

ME 397 DATA-DRIVEN DESIGN AND DECISION-MAKING IN COMPLEX SYSTEMS

Instructor: Dr. Zhenghui Sha

Email: zsha@austin.utexas.edu | **Office:** ETC 4.142

Class Hours: TTH 2:00-3:20 | **Classroom:** ETC 2.140

Office Hours: 3:30 – 5:00 PM by appointment

Pre-requisite: ME 335: Engineering Statistics or equivalent courses with instructor consent

Course References: Hand-outs from recent literature will be provided. The key references are:

- 1) Chen, W., Hoyle, C. and Henk Jan Wassenaar, *Decision-based Design: Integrating Consumer Preferences into Engineering Design*, Springer, 2013.
- 2) G. A. Hazelrigg, 2012, *Fundamentals of Decision Making for Engineering Design and Systems Engineering*: <http://www.engineeringdecisionmaking.com>.
- 3) Trevor Hastie, Robert Tibshirani, Jerome Friedman, 2016, *The Elements of Statistical Learning: Data Mining, Inference, and Prediction*, Springer; 2nd edition.
- 4) R. T. Clemen, 1996, *Making Hard Decisions: An Introduction to Decision Analysis*. Belmont, CA: Wadsworth Publishing Company.
- 5) Mark Newman, 2011, *Networks - An Introduction*. Oxford University Press, Inc. New York, NY.
- 6) Albert-László Barabási, 2016, *Network Science*, Cambridge University Press. <http://networksciencebook.com/>
- 7) P.K. Dutta, 1999, *Strategies and Games: Theory and Practice*, Cambridge, MA: MIT Press.

Course description: This course introduces the state-of-the-art approaches for data-informed decision-making and modeling in complex systems design and provides hands-on experience in applying various data-driven and theory-driven models to model, estimate, analyze, and predict decision-making behaviors of stakeholders in representative complex engineered systems, such as air transportation networks, power grids, and market systems. Topics include decision-based design, game theory, discrete choice analysis, and complex networks. We will also cover the basics of data mining (e.g., clustering), data visualization, and statistical analyses. After completion of this course, students will be familiar with the typical process of decision analysis in support of complex systems engineering and design leveraging the power of data. Students will also be equipped with tools and methodologies introduced to perform research in this area.

Course learning outcomes: Upon the completion of this course, the student should be able to:

- 1) Frame decisions and model designers' preferences under uncertainties.
- 2) Apply formal decision-making approaches to engineering design.
- 3) Evaluate the assumptions and limitations of design decision making approaches.
- 4) Execute decisions in presence of other decision makers using game-theoretic models.
- 5) Apply discrete choice models to elicit customer preferences to support product design.
- 6) Model complex systems as complex networks and perform descriptive network analysis.
- 7) Master basic data mining techniques, including supervised learning (e.g., clustering, regression), dimension reduction, and data visualization (particularly network visualization techniques).

Assessment:

- Individual learning:**
 - Homework: Individual homework typically draws problems from the key references, and will be assigned every three weeks.
 - Level quiz: The course consists of three levels. At the completion of each level, there will be a quiz of that level. The quiz could be a take-home exam.
- Team-based learning**: Team-based learning is assessed by a course project. You will form a team that consists of **four or five members** (team smaller than four and greater than five need to be approved by the instructor). You will apply the knowledge learned in the class to solve real-world engineering problems. In the first half of the project, students will conduct systematic review of the relevant literature and accomplish a literature review report (i.e., the midterm report). In the second half, each team will propose their research questions and utilize the knowledge learned to answer the questions. They will present in PPT slides and submit a final project report. Presentation will be performed in the week before the final week. Project report is due on the last day of class. There is no final exam.
- Peer evaluation**: Each student's performance will be evaluated by their peers in the same group. An evaluation form will be submitted along with the final report.
- Attendance**: Notify the instructor **in advance** if you must be absent for a legitimate reason, which could include a religious holiday, a medical or family emergency, or other extenuating circumstances approved by the instructor. You are responsible for any work missed during your absence.

Grade breakdown:

	Activity	Percentage
Individual work 400 points (50%)	Homework assignments	25 (4 activities)
	Level quizzes	100 (3 quizzes)
Group work 400 points (50%)	Midterm project report	150
	Final project presentation (40%) & report (60%)	200
	Peer evaluation	50
Total points: 800		

Grading policies:

- Letter grades**: A > 93, A- > 90, B+ > 87, B > 83, B- > 80, C+ > 77, C > 73, C- > 70, D+ > 67, D > 63, D- >= 60, F <60
- All grading concerns and issues must be addressed upon the completion of each activity.
- Late homework will be accepted **up to one week** late with a penalty of **20% off** the score achieved. Late project submission will **NOT** be accepted. Late peer evaluation submission will **NOT** be accepted.
- For project report submissions, each group needs to include a statement specifying the responsibilities of each group member in the group work. Submissions without such a statement will receive a penalty of **20% off** the score.
- In case of any disputes emerge, all efforts should be made to settle the disputes within the group. As a next-to-last resort, the instructor will attempt to mediate to reach a solution. All behavior within the groups must be professional and respectful. **Communication** is the most important factor in achieving efficient and productive group work.

