

## MEEG 591V: Special Topics in Mechanical Engineering (Decision-Making in Complex Systems Design)

**Instructor:** Dr. Zhenghui Sha  
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**Class time:** MWF 2:00-2:50pm

**Office Hours:** By appointment

**Pre-requisite:** MEEG 4703 or equivalent engineering courses with instructor consent

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

1. Albert-László Barabási, 2016, *Network Science*, Cambridge University Press.  
<http://networksciencebook.com/>
2. Chen, W., Hoyle, C. and Henk Jan Wassenaar, *Decision-based Design: Integrating Consumer Preferences into Engineering Design*, Springer, 2012.
3. G. A. Hazelrigg, 2012, *Fundamentals of Decision Making for Engineering Design and Systems Engineering*: <http://www.engineeringdecisionmaking.com>.
4. Mark Newman, 2011, *Networks - An Introduction*. Oxford University Press, Inc. New York, NY.
5. P.K. Dutta, 1999, *Strategies and Games: Theory and Practice*, Cambridge, MA: MIT Press.
6. R. T. Clemen, 1996, *Making Hard Decisions: An Introduction to Decision Analysis*. Belmont, CA: Wadsworth Publishing Company.
7. R. L. Keeney and H. Raiffa, 1976, *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*. New York: John Wiley and Sons.

**Course description:** This course introduces the state-of-the-art computational approaches for modeling decision-making in complex systems design, and provides hands-on experience on applying various computational models to model, estimate, analyze, and predict decision-making behaviors of stakeholders in representative complex engineered systems, such as air transportation network, power grid, and vehicle market systems. Topics include decision-based design, multi-objective decision making under uncertainty, multi-attribute utility theory, game-theory, discrete choice models, and complex network theory and models. After completion of this course, students will be familiar with a complete cycle of decision analysis in support of complex systems engineering and design. Students will be also equipped with presented tools and methodologies 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 risk.
2. Apply formal decision-making approaches to mechanical 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. Adopt an interdisciplinary approach among engineering, economics, and social sciences to solve real-world complex systems design problems.

**Assessment:****1. Individual learning:**

- Homework: Individual homework typically draws problems from the key references, and will be assigned every two or 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.

**2. Team-based learning:** There will be two projects in this course, and you will apply the knowledge learnt in the class to solving real engineering design problems as a team of three students. The first project is assessed in a form of final project report. Each group will submit one report. The report is due at the end of the 8th week. The second project is assessed by presentation in a form of PPT slides or posters given by each group AND a project report. Presentation will be performed one week before the final week. Project report is due on Wednesday of the final week.**Grade distribution:**

	<b>Activity</b>	<b>Percentage</b>
Individual work 400 points (50%)	Homework	20 (5 activities)
	Level quiz	100 (3 quizzes)
Group work 400 points (50%)	Midterm project	200
	Final project	200
<b>Total points: 800</b>		

**Grading policies:**

1. To get an "A" you must achieve a 90% or higher. Other letter grades are specified in the same manner.
2. You must achieve a passing grade in both individual and group work to pass this course.
3. Late individual work will be accepted up to one week late with a penalty of 25% off the score achieved. Late group work will not be accepted.

**Academic Honesty:** As a core part of its mission, the University of Arkansas provides students with the opportunity to further their educational goals through programs of study and research in an environment that promotes freedom of inquiry and academic responsibility. Accomplishing this mission is only possible when intellectual honesty and individual integrity prevail. Each student is required to be familiar with and abide by the University's Academic Integrity Policy which can be found at <http://honesty.uark.edu>.

**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.

**Discrimination/Harassment:** Discrimination and harassment of any kind are NOT tolerated. See University Discrimination and Harassment Policy and the procedure to handling complaint at: <https://oeoc.uark.edu/compliance/index.php>

**Accommodation Policy:** University of Arkansas Academic Policy Series 1520.10 requires that students with disabilities are provided reasonable accommodations to ensure their equal access to course content. If you have a documented disability and require accommodations, please contact me privately at the beginning of the semester to decide for necessary classroom

adjustments. Please note, you must first verify your eligibility for these through the Center for Educational Access (contact 479-575-3104 or visit <http://cea.uark.edu> for information on registration procedures).

