Fall 2021

EMIS 8383 Advanced Logistics Networks

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Description of the Course:

This is an advanced course focusing on several topics in logistics with a network design perspective. The emphasis will be on mathematical modelling, analysis and efficient solution methodologies. Background in optimization (linear and integer programming) and some programming experience, preferably with C++, are required.

There are three components of this course:

The first involves lectures in which the instructor covers several fundamental models, exact and heuristic solution algorithms, and analysis. Topics include facility location-allocation, production/distribution system design, multi-commodity flow network design, vehicle routing, location/routing, etc. Once this component is finished, an exam is given on the material.

In the second component, you are first required to identify three topics from the course outline (your choice of three, but the final decisions will be made with the instructor). Then, you will need find three published research articles (preferably recent and/or seminal articles) on each topic. For this purpose, you should utilize the "Topics and Some Literature" section below which provides you only a starting point to search the literature to find recent articles. This component is also initiated with the first component, and by the end of the fourth week of semester, you should provide the instructor with a list of your 9 papers for approval. Following a template provided by the instructor, you prepare short summaries of these 9 papers (at most 2 pages each). Then, we pick 2 or 3 papers (depending on the progression and time availability in the semester) from your 9 papers (either from the same topic or from two different topics) and you prepare and deliver a presentation of these two papers. In doing so, you also lead the discussion with the rest of the class on that topic.

The third component involves implementations of some of the algorithms covered in the previous components. Your implementation should be able to read the input data (using available data or synthetic data you generate) from an input file, execute the algorithm to solve the associated problem and present the results in an easily understandable output file. For an implementation, you are also required to prepare a short documentation outlining the problem and the algorithm first, and then presenting the data structures and components (procedure, subroutines, etc) of the whole program.

Grading: The grading for the class will be based on a
Component 1: Midterm Exam (35% - based on approximately the first half of the semester),
Component 2: Term Paper and Presentations (35% - topics selection, preparation, presentation, report, must use LaTeX(templates provided),
Component 3: Projects (30% - completeness, correctness, efficiency, documentation).

Course Outline:

1. Review of Facilities Location Problems
2. Discrete Facilities Location-Allocation Problems
3. Production/Distribution System Design
4. Multi-commodity Flow Network Design
5. Hub-and-Spoke Network Design Problems
6. Routing Problems
7. Integrated Location-Routing Problems
8. Applications in Supply Chain Logistics and Communications

References (No textbook):

1. G. Ghiani, G. Laporte and R. Musmanno, Introduction to Logistics Systems Management, 2013, John Wiley and Sons, West Sussex, England.
2. P.B. Mirchindani and R. L. Francis (Eds.), Discrete Location Theory, 1990, John Wiley and Sons, NY.
3. M.S. Daskin, Network and Discrete Location: Models, Algorithms and Applications, 1995, John Wiley and Sons, NY.
4. P. Toth and D. Vigo (Eds.), The Vehicle Routing Problem, 2001, SIAM, Philadelphia, PA.
5. R.K. Ahuja, T.L. Magnanti and J.B. Orlin, Network Flows: Theory, Algorithms, and Applications, 1993, Prentice-Hall, NJ.
6. J. Bramel and D. Simchi-Levi,Logic of Logistics: Theory, Algorithms, and Application for Logistics Management, 1997, Springer-Verlag, NY.
7. D. Simchi-Levi, P. Kaminsky and E. Simchi-Levi, Designing and managing the supply chain: concepts, strategies, and case studies, 2003, McGraw-Hill, NY.

Methodologies:

Commonly used solution procedures for the topics above include Branch-and-Cut Methods, Benders Decomposition, Lagrangian Relaxation, Dual-based Methods, Heuristic Techniques.

Topics and Some Literature

You can reach to a wealth of literature using library resources at `http://www.smu.edu/CUL` In particular, you can search for e-journals subscribed by the university and request for articles not available electronically by using electronic delivery resources (pdf to be downloaded). A good way to search for articles related to one you have is to use the Citation Index or the Google Scholar (`http://scholar.google.com/`). SMU has electronic subscription to Citation Index and it is available at `http://apps.webofknowledge.com/`.

