Optimization Theory and Methods

2025 Autumn

同济经管 TONGJI SEM

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https://kejiwei.github.io/

CAMEA 中国高质量MBA教育认证 AACSB ACCREDITED EQUIS ACCREDITED

Keji Wei: Academic and Professional Journey

同济经管 TONGJI SEM

Academic Background:

- **Xi'an Jiaotong University**
  Undergraduate in Automation
- **Dartmouth College**
  Ph.D *Operations Research*
  -Advanced studies in optimization and decision-making processes.

Professional Experience:

- **Sabre**
  Research Scientist
  -Leading research in operations research and its applications in the airline industry.
- **Tongji University**
  Associate Professor (tenured), Department of Management Science and Engineering
  -Specializing in optimization, operations research, and transportation systems.

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Policy

- ☑ **No Laptop, No cell phones**
- ☑ **English or Chinese is okay**
- ☑ **Attend all classes on time**
- ☑ **Answer questions actively**
- ☑ **Solve everything before final exam**

Course Web Site:

https://kejiwei.github.io/teaching/courses/OTM/

- **0.1 Course Content**
  - **Optimization Theory and Methods & Operations Research (OR)**
  - **Why Study Operations Research?**
  - **Optimization Problems**
- **0.2 Course Objectives**
- **0.3 Course Logistics and Personnel**
- **0.4 Reference text and Software**
- **0.5 Course Work and Grading**
- **0.6 Suggestion**

Operations Research (OR)

- **Definition:** as per INFORMS (a professional OR society):
  A discipline that deals with the application of advanced analytical methods to help make **better decisions**. Synonyms include 'Management Science' and 'Analytics'.
- **Origin:**
  - ✓ Military planners in WWII were the first to use these techniques.
  - ✓ For improving the operational efficiency of systems, in that case, radar defense systems.

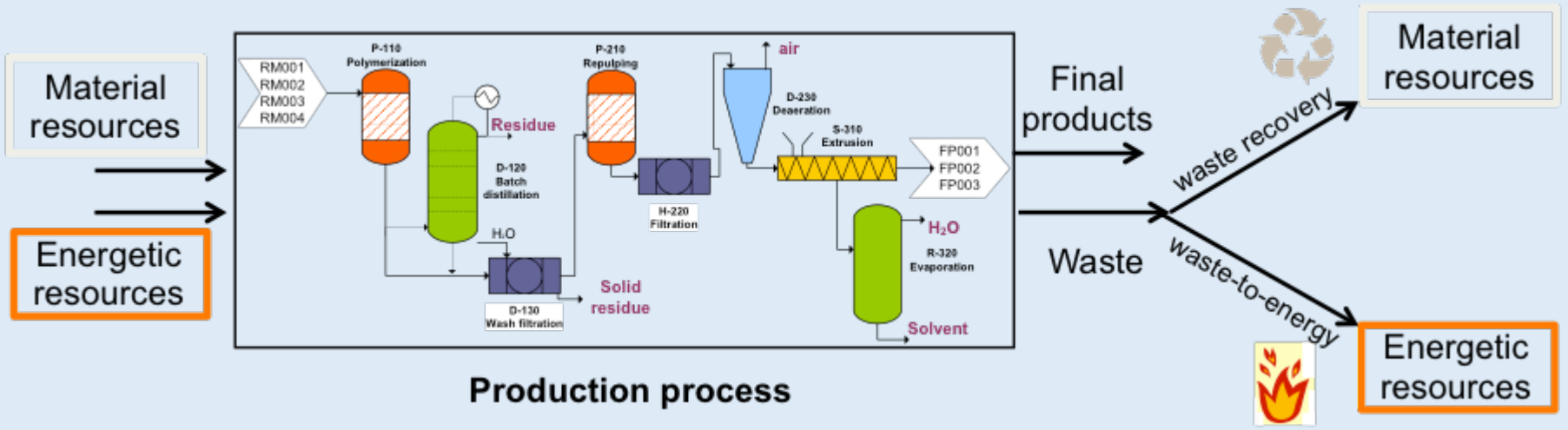
Operations Research (OR)

- **OR techniques include:**
  - ① Linear/non-linear/integer/combinatorial optimization.
  - ② Network optimization/graphical models.
  - ③ Queuing theory.
  - ④ Simulation.
  - ⑤ Game theory.
  - ⑥ Inventory theory; AI related etc.