**Emergency Procedure:** Many types of emergencies can occur on campus; instructions for specific emergencies such as severe weather, active shooter, or fire can be found at <http://emergency.uark.edu>.

- Severe Weather (Tornado Warning):
  - ✓ Follow the directions of the instructor or emergency personnel
  - ✓ Seek shelter in the basement or interior room or hallway on the lowest floor, putting as many walls as possible between you and the outside
  - ✓ If you are in a multi-story building, and you cannot get to the lowest floor, pick a hallway in the center of the building
  - ✓ Stay in the center of the room, away from exterior walls, windows, and doors
- Violence / Active Shooter (CADD):
  - ✓ CALL- 9-1-1
  - ✓ AVOID- If possible, self-evacuate to a safe area outside the building. Follow 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.

**Tentative Course Schedule:**

Level	Week	Topics
<b>Level 1:</b> Individual decisions	1	<ul style="list-style-type: none"> <li>• Introduction to decision-making in complex systems design</li> <li>• Non-rigorous approaches to decision making</li> </ul>
	2	<ul style="list-style-type: none"> <li>• Elements of a decision problem and objective hierarchy</li> <li>• Tradeoffs and decision-making under certainty (Labor day break)</li> </ul>
	3	<ul style="list-style-type: none"> <li>• Modeling uncertainty</li> <li>• Single-attribute utility theory</li> </ul>
	4	<ul style="list-style-type: none"> <li>• Multi-attribute utility theory</li> <li>• <i>Application:</i> utility-based selection in design</li> </ul>
	5	<ul style="list-style-type: none"> <li>• Discrete choice analysis and customer preference modeling</li> <li>• <i>Application:</i> demand modeling for vehicle design</li> </ul>
<b>Level 2:</b> Strategic decisions	6	<ul style="list-style-type: none"> <li>• Static games of complete information – introduction</li> <li>• Nash equilibrium: definition, existence and properties</li> </ul>
	7	<ul style="list-style-type: none"> <li>• Mixed strategies</li> <li>• Iterated strict dominance</li> </ul>
	8	<ul style="list-style-type: none"> <li>• Dynamic games of complete information – introduction</li> <li>• <i>Application:</i> modeling strategic decisions of designers in two-player design competition</li> </ul>
	9	<ul style="list-style-type: none"> <li>• Static game of incomplete information – introduction</li> <li>• Bayesian games and Bayesian equilibrium</li> </ul>
	10	<ul style="list-style-type: none"> <li>• <i>Application:</i> modeling effects of competition on airlines' route selection decisions (guest lecture)</li> </ul>
<b>Level 3:</b> Decisions in complex networks	11	<ul style="list-style-type: none"> <li>• Introduction to complex networks – history and examples</li> <li>• Measures and metrics of characterizing networks</li> </ul>
	12	<ul style="list-style-type: none"> <li>• The large-scale structure of networks</li> <li>• Computation packages for network analysis</li> <li>• <i>Application:</i> network visualization and descriptive network analysis on air transportation network</li> </ul>
	13	<ul style="list-style-type: none"> <li>• Random graphs</li> <li>• Representative models of network formation and evolution</li> <li>• <i>Application:</i> Forecasting U.S. domestic air transportation network using discrete choice models</li> </ul>
	14	<ul style="list-style-type: none"> <li>• Introduction to social network analysis (Thanksgiving break)</li> </ul>
	15	<ul style="list-style-type: none"> <li>• Stochastic network models in engineering design applications</li> <li>• <i>Application:</i> Modeling participation behaviors in design crowdsourcing using a bipartite network-based approach (Guest lecture)</li> </ul>
<b>Dead week and final week</b>	16	<ul style="list-style-type: none"> <li>• Final project presentations</li> </ul>
	17	<ul style="list-style-type: none"> <li>• Final project report due</li> </ul>