Q786: *Network design issues in freight transportation*

Winter 2024 Course Outline

Operations Management Area
DeGroote School of Business
McMaster University

COURSE OBJECTIVES

- Understand the different managerial issues involved in designing freight transportation networks.
- Discuss the classical discrete network location models –such as the *covering* models, *center* models and *median* models.
- Develop an understanding of the tactical and operational issues in *railroad* and *maritime* freight transportation.
- Comprehend the nuances of *intermodal* transportation, with a focus on rail-truck combination.
- Discern the additional considerations required when dealing with: *hazardous materials* such as crude oil and other petroleum products; humanitarian logistics and disaster management; and, green supply chains.

INSTRUCTOR AND CONTACT INFORMATION

Dr. Manish Verma
Instructor
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Office Hours: By appointment
Tel: (905) 525-9140 x 27438
Time: Fridays 11:30-14:30
Location: Please refer to
Avenue to Learn or Mosaic.

COURSE DESCRIPTION

Transportation sustains economic and social activity. Freight transportation, a vital component of the economy, supports a variety of activities by ensuring the efficient movement and timely availability of raw materials and finished goods.

This course will investigate the strategic, tactical and operational issues associated with designing freight transportation networks. To that end, the strategic timeframe would focus on in-depth discussion surrounding classical models in Location. Most of the discussion surrounding the tactical and operational issues would be focused on railroad, maritime and intermodal transportation of freight.

Finally, depending on the research interest of the student, specific characteristics of network design in the chosen domain would be explored. For example, hazardous materials such as crude oil or refined petroleum products; humanitarian logistics and disaster management; green supply chains; random and/or intentional disruptions; etc.,

LEARNING OUTCOMES

Upon completion of this course, students will be able to complete the following tasks:

- Understand the key issues involved in designing freight transportation networks.
- Develop mathematical models for locating facilities, and routing freight using one or more modes of transportation.
- Conceptualize the key elements of network design in one of the indicated domains.

REQUIRED COURSE MATERIALS AND READINGS

This course will draw materials from a variety of sources including basic textbooks and peer-reviewed journal articles. The pertinent reading materials are indicated after each topic in the course schedule. The instructor will provide a copy of the materials that are not available through McMaster library (or other publicly available sources).

This course will be conducted in a seminar format, where each participant is expected to review the appropriate material before the meeting. To facilitate high quality discussion, each participant would be encouraged to share his/her views on the topics.

EVALUATION

Assignment	15%
Critical Evaluation	15%
Research report	35%
Final Exam	35%
Total	100%

Conversion

At the end of the course your overall percentage grade will be converted to your letter grade in accordance with the following conversion scheme.

Letter Grade	Points	Equivalent Percentage
A+	12	90-100
A	11	85-89
A-	10	80-84
B+	9	77-79
B	8	73-76
B-	7	70-72
F	0	69 and under

Assignment (15%, individual)

There will be one assignment covering the foundations and mathematical formulation of the topics discussed in the course. The due date is February 16th, 2024, at the start of the class.

Critical Evaluation of a published journal article (15%, individual)

Each student will undertake a critical evaluation of a published article on Network Design, which will be shared with the class through an in-class presentation. In addition, a written component needs to be submitted to the instructor. Each student is expected to advise the instructor of the topic and the journal article by the 3rd week of the term (i.e., January 26th, 2024). The in-class presentation will take place on March 8th, 2024; and the written critique is also due the same day.

Final Exam (35%, individual)

It will be a 3-hour closed book exam that will test you on the concepts introduced in the course. This will entail some basic formulation and analytical questions.

Research Report (35%, individual)

The purpose of this report is to encourage you to think about one of the application domains, such as those identified on page 2, which interests you. You should approach this as a first step towards developing an academic paper. To that end, we will follow the structure of a peer-reviewed journal.