- If you are interested in either ***research or practice*** in either engineering or business OR can help.
- ***Economy sectors*** actively using OR techniques include：
  Manufacturing, Logistics, Supply Chain, Transportation, Services, Telecommunications, Computing/IT/Internet, Energy, Healthcare, Finance, Marketing, Disaster Relief, Policy/Government….
- ***Engineering disciplines*** that particularly benefit from OR include：
  Aerospace engineering, Biomedical engineering, Civil engineering, Chemical engineering, Computer engineering, Electrical engineering, Industrial engineering, Mechanical engineering, Systems engineering.
- Even if you are not interested in any of the above, OR can still help：
  Remember, it is about ***Advanced Analytical Methods*** to Help Make Better Decisions in any aspect of life.

Manufacturing, Processes and Services

- Electricity/energy distribution
- Computing resource usage
- Medical resource allocation (organ donation, providers)
- Chemical process engineering
- Component design and production
- Telecommunications networks.



From: https://emeritus.setg.ethz.ch/research/process-design-and-optimization.html

Complex Logistics & Transportation Systems

- Airline scheduling and routing
- Public transit and ride share
- Shipping and delivery

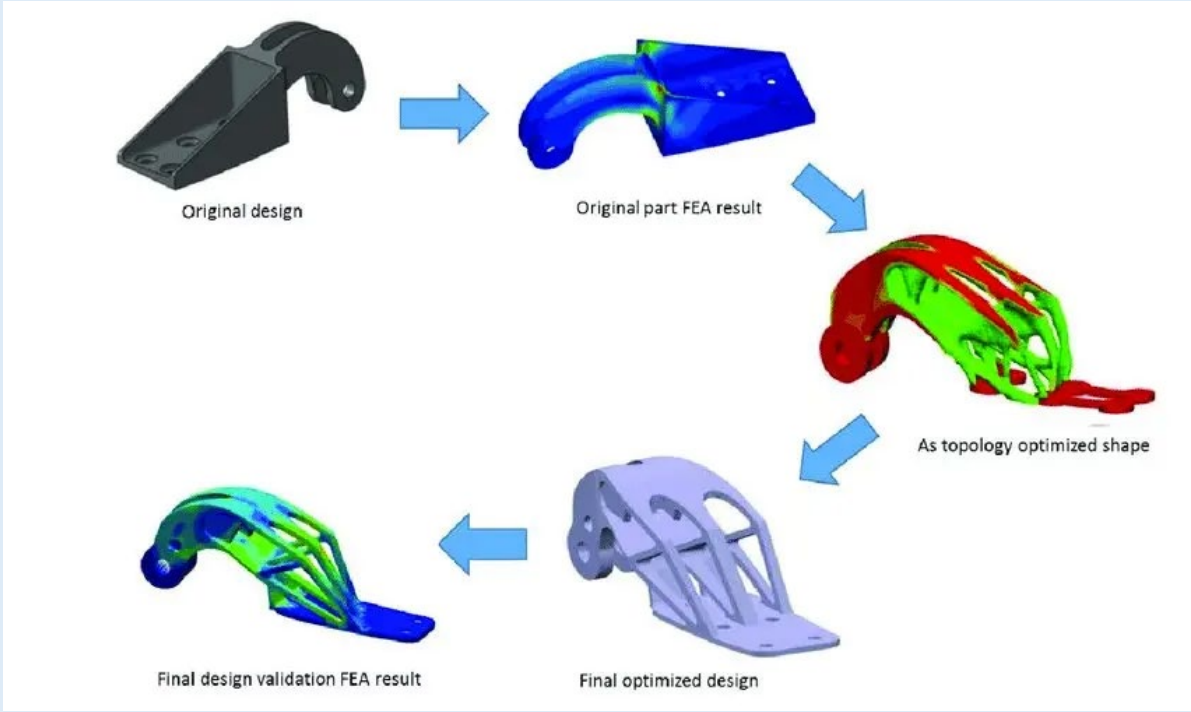
New scheduling tool offers both better flight choices and increased airline profits

by Thayer School of Engineering at Dartmouth

Vaze is currently working on a follow-up paper that will incorporate revenue management considerations into scheduling and fleet assignment.

