# IE 535 Network Theory and Applications
Fall 2024

## 1 Course Contact

- Class Meetings: Tuesdays and Thursdays 10:30–12:00, E2 산업경영학동 1119
- Instructor: Professor Changhyun Kwon (권창현)
  - chkwon@kaist.ac.kr
  - https://www.chkwon.net
- Course Content:
  - https://klms.kaist.ac.kr/course/view.php?id=160377
  - http://bit.ly/ie535

## 2 Course Description

This graduate course focuses on mathematical optimization and equilibrium problems involving network systems arising in logistics, traffic management, telecommunication, urban science, spatial economics, etc. It covers a range of topics, starting with a review of linear programming and graph theory, and then studying network optimization from both theoretical and algorithmic perspectives. The course further explores the characteristics of network user equilibrium, extending the study of nonlinear optimization theory. This graduate course serves as a foundation for students to conduct research in industrial engineering, operations research, transportation engineering, computer science, and applied economics, providing them with the skills to analyze, optimize, and design efficient network systems.

## 3 Prerequisites

No formal prerequisites, but a course in linear programming, IE331 or IE531, is strongly recommended.

## 4 References

There is no required textbook, but the following books will be used as a basis for part of the lectures. Reading lists will be provided.

- Bazaraa, Jarvis and Sherali, *Linear Programming and Network Flows*, 4th Edition, Wiley, 2010. eBook
- Korte, Vygen, *Combinatorial Optimization: Theory and Algorithms*, 6th Edition, Springer, 2019, eBook
- Friesz and Bernstein, *Foundations of Network Optimization and Games*, Springer, 2016, eBook
- Cormen, *Introduction to Algorithms*, 3rd Edition, MIT Press, 2009. eBook

Other useful references include:

- Bertsekas, *Network Optimization: Continuous and Discrete Models*, Athena Scientific, 1998

- Ahuja, Magnanti and Orlin, *Network Flows: Theory, Algorithms, and Applications*, Prentice Hall, 1993
- Cook, Cuttningham, Pulleyblank, Schrijver, *Combinatorial Optimization*, Wiley, 1997.
- Sheffi, *Urban Transportation Networks: Equilibrium Analysis with Mathematical Programming Methods*, Prentice-Hall, 1984, eBook
- Patriksson. *The Traffic Assignment Problem: Models and Methods*, Courier Dover Publications, 2015.
- Facchinei and Pang, *Finite-Dimensional Variational Inequalities and Complementarity Problems, Volumes I and II*, Springer, 2003, eBook

## 5 Topics Covered

- Basics of Linear Programming
- Minimum-Cost Network Flow Problem
- Network Simplex Method
- Transportation Problem
- Assignment Problem
- Maximum Flow Problem
- Shortest Path Problem
- Matching Problem
- Basics of Nonlinear Programming
- Network Games and User Equilibrium
- Complementarity and Variational Inequalities
- Stochastic Network User Equilibrium
- Braess Paradox and Price of Anarchy
- Congestion Pricing

## 6 Grading

- 45% Homework Assignments
- 25% Mid-term Exam
- 25% Final Exam
- 5% Class Participation

## 7 Course Schedule (Tentative)

- Week 1: introduction to the course, review of linear programming
- Week 2: introduction to graph theory, minimum-cost network flow problem
- Week 3: Chuseok (추석) / Julia for LP, shortest path, minimum spanning tree
- Week 4: total unimodularity, network simplex method, time complexity
- Week 5: problem classes (P, NP, NP-complete, NP-hard), data structures (array, list, queue, d-heap)
- Week 6: data structures for networks (Fibonacci heap, incidence matrix, adjacency matrix, adjacency list, forward star, reverse star)

- Week 7: connectivity, graph scanning algorithm
- Week 8: Mid-term Week
- Week 9: minimum spanning tree, Kruskal's algorithm, Prim's algorithm, IP formulation
- Week 10: maximum flow problem, minimal cut problem, max-flow-min-cut theorem, shortest path problem, Dijkstra's algorithm
- Week 11: label-correcting algorithm, robust shortest-path problem, conditional value-at-risk
- Week 12: Monte Carlo simulation, introduction to nonlinear optimization, network games, and equilibrium
- Week 13: Wardrop equilibrium, nonlinear complementarity problem, variational inequality problem, Braess paradox
- Week 14: Frank-Wolfe algorithm, price of anarchy, sensitivity
- Week 15: Nash equilibrium, bounded rationality
- Week 16: Final Exam Week