Q Drop Policy: If you want to drop a class after the 12th class day, you'll need to execute a Q drop before the Q-drop deadline, which typically occurs near the middle of the semester. Under Texas law, you are only allowed six Q drops while you are in college at any public Texas institution. For more information, see:

<http://www.utexas.edu/ugs/csacc/academic/adddrop/qdrop>

Tentative Course Schedule:

Level	Week	Topics*
Level 1: Individual decisions	1	<ul style="list-style-type: none"> • Introduction to decision-making in complex systems design • Non-rigorous approaches to decision making
	2	<ul style="list-style-type: none"> • Elements of a decision problem and objective hierarchy • Tradeoffs and decision-making under certainty
	3	<ul style="list-style-type: none"> • Modeling uncertainty • Single-attribute utility theory
	4	<ul style="list-style-type: none"> • Multi-attribute utility theory • <i>Application:</i> utility-based selection in design
	5	<ul style="list-style-type: none"> • Discrete choice analysis and customer preference modeling • <i>Application:</i> demand modeling for vehicle design • <i>Data-driven techniques: imputation, regression, random sampling</i>
Level 2: Strategic decisions	6	<ul style="list-style-type: none"> • Static games of complete information – introduction • Nash equilibrium: definition, existence and properties
	7	<ul style="list-style-type: none"> • Mixed strategies • Iterated strict dominance
	8	<ul style="list-style-type: none"> • Dynamic games of complete information – introduction • <i>Application:</i> modeling strategic decisions of designers in two-player design competition • <i>Data-driven techniques: design of experiment, statistical analyses and testing.</i>
	9	<ul style="list-style-type: none"> • Static game of incomplete information – introduction • Bayesian games and Bayesian equilibrium
	10	<ul style="list-style-type: none"> • <i>Application:</i> modeling effects of competition on airlines' route selection decisions (guest lecture)
Level 3: Decisions in complex networks	11	<ul style="list-style-type: none"> • Introduction to complex networks – history and examples • Metrics of characterizing networks
	12	<ul style="list-style-type: none"> • The large-scale structure of networks • Computation packages for network analysis • <i>Application:</i> network visualization and descriptive network analysis on product-market networks • <i>Data-driven techniques: data visualization, clustering, dimension reduction</i>
	13	<ul style="list-style-type: none"> • Random graphs • Representative models of network formation and evolution • <i>Application:</i> Forecasting U.S. domestic air transportation network using discrete choice models • <i>Data-driven techniques: clustering, regression</i>
	14	<ul style="list-style-type: none"> • Introduction to social network analysis (SNA)
	15	<ul style="list-style-type: none"> • Stochastic network models in engineering design applications • <i>Application:</i> Modeling sharing mobility networks using graph neural networks (Guest lecture) • <i>Data-driven techniques: artificial neural network, embeddings.</i>
Last week and final exam	16	<ul style="list-style-type: none"> • Final project presentations
	17	<ul style="list-style-type: none"> • Final project report due

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Rules of Civilized Behavior:

- 1) Mute your cell phones and put them away before class.
- 2) If you are going to miss class, send an email before class explaining why you will not be there. Do not just tell the instructor; send an email.
- 3) If you must leave class early, inform the instructor before class begins.

Academic Honesty: Each student in the course is expected to abide by the University of Texas Honor Code: “As a student of The University of Texas at Austin, I shall abide by the core values of the University and uphold academic integrity.” **Plagiarism is taken very seriously at UT.** Therefore, if you use words or ideas that are not your own (or that you have used in previous classes), you must cite your sources. Otherwise, you will be guilty of plagiarism and subject to academic disciplinary action, including failure of the course. You are responsible for understanding UT’s Academic Honesty and the University Honor Code, which can be found at the following web address:

<https://deanofstudents.utexas.edu/conduct/standardsconduct.php>

For more information about academic integrity, please visit:

<https://deanofstudents.utexas.edu/conduct/academicintegrity.php>

Services for Students with Disabilities: This class respects and welcomes students of all backgrounds, identities, and abilities. If there are circumstances that make our learning environment and activities difficult, if you have medical information that you need to share with me, or if you need specific arrangements in case the building needs to be evacuated, please let me know. I am committed to creating an effective learning environment for all students, but I can only do so if you discuss your needs with me as early as possible. I promise to maintain the confidentiality of these discussions. Any student with a documented disability who requires academic accommodations should contact Services for Students with Disabilities at 471-6259 (voice) or 512-410-6644 (Video Phone) as soon as possible to request an official letter outlining authorized accommodations. For more information, visit: <http://ddce.utexas.edu/disability/about/> and <https://diversity.utexas.edu/disability/current-students>

SSD will be partnering with Testing and Evaluation Services to pilot a new Campus Testing Center. Students registered with SSD and instructors will receive more details before the start of the Fall semester via email, the SSD website and the SSD Portal about using this new space for accommodated testing.

