MIE 1616S – Research Topics in Healthcare Engineering

Professor: Michael Carter
Day/Time: Tuesday 1:00 – 4:00 PM

Location: **BA B025**

Background:

Healthcare Engineering has existed for decades. In the late 70's and early 80's, industrial engineering departments were quite common in hospitals across North America. During the late 80's and 90's, for some reason, there was a dramatic decrease in the use of industrial engineers. I suspect that IEs were not working on the issues that were "keeping the CEO awake at night". However, the profession has survived, often under the name "Management Engineering". The term "healthcare engineering" is intended to convey the general philosophy of design and analysis concepts applied to building a better healthcare system.

There have been a number of changes over the past 30 years. First, the medical establishment began to recognize that the industry has serious efficiency and operational problems (poor resource utilization, waste of money, high error rates, etc.) Much of this change in attitude has been fostered by groups like the Institute for Healthcare Improvement (www.ihi.org). Leaders have begun to realize that industrial engineers have the tools necessary for dealing with these issues. Early work in the field was generally individual projects where industrial engineers were asked to look at scheduling small groups of nurses or operating rooms. Gradually, the scope of the problems considered has grown to include patient flow and bed allocation. Recent projects have considered more strategic decisions involving health policy such as immunization guidelines and system-wide resource allocations. There has been a considerable growth in interest from the medical community and the supply of healthcare management engineering specialists is not keeping pace with the demand.

Purpose:

The purpose of this course is to provide an overview of current OR research in healthcare and to develop the insight required to do relevant and significant research in this field. The course attempts to provide an overview to some of the major research topics in the field, but the course also provides an opportunity for students to demonstrate "critical analysis" of the literature.

Graduate students in this class should have an introductory level background in the necessary tools of OR such as mathematical programming, stochastic processes, queueing theory, statistical modelling, decision analysis and dynamic programming. Students must have sufficient knowledge to be able to read and understand the various papers. The majority of the papers involve applications of OR to healthcare problems.

This course will also help you develop the skills required to critically read and evaluate research literature in general. As such, it will help you improve your own writing.

Course Description:

This is a seminar-based course in which we will review a variety of papers in the field of healthcare OR. We will survey and evaluate several papers within topic areas and try to identify areas for potential future research. Some papers will be distinctly OR, while others will come from researchers in the field of health policy and health economics. One thing that you will notice as we go through the literature is that the area of healthcare engineering is interdisciplinary in nature and encourages solutions that are derived from various areas of expertise. This interdisciplinary approach is also encouraged through the many funding bodies that currently support healthcare engineering research in North America. The Canadian Institute of Health Research, CIHR, (http://www.cihr-irsc.gc.ca) funds the majority of healthcare research in Canada. It is composed of 14 virtual 'institutes' that represent all facets of health research. The Institute of Health Services and Policy Research, IHSPR, is most related to the type of collaborative research discussed above. It supports innovative research, capacity-building and knowledge translation in order to improve health care service delivery. In 2001 and 2004, IHSPR was involved with national consultations on health services priorities entitled "Listening for Direction". The result of these consultations was a set of priorities for Canadian researchers in the area of health care policy and management. Of course, not all of the topics are relevant to Healthcare Engineering, but many of the readings and articles discussed in this class will align with the most recent set of priorities:

Research Themes	Key Components
Workforce planning, training, and regulation	• Value of inter-professional team care in different settings • Forecasting models • Scopes of practice and health professional regulation • Relationship between extent/nature of training and health outcomes
Management of the healthcare workplace	• How changing demographics are leading to changing expectations in the workplace • Factors generating organizational commitment and productivity by healthcare professionals • Identification of leaders in healthcare
Timely access to quality care for all	• Waiting time management for specialized and diagnostic services • Timely access to primary and community care • Improving access for rural and remote communities and for minority and vulnerable groups
Managing for quality and safety	• Improving quality, uptake of clinical best practices • Improving patient safety, adverse event reduction systems
Understanding and responding to public expectations	• Impact of market-driven influences • Interpersonal, attitudinal, cognitive, and risk-perception influences • Role of the media in influencing public attitudes and public expectations of health services.