More information: Keji Wei et al, Airline Timetable Development and Fleet Assignment Incorporating Passenger Choice, *Transportation Science* (2019). DOI: 10.1287/trsc.2019.0924

- **Other Domains**
  - Mechanical engineering design (topology optimization)
  - Robotics
  - Data fitting (machine learning)
  - Bioinformatics, aeronautics



From: https://formlabs.com/blog/topology-optimization/From

- **Distribution network:**
  - Transport, energy, bandwidth, healthcare providers.
  - Finite resources (e.g., aircraft, crew)
- **Network interconnection (resources fulfill multiple demands) Trade offs:**
  - Cost/quality of service (flight time, wait time)
  - Robustness of network to disruption
- **Once network disrupted, how difficult to recover?**

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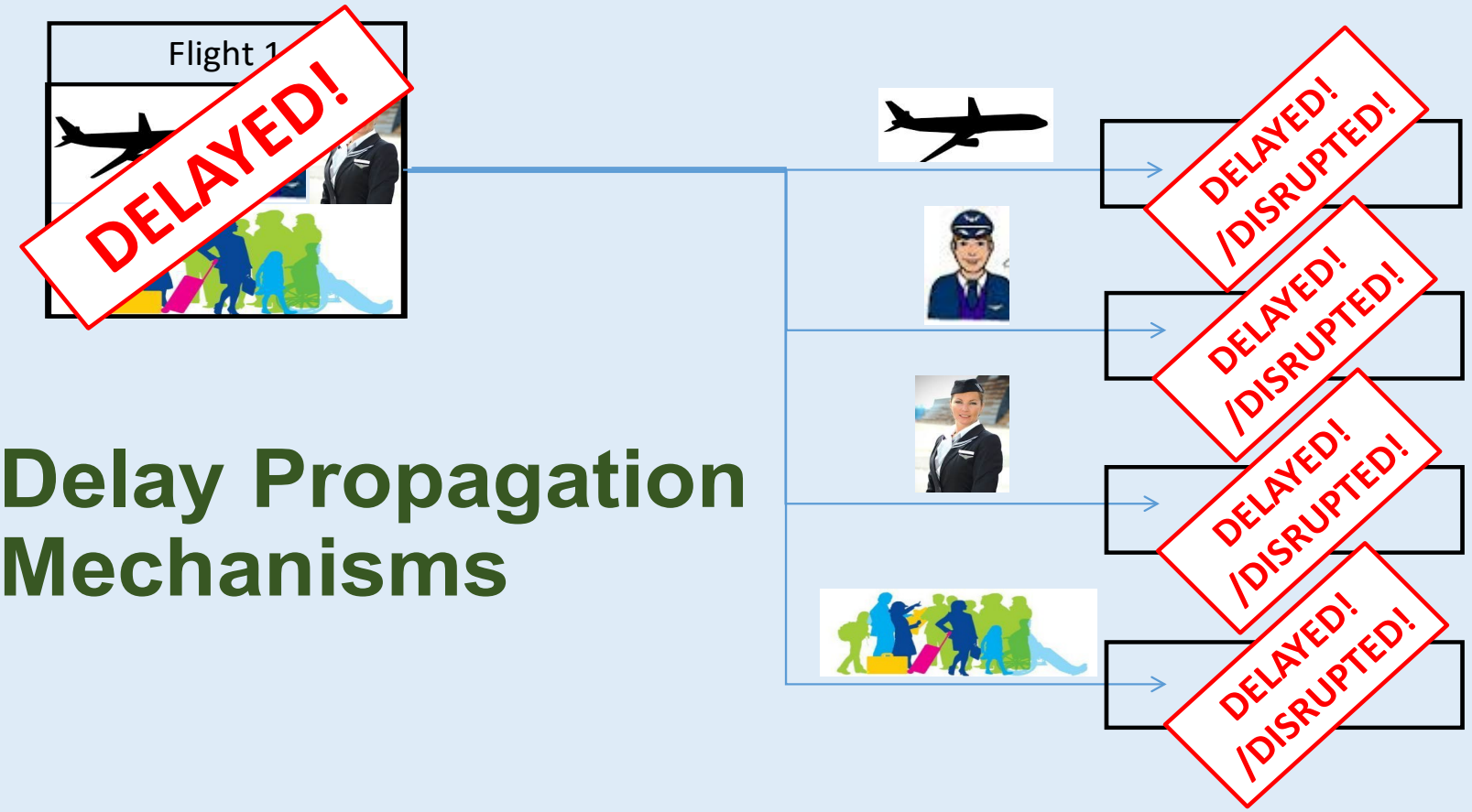
When Resource Allocation Networks Fail…



0.2 Course Objectives

- **After taking this course the students should be able to:**

  1) Convert real-world problems into OR models and appreciate the importance of strong formulations and fast algorithms. Distinguish between problems that can be solved exactly, approximately, and not at all, using fast algorithms.