Counseling and Mental Health Center: Do your best to maintain a healthy lifestyle this semester by eating well, exercising, avoiding drugs and alcohol, getting enough sleep, and taking some time to relax. This will help you achieve your goals and cope with stress. All of us benefit from support during times of struggle. You are not alone. There are many helpful resources available on campus, and an important part of the college experience is learning how to ask for help. Asking for support sooner rather than later is often helpful. If you or anyone you know experiences any academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support.

<http://www.cmhc.utexas.edu/individualcounseling.html>

BeVocal: BeVocal is a university-wide initiative to promote the idea that individual Longhorns have the power to prevent high-risk behavior and harm. At UT Austin, all Longhorns have the power to intervene and reduce harm. To learn more about BeVocal and how you can help to build a culture of care on campus, go to: <https://wellnessnetwork.utexas.edu/BeVocal>.

Emergency Evacuation Procedures: The following recommendations regarding emergency evacuation from the Office of Campus Safety and Security, 512-471-5767, <http://www.utexas.edu/safet>. Occupants of buildings on The University of Texas at Austin campus are required to evacuate buildings when a fire alarm is activated. Alarm activation or announcement requires exiting and assembling outside.

- 1) Familiarize yourself with all exit doors of each classroom and building you may occupy. Remember that the nearest exit door may not be the one you used when entering the building.
- 2) Students requiring assistance in evacuation shall inform their instructor in writing during the first week of class.
- 3) In the event of an evacuation, follow the instruction of faculty or class instructors. Do not re-enter a building unless given instructions by the following: Austin Fire Department, The University of Texas at Austin Police Department, or Fire Prevention Services office.
- 4) Link to information regarding emergency evacuation routes and emergency procedures can be found at: www.utexas.edu/emergency

Violence / Active Shooter (CADD): CALL- 9-1-1. AVOID- If possible, self-evacuate to a safe area outside the building. Follow the directions of police officers. **DENY-** Barricade the door with desk, chairs, bookcases, or any items. Move to a place inside the room where you are not visible. Turn off the lights and remain quiet. Remain there until told by police it's safe. **DEFEND-** Use chairs, desks, cell phones, or whatever is immediately available to distract and/or defend yourself and others from attack.

Title IX Reporting: Title IX is a federal law that protects against sex and gender-based discrimination, sexual harassment, sexual assault, sexual misconduct, dating/domestic violence and stalking at federally funded educational institutions. UT Austin is committed to fostering a learning and working environment free from discrimination in all its forms. When sexual misconduct occurs in our community, the university can:

- 1) Intervene to prevent harmful behavior from continuing or escalating.
- 2) Provide support and remedies to students and employees who have experienced harm or have become involved in a Title IX investigation.
- 3) Investigate and discipline violations of the university's [relevant policies](https://titleix.utexas.edu/relevant-policies/) (<https://titleix.utexas.edu/relevant-policies/>).

Beginning January 1, 2020, Texas Senate Bill 212 requires all employees of Texas universities, including faculty, to report any information to the Title IX Office regarding sexual harassment, sexual assault, dating violence, and stalking that is disclosed to them. Texas law requires that all employees who witness or receive any information of this type (including, but not limited to, writing assignments, class discussions, or one-on-one conversations) must be reported. **I am a Responsible Employee and must report any Title IX-related incidents** that are disclosed in writing, discussion, or one-on-one. Before talking with me or with any faculty or staff member about a Title IX-related incident, be sure to ask whether they are a responsible employee. If you would like to speak with someone who can provide support or remedies without making an official report to the university, please email advocate@austin.utexas.edu. For more information about reporting options and resources, visit <http://www.titleix.utexas.edu/>, contact the Title IX Office via Email at titleix@austin.utexas.edu, or call 512-471-0419.

Although graduate teaching and research assistants are not subject to Texas Senate Bill 212, they are still mandatory reporters under Federal Title IX laws and are required to report a wide range of behaviors we refer to as sexual misconduct, including the types of sexual misconduct covered under Texas Senate Bill 212. The Title IX office has developed supportive ways to respond to a survivor and compiled campus resources to support survivors.