For example, you could decide to study the "rail-truck intermodal transportation system" with the intention to identify possible research topics. Such an endeavour would entail the following:

- Conducting a comprehensive and critical review of the existing literature review to demonstrate your understanding of the domain, and the possible gaps (grey areas).
- Stating the managerial problem you intend to study in a precise fashion.
- Developing the appropriate mathematical model (problem formulation).
- Testing the model on assumed (or real) data.
- Commenting on the appropriate solution methodology, if off-the-shelf software cannot be used to solve the model.

You are encouraged to start thinking about the possible research topic in the domain of interest. Once you have an idea about the possible topic, it is in your interest to discuss it with the Instructor - for both feasibility and approval. Each student is expected to provide a 1-page summary of the proposed topic by the 4th week of the term (i.e., Feb 2nd, 2024). The completed research report is due on April 26th, 2024 (5pm: EST).

ACADEMIC DISHONESTY

It is the student's responsibility to understand what constitutes academic dishonesty. Please refer to the University Senate Academic Integrity Policy at the following URL:
http://www.mcmaster.ca/policy/Students-AcademicStudies/AcademicIntegrity.pdf

This policy describes the responsibilities, procedures, and guidelines for students and faculty should a case of academic dishonesty arise. Academic dishonesty is defined as to knowingly act or fail to act in a way that result or could result in unearned academic credit or advantage. Please refer to the policy for a list of examples. The policy also provides faculty with procedures to follow in cases of academic dishonesty as well as general guidelines for penalties. For further information related to the policy, please refer to the Office of Academic Integrity at:

http://www.mcmaster.ca/academicintegrity

MISSED ACADEMIC WORK

Late assignments will not be accepted. No extensions are available except under extraordinary circumstances. Please discuss any extenuating situation with your instructor at the earliest possible opportunity.

POTENTIAL MODIFICATIONS TO THE COURSE

The instructor and university reserve the right to modify elements of the course during the term. The university may change the dates and deadlines for any or all courses in extreme circumstances. If either type of modification becomes necessary, reasonable notice and communication with the students will be given with explanation and the opportunity to comment on changes. It is the responsibility of the student to check their McMaster email and course websites weekly during the term and to note any changes.

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STUDENT ACCESSIBILITY SERVICES

Student Accessibility Services (SAS) offers various support services for students with disabilities. Students are required to inform SAS of accommodation needs for course work at the outset of term. Students must forward a copy of such SAS accommodation to the instructor normally, within the first three (3) weeks of classes by setting up an appointment with the instructor. If a student with a disability chooses NOT to take advantage of an SAS accommodation and chooses to sit for a regular exam, a petition for relief may not be filed after the examination is complete. The SAS website is:

http://sas.mcmaster.ca

COURSE SCHEDULE

READING LIST	
SESSION AND TOPIC	**ARTICLES**
Week 1 (Jan.12)	**Introduction** Supply Chain Management: Strategy, Planning, and Operation -5/E: by S. Chopra and P. Meindl • Ch.05: Network Design in the Supply Chain. • Ch.14: Transportation in a Supply Chain. 1. Crainic, T.G. 2000. Service network design in freight transportation. *European Journal of Operational Research*, 122, 272-288. 2. Crainic, T.G., and Laporte, G. 1997. Planning models for freight transportation. *European Journal of Operational Research*, 97, 409-438. 3. Wieberneit, N. 2007. Service network design for freight transportation: a review. *OR Spectrum*, 30, 77-122.
Weeks 2-3 (Jan.19/26)	**Facility Location Models** a) Set covering. b) Maximal covering. c) p-Center. d) p-Dispersion. e) p-Median. f) Fixed charge. g) Hub. h) Maxisum.