  2) Appreciate the flexibility of network models, formulate and solve real-world engineering and business problems using a variety of network models.

  3) Analyze the concept of algorithmic complexity, including the classes P, NP, and NP-hard, their relationships, and the notion of reducibility.

0.2 Course Objectives (cont'd)

- **After taking this course the students should be able to:**

  4) Identify and model situations involving multi-agent decision-making, and apply equilibrium concepts to analyze them.

  5) Understand the concepts of the most commonly used AI algorithms and learn about the development of GPT.

0.3 Course Logistics and Personnel

- **Class Times :** Thursday, 8:50 am – 12:00 pm
- **Venue:** Building A 401 Week [1-2, 4-9].
- **Instructor:** Keji Wei (kejiwei@tongji.edu.cn)
- **Office Hours:** Fr.: 1:30 – 2:30 pm Building A 1229
- **TA**: Xiaoyun Niu, Fr.: 11:00 – 11:59 am Building A Floor 12
- Course Web Site:

  https://kejiwei.github.io/teaching/courses/OTM/

0.4 Reference text and Software

- **Required Text:** None
- **Optional Text:**

  1) Bertsimas, D., and J.N. Tsitsiklis. Introduction to Linear Programming.

  2) Ahuja R.K., T.L. Magnanti, and T.L. Orlin. Network Flows: Theory, Algorithms and Applications.

  3) Larson, R.C., and A.R. Odoni. Urban Operations Research.

  4) Fudenberg, D., and J. Tirole. Game Theory.

- **Software:** Python/Matlab

  Download Address: https://software.tongji.edu.cn

0.5 Course Work and Grading

Grading	Percentage	Instruction
Attendance/Discussion	5%	When I took the course, I tried my best to attend every discussion and ask questions whenever I was confused!
Course Project	35%	Report (15%), presentation (10%) and peer review (10%).
Final exam	60%	Students are permitted to bring a single A4 sheet into the exam room to record essential information. Electronic devices are not allowed.

0.5 Announcements: Project

- Choose a team of **at Most by 5** by Sept 31th at 11:59 pm. Review example proposals posted on website.
- Start thinking of the details of the problem description and the solution approaches you will use.
- Pick a problem statement of your interest. It can be anything of your liking as long as you can use OR techniques taught in the class for solving it. Solve a problem of practical interest.
- Use real data if possible. If not possible, then made-up data is ok.
- **Justify Each and Every Decision: Always be ready to answer What Why How?** Choice of problem context, Choice of problem statement, Choice of data, Choice of model, Choice of solution algorithm, Choice of software used.
- Interpret results and make practical recommendations.

0.5 Project: Important Dates and Deliverables (1)

- Final Project Proposals due: Oct 24th
- Email to me as a PDF.
- Project proposals (at most 1 page long) should include:
- Title
- Names of team members
- Problem context and tentative problem statement (Small modifications to exact problem statement are ok after Week 4).
- Tentative plan for the following:
- Where will you get the data from?
- What will be the types of models/algorithms/software you will likely use?
- What do you expect to conclude at the end?
- Discuss draft proposals with the instructors ahead of time if you would like our inputs on any aspect.
- We are happy to help you define problem statements, if you want.

0.5 Project: Important Dates and Deliverables (2)

- Final Report due: Nov 14th
- Uploaded onto Canvas as a PDF.
- Main text: At most 4 pages in length.
- Appendix is optional: Can be at most 6 pages in length.
- Can include tables, figures, algorithms, and/or code.
- Project Presentations: – during class time.
- Each presentation will be, at most, $4n$ minutes long (where n =number of team members). Each presentation will be followed by 4 minutes of questions/answers.
- Every team member should present some part of presentation.
- Project Report + Presentation is worth 25% of the overall grade in this course. And peer review is worth 10% of the grade.

0.6 Suggestion

- Solve additional exercises from text books
- Prepare lesson content in Advance
- Think and finish exams independently
- Fully utilize TA/Instructor resources

?Let me know if you have any questions/suggestions.

(kejiwei@tongji.edu.cn)