- **Facilities Location-Allocation problems** are concerned with the selection of new facility sites out of a set of candidate locations and the allocation of customers to these facilities. Thus, they are in the general class of discrete location models. There are two major classes of problems in this category:

  Uncapacitated problems where there are no capacity restrictions on the new facilities. This is a very widely studied problem, well-known results are obtained using Lagrangian relaxation [1, 2, 3] and the infamous dual-based iterative heuristic procedure [4].

  Capacitated problems where the total demand assigned to a new facility cannot exceed the capacity of the facility. There are two subclasses of this type of models: Multi-sourcing where a customer can receive its total demand in portions from different new facilities [5, 6, 7]; and Single-sourcing models where each customer must be assigned to a single new facility [8, 9, 10].

- **Production-Distribution System Design (PDSD) problems** These are mostly 2-stage production-distribution systems involving *plants-distribution centers (warehouses)- customers* (some recent studies consider 3-stage systems also including suppliers of the plants). Each customer location specifies demand for different commodities. Design questions involve the location of distribution centers, sometimes also the location of plants in the presence of capacity constraints, the specification of the flow of commodities from plants to customers through distribution centers. Modelling and solution studies and discussions include [11, 12, 13, 14, 15, 16, 17].

- **Product Recovery Supply Chain Network Design problems** In the area of supply chain network designs that include product recovery (e.g. remanufacturing), the studies can be classified under two general headings including reverse logistics network design (RLND) and closed-loop supply chain network design (CLSCND). The former usually includes 2-stage systems where returns, e.g. at retail locations, are sent to collection centers for sorting, inspection, etc. and then, to remanucaturing locations [18, 19, 20, 21]. That is, in a sense, these are reverse PDSD networks. In the latter, the PDSD and RLND structures are considered together where the loop is closed via shipments from remanufacturing locations to distribution centers [22, 23, 24, 25, 26, 27].

- **Multi-commodity Flow Network Design problems** studies generally began to appear in the 80's, after the deregulation of transportation services in the United States, when a

severely competitive environment forced the common-carriage companies to search for ways to improve the efficiency of their operations. Early studies [28, 29, 30, 31, 32, 33, 34, 35] were usually practical cases that provided theoretical insight and an introduction to the general network design area, mostly in the context of freight transportation. There are two mainstream equivalent formulations for network design/arc loading models:

***Arc-based*:** The decisions relate to which arcs should be created and how the commodities should be assigned to these arcs. In most of these studies, commodities can be bifurcated so that portions of the commodity can follow different routes from origin to destination.

***Path-based*:** All of the possible paths for the commodities are considered as decision variables.

There are primarily two classes of problems utilizing these formulations.

Uncapacitated network design models concern the routing of multi-commodity flows over general networks where there are fixed charges associated with each arc [36, 37, 38, 39, 40]. Concave arc cost models are considered in some studies [41, 42, 43, 44].

Capacitated models, attracted the attention of researchers only recently [45, 46, 47, 48, 49, 50]. These are usually motivated by telecommunication applications where communication lines with different capacities must be considered in designing networks. Recent reviews of general network design and the freight transportation area can be found in [51, 52, 53, 54, 55]; also see [56] for an extensive early bibliography.

- **Hub location problems** generalize the above discussed network design/loading models by incorporating hub locations as decision variables. However, the hub networks are primarily designed with a prespecified number of hubs with large capacities, e.g. location of airline hubs. These designs assume that the hubs form a complete graph and that the flows on the network must pass through at least one hub. Formulations of various hub location problems, such as p-hub median and p-hub center, are given in [57], and early reviews are provided in [58, 59, 60].

- **Vehicle Routing problems** In this type of problems customers are not served directly from the facility, but rather on route followed by the vehicles initially stationed at the facility (depot). The objective is to form a set of *capacitated* routes out of the depot visiting each customer and having a minimum total length. Several variations exist such as split-unsplit demands, time window considerations, multiple-depots, pick-up and deliveries, and backhaul considerations. Solution methodologies include branch-and-bound, branch-and-cut, specialized heuristics and meta-heuristics [61].

