1(i)	Basics of optimization	Motivating optimization formulations, types of decision variables (continuous vs discrete), constraints as sets, functions as objectives, unconstrained optimization, convexity, global vs local optima, introduction to linear programming	10
1 (ii)	Combinatorial network optimization problems and solution approaches	Computational complexity, applications of network optimization problems (shortest path algorithms, minimum spanning tree, travelling salesman problem, vehicle routing problems, facility location, knapsack problems), approximation algorithms, heuristic and metaheuristic algorithms, integer programming algorithms such as branch-and-bound	10

After covering the basics of optimization, any one of the two modules listed below will be taught in a given semester.

Module 2 (Traffic assignment): 20 lectures

S. No.	Broad Title	Topics	No. of Lectures

2(i)	Introduction to traffic assignment	Beckmann's formulation, equivalency conditions, system-optimum formulation, Braess' paradox, convex combinations method, network loading models	7
2(ii)	Stochastic user equilibrium	Discrete choice models, stochastic network loading, stochastic user equilibrium	5
2(iii)	Dynamic user equilibrium	Link transmission model, node models, dynamic network loading models, time-dependent shortest path problems, dynamic user equilibrium	8

Module 3 (Infrastructure management): 20 lectures

S. No.	Broad Title	Topics	No. of Lectures
3(i)	Introduction to infrastructure management	Overview of maintenance rehabilitation and reconstruction (MR&R) decision-making and the associated sub-problems: network-level and facility-level optimization, performance models, inspection and data considerations; motivating the need for life cycle cost optimization, user vs agency costs; serviceability vs distress metrics, discrete vs continuous indices	4
3(ii)	Performance models	Deterioration and maintenance effectiveness models for discrete and continuous condition indices	4
3(iii)	Facility-level optimization problems	Optimizing decision-making for continuous and discrete condition states at the facility-level, dynamic programming, applications in maintenance optimization	6
3(iv)	System-level optimization problems	Finite horizon and infinite planning horizon problems; applications in budget allocation problems for pavement and bridge management.	6

C) Pre-requisites: Basic knowledge of calculus, probability, statistics and linear algebra. Basic programming skills.

D) Short summary for including in the Courses of Study Booklet: The course presents a systems perspective of transportation network operations and management. The course will cover the fundamental of optimization techniques and their applications in transportation engineering. After covering the basics of optimization, any one of the following two modules will be covered i) traffic assignment: introduction to traffic assignment, stochastic user equilibrium and dynamic user equilibrium ii) infrastructure management: modeling and optimization methods and their application to inspection, performance prediction and maintenance decision-making for the management of infrastructure systems such as highways, bridges, airfield pavements, railway tracks, etc.

7. Recommended Books:

Textbook: None

References:

1) Sheffi, Y., 1985. Urban transportation networks (Vol. 6). Prentice-Hall, Englewood Cliffs, NJ. (Publicly accessible at http://web.mit.edu/sheffi/www/selectedMedia/sheffi_urban_trans_networks.pdf)
2) Boyd, S. and Vandenberghe, L., 2004. Convex optimization. Cambridge university press. (Publicly accessible at https://web.stanford.edu/~boyd/cvxbook/)
3) Simchi-Levi, D., Chen, X. and Bramel, J., 2005. The logic of logistics. Theory, algorithms, and applications for logistics and supply chain management.
4) Cormen, T.H., Leiserson, C.E., Rivest, R.L. and Stein, C., 2022. Introduction to algorithms. MIT press.
5) Winston, W.L., 2004. Operations research: applications and algorithm. Thomson Learning, Inc.
6) Papadimitriou, C.H. and Steiglitz, K., 1998. Combinatorial optimization: algorithms and complexity. Courier Corporation.
7) Bertsimas, D., & Tsitsiklis, J. N. 1997. Introduction to linear optimization. Athena Scientific.
8) Washington, S., Karlaftis, M. G., Mannering, F., & Anastasopoulos, P. (2020). Statistical and econometric methods for transportation data analysis. CRC Press.

Additional Resources: None.

8. Other remarks: This course will be offered to PG students who register in the proposed course alongside the students who register in UG course CE382 (Transportation Systems Analysis).

Dated: 17/7/2024 Proposer: _____

Dated: _____ DPGC Convener: _____

The course is approved / not approved

Chairman, SPGC

Dated: _____