	• Effectiveness of alternative approaches to public engagement
Sustainable funding and ethical resource allocation	• Ethical framework for resource allocation • Models for institution-level resource allocation • Evidence on system efficiencies and resource redeployment • Effects and effectiveness of public-private partnerships
Governance and accountability	• Selection, role, and use of individual performance indicators • Current organizational frameworks for using performance indicators • The link between population-based funding and accountability • Implications of foreign experiences of public-private partnerships for Canada • Intelligence from regionalization experiences
Managing and adapting to change	• Models and mechanisms of knowledge translation • Intra-organizational management structures
Linking care across place, time, and settings	• Improving chronic disease management • Caregiver support and informal and voluntary care • Technology and chronic disease management
Linking public health to health service	• Surge capacity: How to organize health services to cope with emergencies? • Relationship between specific disease prevention or health promotion products/services on need for traditional healthcare services • Public health threats & the need for healthcare/public health professionals

Required Materials:

All materials for the course will be downloaded from the course website. All articles have been retrieved from University of Toronto library full-text databases.

Additional Reference Materials:

1. Brandeau, M, Sainfort, F. and Pierskalla, W.P. , *Operations Research and Health Care*, Kluwer Academic Publishers, 2004.
2. Vissers, J. and Beech, R., *Health Operations Management: Patient Flow Logistics in Health Care*, Routledge: London, 2005
3. Ronen, B. and Pliskin, J.S., *Focused Operations Management for Health Services Organizations*, Wiley and Sons: San Francisco, 2006
4. Hall, R.W., (ed.) *Patient Flow: Reducing Delay In Healthcare Delivery*, Springer, 2007.

5. Langabeer, J.R., *Health care operations management: a quantitative approach to business*, Jones & Bartlett Publishing Company, 2007
6. D. Ravì, C Wong, F Deligianni, M Berthelot, J Andreu-Perez, B Lo, GZ & Yang (2016). Deep learning for health informatics. IEEE journal of biomedical and health informatics, 21(1), 4-21
7. Paul M. Griffin, Harriet Black Nembhard, Christopher J. DeFlitch, Nathaniel D. Bastian, Hyojung Kang, David A. Muñoz "Healthcare Systems Engineering" Wiley, August 2015.

	Date	Topic	Paper(s)
1	Sept 8	Course Introduction	• Course Outline • Pick papers you would like to lead.
2	Sept 15	Scheduling – OR	• J. T. Blake and J. Donald, "Mount Sinai hospital uses integer programming to allocate operating room time", Interfaces, 32(2): 63-73, 2002. • J.Wang, S.Vahid, M.Eberg, S.Milroy, J.Milkovich, F.C.Wright, A.Hunter, R.Kalladeen, C.Zanchetta, H.C.Wijeysundera, J.Irish "Clearing the surgical backlog caused by COVID-19 in Ontario: a time series modelling study" CMAJ 2020 November 2;192:E1347-56. doi: 10.1503/cmaj.201521.
3	Sept 22	Emergency medical services	• J.L. Vile, J.W. Gillard, P.R. Harper, V.A. Knight "Time-dependent stochastic methods for managing and scheduling Emergency Medical Services" Operations Research for Health Care 8 (2016) 42–52. • J.T Boutilier, T. C. Y. Chan. 2020. "Ambulance Emergency Response Optimization in Developing Countries." *Operations Research* 68 (5): 1315-1334.
4	Sept 29	TBD	• TBD
5	Oct 6	Organ transplant	• Gentry, S., Chow, E., Massie, A., & Segev, D. (2015). "Gerrymandering for justice: redistricting US liver allocation". Interfaces, 45(5), 462-480. • D. Bertsimas, V. F. Farias, and N. Trichakis, "Fairness, efficiency and flexibility in organ allocation for kidney transplantation", Operations Research 61(1), pp. 73–87, 2013.
6	Oct 13	Screening	• J.O. Jónasson, S. Deo, and J. Gallien: "Improving HIV Infant Diagnosis Supply Chains" Operations Research vol. 65, no. 6, 2017,pp. 1479–1493 • A. Sabouri, W.T. Huh and S.M. Shechter "Screening Strategies for Patients on the Kidney Transplant Waiting List" Operations Research 65(5), 2017,pp.1131–1146.
7	Oct 20	Markov decision processes in healthcare	• Alagoz, Chhatwal, Burnside "Optimal Policies for Reducing Unnecessary Follow-Up Mammography Exams in Breast Cancer Diagnosis" Decision Analysis Vol. 10, No. 3, September 2013, pp. 200–224. • S. M. Shechter, M. D. Bailey, A. J. Schaefer, and M. S. Roberts "The Optimal Time to Initiate HIV Therapy Under Ordered Health States" Operations Research 56, (1), 2008, pp. 20–33. Explain MDP