- **Location-Routing problems** combine facility location and vehicle routing problems and attempt to identify optimum depot locations from a given set of locations, assign customers to the selected depots and determine the routing of capacitated vehicles located at the depots through the assigned customers so that the total cost of transportation, depot location and vehicle dispatch is minimized. Some solution algorithms and synthesis are described in [62, 63, 64, 65].

References

[1] A. M. Geoffrion. Lagrangian relaxation for integer programming. *Mathematical Programming Study*, 2:82–114, 1974.

[2] J. Krarup and P. M. Pruzan. The simple plant location problem: Survey and synthesis. *European Journal of Operational Research*, 12:36–81, 1983.

[3] M. L. Fisher. The lagrangian relaxation method for solving integer programming problem. *Management Science*, 27:1–18, 1981.

[4] D. Erlenkotter. A dual-based procedure for uncapacitated facility location. *Operations Research*, 26:992–1009, 1978.

[5] U. Akinc and B. M. Khumawala. An efficient branch and bound algorithm for the capacitated warehouse location problem. *Management Science*, 23:585–594, 1977.

[6] G. Cornuejols, R. Sridharan, and J. M. Thizy. A comparison of heuristics and relaxations for the capacitated plant location problem. *European Journal of Operational Research*, 50:280–297, 1991.

[7] T. J. Van Roy. A cross decomposition algorithm for capacitated facility location. *Operations Research*, 34:145–163, 1986.

[8] J. G. Klincewicz and H. Luss. A lagrangian relaxation heuristic for capacitated facility location with single source constraints. *Journal of the Operational Research Society*, 37:495–500, 1986.

[9] H. Pirkul. Efficient algorithms for the capacitated concentrator location problem. *Computers and Operations Research*, 14:197–208, 1987.

[10] J. E. Beasley. Lagrangian heuristics for location problems. *European Journal of Operational Research*, 65:383–399, 1993.

[11] A. M. Geoffrion and G. W. Graves. Multicommodity distribution system design by bender's decomposition. *Management Science*, 20:822–844, 1974.

[12] H. Pirkul and V. Jayaraman. Production, transportation, and distribution planning in a multi-commodity tri-echelon system. *Transportation Science*, 30:291–302, 1996.

[13] H. Pirkul and V. Jarayaman. A multi commodity, multi-plant, capacitated facility location problem: Formulation and efficient heuristic solution. *Computers and Operations Research*, 25:869–878, 1998.

[14] V. Jayaraman and H. Pirkul. Planning and coordination of production and distribution facilities for multiple commodities. *European Journal of Operations Research*, 133:394–408, 2001.

[15] G. G. Brown, G. W. Graves, and M. D. Honczarenko. Design and operation of a multicommodity production/distribution system using primal goal decomposition. *Management Science*, 33:1469–1480, 1987.

[16] D. F. Pyke and M. A. Cohen. Multiproduct integrated production/distribution systems. *European Journal Operations Research*, 74:18–49, 1994.

[17] A. M. Geoffrion and R. F. Powers. Twenty years of strategic distribution system design: An evolutionary perspective. *Interfaces*, 25:105–127, 1995.

[18] M. Fleischmann, J.M. Bloemhouf-Ruwaard, R. Dekker, E. van der Laan, J.A.E.E. van Nunen, and L.N. van Wassenhove. Quantitative models for reverse logistics: a review. *European Journal of Operational Research*, 103:1–17, 1997.

[19] V. Jayaraman, Jr. V.D.R. Guide, and R. Srivastava. A closed-loop logistics model for remanufacturing. *Journal of the Operational Research Society*, 50:497–508, 1999.

[20] J. M. Bloemhof-Ruwaard, M. Fleischmann, and J. A. E. E. van Nunen. Reviewing distribution issues in reverse logistics. *Lecture Notes in Economics and Mathematical Systems*, 480:23–44, 1999.

[21] V. Jayaraman, R.A. Patterson, and E. Rolland. The design of reverse distribution networks: Models and solution procedures. *European Journal of Operational Research*, 150:128–149, 2003.

