

CE 637 Infrastructure Systems: Planning and Management

Semester I, 2026-27 | Instructor: Prof. Udit Bhatia | Wednesday and Friday, 10:00-11:20 | Room 7/209

Course Intent

This course develops the analytical and computational foundations needed to plan, evaluate, and manage infrastructure systems under uncertainty. The emphasis is on infrastructure as a decision system: physical assets provide services, services face uncertain demand and hazards, agencies operate under budgets and institutions, and engineers must translate data and assumptions into defensible choices.

Learning Objectives

1. Represent infrastructure decisions using states, alternatives, consequences, constraints, and performance measures.
2. Use probability, statistics, and data summaries to quantify uncertainty in infrastructure demand, loading, deterioration, and hazards.
3. Construct and interpret decision trees, expected value calculations, utility-based choices, and value of information.
4. Formulate infrastructure allocation, maintenance, and network problems as optimization models and interpret their solutions.
5. Analyze reliability, risk, resilience, and recovery for components, systems, and networks.
6. Communicate assumptions, limitations, tradeoffs, and implementation implications clearly.

Course Breakdown

Block	Approx. dates	Main questions
Uncertainty and data for infrastructure	Aug 05-Aug 14	What is uncertain? What data do we trust? What assumptions are we making?
Decision analysis	Aug 19-Aug 28	How should we choose when outcomes depend on uncertain states of nature?
Optimization for planning and management	Sep 02-Sep 16	How do budgets, constraints, and tradeoffs become mathematical programs?
Reliability, risk, and resilience	Sep 25-Oct 16	How do components and systems fail, recover, and provide service after shocks?
Networks, interdependence, and implementation	Oct 28-Nov 18	How do connected systems propagate disruption, and how should plans be communicated?

Assessment Plan

Component	Weight	Notes
Assignments	30%	A0-A3; individual unless stated otherwise.
Quizzes	10%	Surprise and/or announced quizzes; no phone, laptop, or electronic device.
Mid-semester examination	20%	Closed book and closed notes unless explicitly announced otherwise.
End-semester examination	25%	Closed book and closed notes unless explicitly announced otherwise.
Project	15%	Infrastructure planning and management analysis with defensible assumptions.

Submission and Classroom Policies

- All assignments must be submitted as a single PDF using the file name convention <roll_number>_<first_name>_<last_name>. Code, if any, should be attached as an annexure unless instructed otherwise.
- Evaluation will focus on correctness, reasoning, assumptions, interpretation, and learning quality, not on the length of a submission.
- AI and GenAI tools may be used for assignments, but students are accountable for the final answer. Viva on any assignment may happen at the discretion of the instructor.
- Students must maintain a separate course notebook and bring it to class. Only this notebook may be allowed for open-notebook quizzes or exams if such an assessment is announced.
- No cellphones or laptops are allowed in class unless explicitly requested for a tutorial or activity.
- Class doors close after 5 minutes. There is no make-up credit for a quiz missed because of late arrival.

