1.200 Transportation Systems Analysis
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Course Overview (1)

- The course has two basic parts, organized by model type, stochastic and deterministic. Within each part, we will cover a set of models and solution methodologies. However, the structure of the course will be problem-centric to the largest extent possible. That is, we present the models and solution methodologies in the context of a set of transportation problems. This is not a math course. We will examine the role of these models in an overall methodology of Transportation System Analysis.
- The transportation problems we will examine will be taken primarily from air and rail transportation problems. The following table lists the models/methods we will study in the course.

Stochastic	Deterministic
Probability spaces	Linear Programs
Random variables	Duality
Distributions	Networks
Stochastic processes	Integer programs
Queues	Decomposition
Statistics	Heuristics
Estimation	
Hypothesis testing	
Regression	

Course Overview (2)

Examples will be drawn primarily from:

- Air transportation
  - Air traffic flow management
    - Ground delay
    - Airport configuration management
  - Airline operations
- Rail transportation
  - Line planning and control
  - Yard planning and control
  - Network planning and control

Steps in Transportation Systems Analysis

- Problem understanding and formulation
  - Operational analysis: study current operations and procedures
    - Site visits
    - Documentation
  - Literature review
- Functional analysis
  - What must be done, not how it must be done
    - Better to model functionally and then put operational layer on it
  - System components and their relationships
- Decomposition
  - Hierarchical decomposition common
  - Makes complex problems manageable
  - Formal approaches to augment “seat-of-the-pants”

Steps in Transportation Systems Analysis: Decision Aids (1)

- Modeling and simulation
  - Multiple levels of fidelity
    - Simple statistical model
    - Detailed simulation model
  - Object-oriented
- Heuristic algorithms
  - Utilize problem structure in development of heuristic algorithms for decision support
  - Solutions using heuristic algorithms are not necessarily optimal
  - Typically can bound performance
  - "Good solutions, cheap"
    - Means that "good" solutions can be calculated quickly
    - "Good" is typically good enough since difficult to specify "optimality" in problems with multiple goals
    - Quickly is needed because the dynamic nature of real-world operations requires real-time resolving capability, time to solve is an input
    - If there is time, can let heuristics run longer to find better and better solutions

Steps in Transportation Systems Analysis: Decision Aids (2)

- Large-scale system optimization (this example is taken from Prof. Barnhart's work)
  - Determines optimal solutions to huge integer programs without evaluating all variables
    - Combines branch-and-bound with column generation and cut generation to solve the LP's
    - Requires a combination of domain knowledge and large-scale transportation modeling experience
  - Decomposition: solve large-scale problem by repeatedly solving smaller problems
    - Success of approach depends on ease of solution of sub-problems
    - Intelligent optimization: using heuristics to guide and speed-up optimization approach
    - Exploitation of problem structure and domain knowledge
- Open computer architecture
  - Meaning of "open" changes over time

Decision Aid Development

- The methodology should provide a structure for the creation of tools that aid decision makers in making intelligent, informed decisions
- The tools should be easy to use and allow for "closed-loop" decision-making, i.e., tracking the current set of decisions and adjusting the decisions given the best, latest information — one important way to handle dynamic stochastic behavior of most transportation systems
- Tools are best developed incrementally, with increasing capability added in stages
  - An incremental strategy results in elements of the decision aids that can be made available early on
  - Thus, at each stage
    - A deliverable decision aid
    - ***Customer concurrence and feedback***

Baseline Tool Development Methodology

- Develop a database with data objects and models of the functional dependencies among data objects
- Develop the specific decision framework description; i.e., a "language" to describe a decision, not an actual decision itself
- Develop or apply heuristic methodologies that generate feasible decisions among the set of decisions
- Develop a metric or metrics for evaluation of decisions
- Develop or apply heuristic search methodologies that generate good decisions among the set of feasible decisions
- Develop or apply optimization-based search methodologies

- At each stage, there should be a "user-friendly" graphical user interface (GUI) providing data visibility and appropriate capability
  - What "User-friendly" means should be determined by the ***users***