[22] M. Fleischmann, P. Beullens, J.M. Bloemhof-Ruwaard, and L.N. Van Wassenhove. The impact of product recovery on logistics network design. *Production & Operations Management*, 10(2):156–173, 2001.

[23] B.M. Beamon and C. Fernandes. Supply-chain network configuration for product recovery. *Production Planning and Control*, 15(3):270–281, 2004.

[24] E. Sim, S. Jung, H. Kim, and J. Park. A generic network design for a closed-loop supply chain using genetic algorithm. In Kalyanmoy D., Riccardo P., W. Banzhaf, H.-G. Beyer, E.K. Burke, P.J. Darwen, D.Dasgupta, D. Floreano, J.A. Foster, M. Harman, O. Holland, P.L. Lanzi, L. Spector, A. Tettamanzi, D. Thierens, and A.M. Tyrrell, editors, *GECCO (2)*, volume 3103 of *Lecture Notes in Computer Science*, pages 1214–1225. Springer, 2004.

[25] Z. Lu and N. Bostel. A facility location model for logistics systems including reverse flows: The case for remanufacturing activities. *Computers & Operations Research*, 34(2):299–323, 2007.

[26] H. Üster, G. Easwaran, E. Akçalı, and S. Çetinkaya. Benders decomposition with alternative multiple cuts for a multi-product closed-loop supply chain network design model. *Naval Research Logistics*, 54:890–907, 2007.

[27] K. Sahyouni, R. C. Savaskan, and M. S. Daskin. A facility location model for bidirectional flows. *Transportation Science*, 41:489–499, 2007.

[28] J. W. Braklow, W. W. Graham, S. M. Hassler, K. E. Peck, and W. B. Powell. Interactive optimization improves service and performance for Yellow Freight System. *Interfaces*, 22(1):147–172, 1992.

[29] T. G. Crainic and J-M. Rousseau. Multicommofity, multimode freight transportation: a general modeling and algorithmic framework for the service network design problem. *Transportation Research: Part B–Methodological*, 20(3):225–242, 1986.

[30] L. Delorme, J. Roy, and J-M. Rousseau. Motor-carriers operations planning: a state of the art. In L. Bianco and A. La Bella, editors, *Freight Transport Planning and Logistics*. Springer-Verlag, Berlin, 1987.

[31] B. W. Lamar and Y. Sheffi. An implicit enumeration method for LTL network design. *Transportation Research Record*, 1120:1–11, 1987.

[32] T. L. Magnanti and R. T. Wong. Network design and transportation planning: Models and algorithms. *Transportation Science*, 18:1–55, 1984.

[33] W. B. Powell. A local improvement heuristics for the design of Less-than-Truckload motor carrier networks. *Transportation Science*, 20:246–257, 1986.

[34] W. B. Powell and Y. Sheffi. The load planning problem of motor carriers: problem description and a proposed solution approach. *Transportation Research: Part A–Policy and Practice*, 17:471–480, 1983.

[35] W. B. Powell and Y. Sheffi. Design and implementation of an interactive optimization system for network design in the motor carrier industry. *Operations Research*, 37(1):12–29, 1989.

[36] A. Balakrishnan, T. L. Magnanti, and R. T. Wong. A dual-ascent procedure for large-scale uncapacitated network design. *Operations Research*, 37(5):716–740, 1989.

[37] C. Barnhart, C. A. Hane, and P. H. Vance. Using branch-and-price-and-cut to solve origin-destination integer multicommodity flow problems. *Operations Research*, 48(2):318–326, 2000.

[38] J. Eckstein and Y. Sheffi. Optimization of group line-haul operations for motor carriers using twin trailers. *Transportation Research Record*, 1120:12–23, 1987.

[39] J. M. Farvolden and W. B. Powell. Subgradient methods for the service network design problem. *Transportation Science*, 28(3):256–272, 1994.

[40] B. W. Lamar, Y. Sheffi, and W. B. Powell. A capacity improvement lower bound for fixed charge network design problem. *Operations Research*, 38(4):704–710, 1990.

[41] A. Amiri and H. Pirkul. New formulation and relaxation to solve a concave-cost network flow problem. *Journal of Operational Research Society*, 48:278–287, 1997.