	1. Alumur, S., and Kara, B.Y. 2008. Network hub location problems: The state of the art. *European Journal of Operational Research*, 190 (1), 1-21. 2. Farhani, R.Z., Hekmatfar, M., Arabani, A.B., and Nikbaksh, E. 2013. Hub location problems: A review of models, classification, solution techniques, and applications. *Computers & Industrial Engineering*, 64, 1096-1109. 3. Melo, M.T., Nickel, S., and Saldanha-da-Gama, F. 2009. Facility location and supply chain management – A review. *European Journal of Operational Research*, 196(2), 401-412. 4. ReVelle, C.S., Eiselt, H.A., and Daskin, M.S. 2008. A bibliography for some fundamental problem categories in discrete choice location science. *European Journal of Operational Research*, 184, 817-848.
Week 4 (Feb.02)	**Network Models** a) Transportation model. b) Transshipment model. c) Assignment model. d) Maximal-Flow model. e) Shortest-Path model. f) Minimal-Spanning tree model. g) Network models with yields. h) Minimum cost flow model. i) Multicommodity flow model. 1. *Optimization in Operations Research* by R.L.Rardin. Pretince Hall Publication. 2. *Introduction to Operations Research* by F.S. Hillier and G.L. Lieberman. McGraw-Hill Publications.
Week 5 (Feb.9)	<u>Location-Routing</u> 1. Nagy, G., and Salhi, S. 2007. Location-routing: Issues, models and methods. *European Journal of Operational Research*, 177, 649-672. 2. Prodhon, C., and Prins, C. 2014. A survey of recent research on location-routing problems. *European Journal of Operational Research*, 238, 1-17. 3. Schneider, M., and Drexl, M. 2017. A survey of the standard location-routing problem. *Annals of Operations Research*, 259, 389-414. <u>Facility Location Network Design</u> 1. Melkote, S., and Daskin, M.S. 2001. An integrated model of facility location and transportation network design. *Transportation Research Part A*, 35, 515-538. 2. Melkote, S., and Daskin, M.S. 2001. Capacitated facility location/network design problems. *European Journal of Operational Research*, 129, 481-495.
Week 6 (Feb.16)	**Railroad Transportation System**[1] <u>Yard operations</u> 1. Boysen, N., Fliedner, M., Jaehn, F., and Pesch, E. 2012. Shunting yard operations: Theoretical aspects and applications. *European Journal of Operational Research*, 220(1), 1-14.

[1] Cordeau, Toth and Vigo (1998) provide an excellent review of various optimization models for train routing and scheduling (*Transportation Science*).

	2. Petersen, E.R. (1977a) "Railyard Modeling. Part I. Prediction of Put-Through Time", *Transportation Science*, 11, 37-49. 3. Petersen, E.R. (1977b) "Railyard Modeling. Part II. The Effect of Yard Facilities on Congestion", *Transportation Science*, 11, 50-59. <u>Railcar grouping (blocking)</u> 1. Ahuja, R.K., Jha, K.C. and Liu, J. (2007) "Solving real-life railroad blocking problems", *Interfaces*, 37, 404-419. <u>Routing</u> 1. Crainic, T.G., Ferland, J-A., and Rousseau, J.-M. (1984) "A tactical planning model for rail freight transportation", *Transportation Science*, 18, 165-184. 2. Crainic, T.G., Florian, M., and Leal, J.-E. (1990) "A model for the strategic planning of national freight transportation by rail", *Transportation Science*, 24, 1-24. 3. Gorman, M.F. (1998) "An application of genetic and tabu searches to the freight railroad operating plan problem", *Annals of Operations Research*, 78, 51-69. 4. Khaled, A.A., Jin, M. Clarke, D.B., and Hoque, M.A. 2015. Train design and routing optimization for evaluating criticality of freight railroad infrastructures. *Transportation Research Part B: Methodological*, 71, 71-84.
Week 7 (Feb. 23)	**Maritime Transportation System**[2] 1. Christiansen, M., Fagerholt, K. and Ronen, D. (2004) "Ship routing and scheduling: Status and perspectives", *Transportation Science*, 38(1), 1-18. 2. Christiansen, M. and Nygreen, B. (1998) "A method for solving ship routing problems with inventory constraints", *Annals of Operations Research*, 81, 357-378. 3. Christiansen, M. and Nygreen, B. (1998) "Modeling path flows for a combined ship routing and inventory management problem", *Annals of Operations Research*, 82, 391-412. 4. Siddiqui, A., Verma, M. and Tulett, D. (2013) "A periodic requirement scheduling approach to maritime transportation of crude oil", *EURO Journal on Transportation and Logistics*, 2, 307-335.
Week 8 (Mar.1)	**Guest Lecture**
Week 9 (Mar.8)	**Student Presentation**
Week 10 (Mar.15)	**Intermodal Transportation System** 1. Crainic, T.G. and Kim, K.W. (2007) "Intermodal Transportation in *Handbook in Operations Research & Management Science* (eds) C. Barnhart and G. Laporte, pages 467-477. 2. Macharis, C. and Bontekoning, Y.M. (2004) "Opportunities for OR in intermodal freight transport research: A review", *European Journal of Operational Research*, 153, 400-416.