Lecture Calendar

Lec.	Date	Topic	Focus
1	Aug 05	Infrastructure Systems as Decision Systems	Course objectives; assets, services, institutions, data, constraints, uncertainty, and decisions.
2	Aug 07	Probability Refresher for Infrastructure	Events, conditional probability, random variables, expectation, variance, quantiles, return periods.
3	Aug 12	Distributions, Data, and Estimation	Empirical distributions, parametric distributions, sample statistics, estimation, uncertainty.
4	Aug 14	Infrastructure Data and Model Assumptions	Measurement error, missing data, censoring, aggregation, sensor and administrative data, assumption audits.
5	Aug 19	Decision Trees and Expected Value	Alternatives, states of nature, consequences, expected monetary value, expected loss.
6	Aug 21	Utility, Risk Attitudes, and Value of Information	Utility, risk aversion, certainty equivalent, expected value of information, staged investigation.
7	Aug 26	Influence Diagrams and Multi-Criteria Decisions	Influence diagrams, objectives, constraints, criteria, scoring, pairwise comparison, transparency.
8	Aug 28	Linear Programming for Infrastructure Allocation	Decision variables, objective functions, constraints, slack, shadow prices, feasible regions.
9	Sep 02	Simplex Method and Sensitivity	Extreme points, basis, binding constraints, post-optimality reasoning, operational interpretation.
10	Sep 04	Integer and Network Optimization	Binary decisions, knapsack, set covering, shortest paths, location, routing, maintenance planning.
11	Sep 09	Multi-Objective Planning and Tradeoffs	Pareto efficiency, weighted objectives, epsilon constraints, cost-equity-risk tradeoffs.
12	Sep 11	Metaheuristics for Simulation-Based Planning	Genetic algorithms, simulated annealing, particle swarm optimization, constraint handling, diagnostics.
13	Sep 16	Mid-Semester Synthesis	Probability, decision analysis, optimization, interpretation, and exam-oriented problem solving.
Mid-sem	Sep 18-23	Mid-semester examination window	Exact examination date as per institute schedule.
14	Sep 25	Component Reliability	Limit states, failure probability, reliability index, load and resistance, fragility.
15	Sep 30	System Reliability	Series and parallel systems, minimal paths and cuts, redundancy, common-cause failures.
No class	Oct 02	Holiday	No lecture scheduled.
16	Oct 07	Markov Chains and Deterioration	Condition states, transition matrices, inspection intervals, maintenance policies, lifecycle reasoning.
17	Oct 09	Risk, Exposure, Vulnerability, and Loss	Hazard, exposure, vulnerability, consequence models, expected annual loss, risk curves.
18	Oct 14	Resilience Metrics and Recovery	Service curves, recovery functions, robustness, rapidity, resourcefulness, adaptation.
19	Oct 16	Infrastructure Networks	Graph representation, connectivity, flows, centrality, robustness, critical links and nodes.
Recess	Oct 17-25	Mid-semester recess	No regular lectures.
20	Oct 28	Interdependence and Cascading Failure	Coupled systems, dependency matrices, failure propagation, restoration priority.
21	Oct 30	Climate Risk and Infrastructure Adaptation	Non-stationarity, design life, scenario analysis, robustness, adaptive planning.
22	Nov 04	Asset Management and Lifecycle Planning	Inspection, deterioration, lifecycle cost, maintenance scheduling, budget-constrained planning.
23	Nov 06	Data-Supported Infrastructure Management	Dashboards, monitoring, digital records, uncertainty communication, governance and accountability.
24	Nov 11	Case Clinic: Roads, Stormwater, and Public Facilities	Integrated formulation using probability, optimization, reliability, and implementation constraints.

Lec.	Date	Topic	Focus
25	Nov 13	Project Studio and Communication	Problem framing, quantitative evidence, assumptions, limitations, and technical communication.
26	Nov 18	Course Synthesis	Connecting decisions, uncertainty, optimization, reliability, resilience, and responsible infrastructure management.

Calendar may be adjusted for institute notifications, class progress, or unavoidable disruptions. Assessment windows will follow institute rules.

Assignments and Project

Item	Title	Planned release	Nature
A0	Infrastructure Mathematics and Systems Primer	Planned release: Aug 05	Individual written prerequisite and systems-thinking refresher.
A1	Decision Trees and Value of Information	Planned release: Aug 21	Applied decision analysis problems using infrastructure choices under uncertainty.
A2	Infrastructure Allocation as Optimization	Planned release: Sep 11	LP/IP/network formulations and interpretation for public works planning.
Project	Infrastructure Planning and Management Project	Planned release: Sep 25	Teams of two; individual projects require prior approval. Includes framing, analysis, and communication.
A3	Reliability, Risk, and Resilience Analysis	Planned release: Oct 09	Failure probability, system reliability, risk, and recovery metrics.

Reference Books and Sources

- Alfredo H-S. Ang and Wilson H. Tang, Probability Concepts in Engineering Planning and Design, Volume II: Decision, Risk, and Reliability. Core reference.
- Alfredo H-S. Ang and Wilson H. Tang, Probability Concepts in Engineering Planning and Design, Volume I: Basic Principles.
- Yacov Y. Haimes, Risk Modeling, Assessment, and Management.
- Sheldon M. Ross, Introduction to Probability Models.
- Frederick S. Hillier and Gerald J. Lieberman, Introduction to Operations Research.
- Mark Newman, Networks.
- Udit Bhatia, Critical Infrastructure Resilience: Policy and Engineering Principles.
- Selected papers, case studies, and official datasets will be assigned during the semester.

Source note: this draft uses the recovered CE637 course proposal, CE637 qualifier material, and the Semester I, 2026-27 IITGN timetable entry for CE 637.