[42] A. Balakrishnan and S. C. Graves. A composite algorithm for a concave-cost network flow problem. *Networks*, 19:175–202, 1989.

[43] K. L. Croxton, B. Gendron, and T. L. Magnanti. Models and methods for merge-in-transit operations. *Transportation Science*, 37, 2003. forthcoming.

[44] M. Minoux. Network synthesis and optimum network design problems: Models, solution methods and applications. *Network*, 19:313–360, 1989.

[45] Y. K. Agarwal. Design of capacitated multicommodity networks with multiple facilities. *Operations Research*, 50(2):333–344, 2002.

[46] A. Atamturk. On capacitated network design cut-set polyhedra. *Mathematical Programming, Ser. B*, 92:425–437, 2002.

[47] A. Atamturk. On splittable and unsplittable flow capacitated network design arc-set polyhedra. *Mathematical Programming, Ser. A*, 92:315–333, 2002.

[48] T. G. Crainic, M. Gendreau, and J. M. Farvolden. A simplex-based tabu search method for capacitated network design. *Journal on Computing*, 12(3):223–236, 2000.

[49] T. L. Magnanti, P. Mirchandani, and R. Vachani. The convex hull of two core capacitated network design problems. *Mathematical Programming*, 60:233–250, 1993.

[50] T. L. Magnanti, P. Mirchandani, and R. Vachani. Modeling and solving the two-facility capacitated network loading problem. *Operations Research*, 43(1):142–157, 1995.

[51] T. G. Crainic. Long-haul freight transportation. In R. W. Hall, editor, *Handbook of Transportation Science*. Kluwer, Boston, 1999.

[52] T. G. Crainic. Service network design in freight transportation. *European Journal of Operational Research*, 122:272–288, 2000.

[53] T. G. Crainic and G. Laporte. Planning models for freight transportation. *European Journal of Operational Research*, 97:409–438, 1997.

[54] B. Gendron, T.G. Crainic, and A. Frangioni. Multicommodity capacitated network design. In B. Sanso and P. Soriano, editors, *Telecommunications Network Planning*. Kluwer, Berlin, 1998.

[55] M. Minoux. Discrete cost multicommodity network optimization problems and exact solution methods. *Annals of Operations Research*, 106:19–46, 2001.

[56] M. Dell'Amico, Maffioli F., and S. Martello, editors. *Annotated Bibliographies in Combinatorial Optimization*. John Wiley and Sons, New York, NY, 1997.

[57] J. F. Campbell. Integer programming formulations of discrete hub location problems. *European Journal of Operational Research*, 72:387–405, 1994.

[58] D. L. Bryan and M. E. O'Kelly. Hub-and-spoke networks in air transportation: An analytical review. *Journal of Regional Science*, 39(2):275–295, 1999.

[59] M. E. O'Kelly and H. J. Miller. The hub network design problem: A review and synthesis. *Journal of Transport Geography*, 2(1):31–40, 1994.

[60] J. F. Campbell, A. T. Ernst, and M. Krishnamoorthy. Hub location problems. In Z. Drezner and H. W. Hamacher, editors, *Facility Location: Applications and Theory*. Springer-Verlag, New York, NY, 2002.

[61] P. Toth and D. Vigo. Models, relaxations and exact approaches for the capacitated vehicle routing problem. *European Journal of Operational Research*, 123:487–512, 2002.

[62] G. Laporte. Location-routing problems. In B. Golden and A. A. Assad, editors, *Vehicle Routing: Methods and Studies*, pages 163–198. North-Holland, Amsterdam, 1988.

[63] J. Perl and M. S. Daskin. A warehouse location-routing problem. *Transportation Research Quarterly, Part B–Methodological*, 19:381–396, 1985.

[64] T. Wu, C. Low, and J. Bai. Heuristic solutions to multi-depot location-routing problem. *Computers and Opeartions Research*, 29:1393–1415, 2002.

[65] H. Min, V. Jayaraman, and R. Srivastava. Combined location-routing problems: A synthesis and future research directions. *European Journal Operations Research*, 108:1–15, 1998.