[2] Christiansen, Fagerholt, Nygreen, and Ronen (2007) provide an excellent review of maritime transportation in *Handbook in Operations Research & Management Science*, Vol. 14.

	3. SteadieSeifi, M., Dellaert, N.P., Nuijten, W., Woensel, T. Van and Raoufi, R. (2013) "Multimodal freight transportation planning: A literature review", *European Journal of Operational Research*, 233(1), 1-15. 4. Verma, M., Verter, V., and Zuffrey, N. 2012. A bi-objective model for planning and managing rail-truck intermodal transportation of hazardous materials. *Transportation Research Part E: Logistics and Transportation Review*, 48(1), 132-149.
Week 11 (Mar.22)	**Class cancelled. Makeup class during mid-term recess on February 23, 2024**
Week 12 (Mar. 29)	**Incorporating uncertainty in Location and Transportation** 1. Alumur, S., Nickel, S., and Saldanha-da-Gama, F. 2012. Hub location under uncertainty. *Transportation Research Part B: Methodological*, 46(4), 529-543. 2. De Maio, A., Lagana, D., Musmanno, R., and Vocaturo, F. 2021. Arc routing under uncertainty: Introduction and literature review. *Computers & Operations Research*, 135, 105442. 3. Mohammadi, M., Jula, P., and Tavakkoli-Moghaddam, R. 2017. Design of a reliable multi-modal multi-commodity model for hazardous materials transportation under uncertainty. *European Journal of Operational Research*, 257(3), 792-809. 4. Sarhadi, H., Naoum-Sawaya, J., and Verma, M. 2020. A robust optimization approach to locating and stockpiling marine oil-spill response facilities. *Transportation Research Part E: Logistics and Transportation Review*, 141, 102005. 5. Vaezi, A., Dalal, J., and Verma, M. 2021. Designing emergency response network for rail hazmat shipments under uncertainties: Optimization model and case study. *Safety Science*, 141, 105332. 6. Verma, M., Gendreau, M., and Laporte, G. 2013. Optimal location and capability of oil response facilities for the south coast of Newfoundland. *OMEGA –The International Journal of Management Science*, 41(5), 856-867. 7. Yao, T., Mandala, S.R., and Do Chung, B. Evacuation Transportation Planning Under Uncertainty: A Robust Optimization Approach. *Networks and Spatial Economics*, 9, 171-189.
Week 13 (Apr. 05)	**Random and/or intentional disruptions in transportation systems.** 1. Azad, N., Hassini, E., and Verma, M. 2016. Recovery from Railroad Disruptions: An Optimization Framework and a Case Study. *Transportation Research Part B: Methodological*, 85, 70-88. 2. Ke, G.Y., and Verma, M. 2021. A framework to managing disruption risk in rail-truck intermodal transportation networks. *Transportation Research Part E: Logistics and Transportation Review*, 153, 102340. 3. Jabbarzadeh, A., Azad, N., and Verma, M. 2020. An optimization approach to planning rail hazmat shipments in the presence of random disruptions. *OMEGA -The International Journal of Management Science,* 96, 102078. 4. Sarhadi, H., Tulett, D.M., and Verma, M. 2017. An analytical approach to the protection planning of a rail intermodal terminal network. *European Journal of Operational Research*, 257, 511-525.