8	Nov 3	Stochastic programming in healthcare	• TBD • S. Rath, K. Rajaram and A. Mahajan. "Integrated Anesthesiologist and Room Scheduling for Surgeries: Methodology and Application", Operations Research (2017) 65(6), 1460–1478.
9	Nov 10	Radiotherapy	• H. E. Romeijn, R. K. Ahuja, J. F. Dempsey, and A. Kumar, "A new linear programming approach to radiation therapy treatment planning problems", Operations Research, 54(2), 201-216, 2006. • B. Vieira, D. Demirtas, J.B. van de Kamer, E.W. Hans, W. van Harten "Mathematical programming model for optimizing the staff allocation in radiotherapy under uncertain demand" European Journal of Operational Research 270 (2018) 709-722.
10	Nov 17	Data mining in healthcare	• TBD • Samorani, S. L. Harris, L. G. Blount, H. Lu, and M. A. Santoro, "Overbooked and Overlooked: Machine Learning and Racial Bias in Medical Appointment Scheduling," Manufacturing & service operations management, pp. 1-18, 2021 Extra Reading: Chen, Pierson, Rose, Joshi, Ferryman, Ghassemi, "Ethical Machine Learning in Healthcare". Annual Review of Biomedical Data Science 2021 4:1, 123-144.
11	Nov 24	Emergency Departments	• W Chen, NT Argon, T Bohrmann, B Linthicum, K Lopiano, A Mehrotra, D Travers, S Ziyab "Using Hospital Admission Predictions at Triage for Improving Patient Length of Stay in Emergency Departments" OPERATIONS RESEARCH Vol. 71, No. 5, September–October 2023, pp. 1733–1755. • Lee, E. K., Atallah, H. Y., Wright, M. D., Post, E. T., Thomas IV, C., Wu, D. T., & Haley Jr, L. L. (2015). "Transforming Hospital Emergency Department Workflow and Patient Care". Interfaces 45 (1), January–February 2015, pp. 58–82.
12	TBD	Course Wrap Up	• Summary of lessons learned, and trends seen. Discussion of the papers you liked and the ones that you didn't. Plans for future research.

Discussion Seminars:

Each 'seminar' will be led by two students – one per paper. The "Discussion Leaders" will ***facilitate*** the discussion, giving everyone an opportunity to contribute. The leaders will not present their views on the paper. For most sessions, I have provided two papers that either present similar topics with a different approach or use similar methodologies but with different applications. During your background preparation for the two papers, you may come across other papers that you feel add to the topic and you may certainly discuss those as well. In addition, there are several other files on the web site that you may

wish to use as background material, but feel free to bring in any relevant and interesting information that you find.

ALL students will read each paper before the presentations and are expected to participate in a meaningful way. Students will receive a mark based on their level of participation in each class. My marking scheme is simpe: I give people one mark each time they make a substantial contribution to the discussion up to a maximum of four per paper.

Each student will lead one or two topic discussions depending on the number of students in the course.

Take Home Essay:

The final deliverable will be a brief report describing: three papers discussed in the class that you liked and why, three papers that you didn't like (and think should be removed for next year), and finally at least three new papers/topics that you think should be added to the course. If you think I should add a new topic, you need to suggest at least two papers in the area. Please include a pdf for each paper. For the remaining papers, please be prepared to vote on "Like or dislike, but not in my top three."