OTHER INFORMATION

Title IX and Disability Accommodations

Disability Accommodations	Students who need academic accommodations for a disability must first register with Disability Accommodations & Success Strategies (DASS). Students can call 214-768-1470 or visit http://www.smu.edu/Provost/SASP/DASS to begin the process. Once they are registered and approved, students then submit a DASS Accommodation Letter through the electronic portal, *DASS Link,* and then communicate directly with each of their instructors to make appropriate arrangements. Please note that accommodations are not retroactive, but rather require advance notice in order to implement.
Sexual Harassment	All forms of sexual harassment, including sexual assault, dating violence, domestic violence and stalking, are violations of SMU's Title IX Sexual Harassment Policy and may also violate Texas law. Students who wish to file a complaint or to receive more information about the grievance process may contact Samantha Thomas, SMU's Title IX Coordinator, at accessequity@smu.edu or 214-768-3601. Please note that faculty are mandatory reporters. If students notify faculty of sexual harassment, faculty must report it to the Title IX Coordinator. For more information about sexual harassment, including resources available to assist students, please visit www.smu.edu/sexualmisconduct.
Pregnant and Parenting Students	Under Title IX, students who are pregnant or parenting may request academic adjustments by contacting Elsie Johnson (elsiej@smu.edu) in the Office of the Dean of Students, or by calling 214-768-4564. Students seeking assistance must schedule an appointment with their professors as early as possible, present a letter from the Office of the Dean of Students, and make appropriate arrangements. Please note that academic adjustments are not retroactive and, when feasible, require advance notice to implement.

SMU Requirements

Religious Observance	Religiously observant students wishing to be absent on holidays that require missing class should notify their professors in writing at the beginning of the semester and should discuss with them, in advance, acceptable ways of making up any work missed because of the absence. Click here for a list of holidays.
COVID-19 and Other Medical-Related Absences	Students who test positive for COVID-19 and need to isolate, or who are notified of potential exposure, must follow SMU's Contact Tracing Protocol. To ensure academic continuity and avoid any course penalties, students should follow the same procedures described by their instructors as they would for any other medical-related absence in order to be provided with appropriate modifications to assignments, deadlines, and exams.
Excused Absences for University Extracurricular Activities	Students participating in an officially sanctioned, scheduled university extracurricular activity should be given the opportunity to make up class assignments or other graded assignments that were missed as a result of their participation. It is the responsibility of the student to make arrangements for make-up work with the instructor prior to any missed scheduled examinations or other missed assignments. (See 2020-2021 SMU Undergraduate Catalog under "Enrollment and Academic Records/Excused Absences.")
Final Exams	Final course examinations shall be given in all courses where appropriate, and some form of final assessment is essential. Final exams and assessments must be

	administered as specified in the official examination schedule. Exams cannot be administered or due during the last week of classes or during the Reading Period. Syllabi must state clearly the form of the final exam or assessment, and the due date and time must match the official SMU exam schedule. Final exams are not required to be provided online.

Student Support

Student Academic Success Programs	Students needing assistance with writing assignments for SMU courses may schedule an appointment with the Writing Center through Canvas. Students who would like support for subject-specific tutoring or success strategies should contact SASP, Loyd All Sports Center, Suite 202; 214-768-3648; https://www.smu.edu/sasp.
Caring Community Connections Program	CCC is a resource for anyone in the SMU community to refer students of concern to the Office of the Dean of Students. The online referral form can be found at smu.edu/deanofstudentsccc. After a referral form is submitted, students will be contacted to discuss the concern, strategize options, and be connected to appropriate resources. Anyone who is unclear about what steps to take if they have concerns about students should either consult the CCC Reference Guide or contact the Office of the Dean of Students at 214-768-4564.

Campus Carry Law	In accordance with Texas Senate Bill 11, also known as the 'campus carry' law, and following consultation with entire University community, SMU chooses to remain a weapons-free campus. Specifically, SMU prohibits possession of weapons (either openly or in a concealed manner) on campus. For more information, please see: http://www.smu.edu/BusinessFinance/Police/Weapons_Policy.