Grading:

Class Participation	50%
Discussion Leader	5%
Take-home Essay (2000 word approximate)	45%
Total	**100%**

Analysis of Papers:

When you lead a discussion, you may find the following questions help guide a critical analysis of the paper. (Thank you to Prof. Marty Puterman for his original list that I have added to)

Problem: Why was this paper written? What problem was it trying to solve? Is the problem important? Why or why not? Is the problem real or contrived? Is it still relevant?

Formulation: How was the problem formulated? Is this the best way possible? What other formulations could be used? Was the level of detail appropriate? Why was this formulation chosen?

Methodology and Analysis: Is it appropriate and correct? Why was each step done? (When presenting be sure to go through details at an appropriate level. This doesn't mean repeating derivations or proofs line by line but it does mean that you have to understand them and be able to convey the main ideas.)

Results: What are the key results of the paper? Are they complete? Do they address the problem that the paper was trying to solve? Are the results reproducible? Could they be generalized for other problems, locations?

Further Directions: What open problems remain and what extensions are possible? How would you follow them up? Are there good research questions that would extend this research?

General Assessment of the Paper: Was it well presented? What are its strengths and weaknesses?

Comparison of Papers: If both papers used different approaches, which one did you prefer? Under what circumstances would you prefer the other?

Notes on the Publication Process:

- The process is highly subjective!
- Papers submitted to a journal will be sent to an "appropriate" Associate Editor in the area.
- They will search for volunteer reviewers (often by scanning the references in the paper)
- The reviewers agree to accept the paper and send in a report and a recommendation.
- Some reviewers are very conscientious, but others less so and may not even read the paper carefully.
- When all reviews are in, the Associate Editor will make a decision.
- Typical decisions: Minor/major revisions, reject, accept as is (very rare).
- When you get a paper back, it is normally wise to just do what the referees ask for

Some Tips for Taking this Course

- Some students have said that they spent many hours reading the papers in the first couple of weeks. In time, they learned how to read papers much faster and still pick out interesting comments (plus and minus)
- Remember that you should save your notes/comments for each paper. You will need the notes for the report at the end of term.
- You are not proof-reading the papers. You do not need to check all the math. You do need to understand what they are trying to do
- The class works best if everyone participates. You should come to each class with 1 or 2 thoughts about each section of the papers.

Encourage students to use a consistent rubric when reviewing papers. This could be optional and self-directed, with flexibility for students to use their own scoring criteria. The goal is not to standardize opinions but to provide a structure that helps students retain insights and participate more meaningfully in end-of-term discussions. Example rubrics from ML or OR conferences could be good starting points. The rubric (Jerry) used for evaluating each paper is based on some Machine Learning conferences' reviewing rubrics. For the following three criteria, give a score out of 5:

- Significance: The novelty of the contributions.
- Soundness: The technical soundness of the solution presented (are the proofs correct, are the experiments valid, etc.)
- Presentation: Is the paper well-written? Are the results well presented, etc.

Focus on whether each paper studies an important and well-defined healthcare operations problem, whether it offers a meaningful methodological contribution rather than a routine application of a familiar model, whether its evidence is convincing through real data, simulation, benchmarking, or sensitivity analysis, whether the findings have practical or policy relevance, and whether the paper's claims, methods, and conclusions are coherently aligned.

Comments from someone not from Industrial:

- Find opportunities to forge connections between reading topics and your interests outside of the course.
- For those outside the operations research field (such as myself), seek to approach the papers by linking them to your research and engaging with the researcher's positionality.
- As a non-subject matter expert, the mathematical equations were not always easy to read. It took some time for me to understand and be comfortable that the rationale for the equations exists in the text, and that it is sufficient in understanding how researchers framed their approach. I would suggest focusing on the intention and the rationale of the math rather than the equations.
- Dedicate some time before the seminar to intentionally compare the two papers for that week. I took much of my understanding of the papers by trying to connect their work, whether that be through the papers' methods or the week's topic. It also proved a useful exercise in distilling a paper down to its fundamental concepts and helped clarify the researcher's positionality and intended audience.

- Don’t be afraid to go to the seminar with questions. Even on weeks where I wasn’t facilitating, keeping note of questions I had while doing the readings proved to be a helpful way to learn from other students with increased expertise.