

ISE 662 – Advanced Decision Theory

Instructor – Ali Abbas

Term: Spring 2024, Units: 4 , Location: KAP 147

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Course Description

Rational decision making; value and utility functions; distribution theory; invariance relations; copulas; value of information and control; multiattribute utility; decision and game theory; behavioral research.

Learning Objectives

- Understanding the foundations of decision theory and its history and evolution to date
- Understanding of the rationality principles of decision making
- Introduction to flawed methods of decision making. Ability to analyze flaws in some decision-making methods e.g. Rank Reversal in AHP and Min-Max Regret.
- Ability to develop complex models of choices under uncertainty e.g. national security models, medical decision making models, bidding models with inference and winner's curse, risk sharing and scaling, and others.
- Ability to conduct complex value of information calculations including value of experimentation, value of information with influence, value of incomplete information, tests with multiple indications, entropy, and value of information on multiple uncertainties.
- Ability to construct complex probability distributions and Bayesian revision algorithms, including conjugate distributions and copula functions.
- Ability to test decomposition forms of multiattribute utility models and to construct multiattribute value and utility models.
- Ability to construct sophisticated forms of multiattribute utility functions when traditional independence decompositions do not hold.
- Understanding the relation between Bayesian statistics and classical statistics.
- Understanding of the interplay between decision theory, game theory, and Real Options.
- Understanding the relation between descriptive and normative modeling.
- Awareness of the impact of biases and heuristics for decision analysis.
- Prepare students for research in decision theory at the Ph.D. thesis level.

Prerequisite(s): The requirements for admission to the ISE Ph.D. program including multivariate calculus, basic background in linear algebra, probability, and statistics. Some knowledge of real analysis is preferred. Some knowledge of Matlab, Excel or R is recommended.

Required Readings and Supplementary Materials

Text(s):

Abbas, A. E. (2018) *Foundations of Multiattribute Utility*. Cambridge University Press. Cambridge, UK

Supplementary Materials

Due to the research nature of the course, a selection of classic research and journal papers will also be distributed. A sample reading list is included below.

Description and Assessment of Assignments

The class will be primarily in lecture format. There will be several homework assignments. The assignments involve computations and derivations. For example, an assignment may calculate the value-of-information for a complex decision or derive a multiattribute utility function that corresponds to certain axiomatic criteria. In addition, students will choose an advanced research topic and write a research paper.

Course project

The purpose of the class project is to develop the ability to conduct research in the field of decision analysis. You are encouraged to conduct a thorough literature review in your project area, and identify new research directions. The lecture discussions will provide samples of possible research directions. In addition, sample topics will be discussed in class upon the assignment of the project. A team can consist of no more than 3 persons.

Project Timeline:

Week 2: Identifying team members and project topics

Week 3: Project abstracts due.

Week 4: Project Progress Presentation 1

Week 7: Project Progress Presentation 2

Week 13: Mid-term report due

Week 14: Project presentation

Finals week: Final report due

Project Progress Presentations are approximately 10 minutes. They will provide you with the opportunity to get feedback on your project.

Final Project Presentation: The presentation should be approximately 15 minutes in duration and should cover all aspects of the project development, solution and outcomes. Typically plan on one slide per minute.

Final Report: The project should be documented with a written report that documents the motivation for the project, literature review, assumptions used, methodology, results, observations, conclusions and references. The main text of the report will typically be 8–10 pages (single-spaced, 1" margins, 11pt Times or 10pt Arial or similar) plus appendices (graphs, code, etc.).

Project Grading breakdown

All aspects of the project combined are 50 % of the semester grade, with a breakdown:

- Project Progress Presentation 1: 5%
- Project Progress Presentation 2: 5%
- Final Presentation: 10%
- Mid-term report: 10%
- Final report: 20%

Grades

Grades will be assigned on the basis of:

Class participation (10%),

HW assignments (40%),

Project (50%) comprising three project presentations (20%), and the midterm and final reports (30%).

Total points will be curved for the final letter grade. **Grading Scale** (Course final grades will be determined using the following scale)

A 95-100

A- 90-94

B+ 87-89

B 83-86

B- 80-82

C+ 77-79

C 73-76

C- 70-72

D+ 67-69

D 63-66

D- 60-62

F 59 and below

Assignment Submission Policy

Assignments should be submitted on or before due date and time.

Weekly Schedule (Subject to Change Based on Class Discussion)

	Topics	Assignments Due
1	Introduction; class overview; introduction to decision analysis; history, axioms	HW 1- Desiderata, Literature search, Flawed Methods
2	Structuring the decision; visualization tools, flawed methods, Paradoxes	HW 2- Project Identification, Paradoxes in Decision Making
3	Objectives hierarchies, measures; entropy, value of information, conjugate priors	HW 3 - Entropy, Conjugate Priors, Project Abstracts
4	Presentation 1: Project Progress ; advanced models of joint probability distributions, copula functions, maximum entropy	HW 4 - Group Assignment (Matlab or R or Excel) Entropy, Copula Functions
5	Single attribute utility and value assessments, functional equations, risk aversion	HW 5- Single attribute utility and value assessments
6	Multiattribute Utility theory Part 1: functions using independence, utility trees	HW 6- Simple multiattribute utility analysis using utility independence, Value functions
7	Multiattribute utility theory Part 2: Pricing model; value functions, utility transversality, consistency checks.	
8	Applications: Linking decision models to other models; multi-attribute models and optimization; portfolio analysis with resource constraints; simulation and decision models	
9	Valuations: Decision analytic vs. Real Options Valuation	
10	Applications: Risk Sharing and Scaling, Theory of Syndicates, Risk Premium, Taylor Expansions	

11	Presentation 2: Project Progress. Advanced Information Gathering: perspectives on inference, decision, and experimentation.	HW 7- Advanced Information Gathering
12	Bayesian analysis vs. classic statistics. Bayesian view of regression, confidence intervals.	Midterm Progress report on research papers, annotated literature review
13	Game theory: Distinctions and similarities between game theory and decision theory; overview of types of games; cooperative, non-cooperative, and adversarial games	
14	Behavioral decision research: The prescriptive-descriptive distinction; heuristics and biases in probability and utility	
15	Presentation of Research Papers	PowerPoint version of research papers
	Final research papers due	Date of Final Exam

* Disclaimer: Materials covered in each week may vary from the schedule. Date and time of the final for this class is shown in the USC Schedule of Classes at classes.usc.edu/.

Selected Supplementary Readings for Advanced Decision Theory

History and Overview of the Class (Session 1)

- Howard, R.A. (1966). Decision analysis: applied decision theory. In D.B. Hertz and J. Melese (eds.). *Proceedings of the Fourth International Conference on Operational Research*. New York: Wiley. pp. 55-71. (RH1966)
- Howard, R. (2007). The foundation of decision analysis revisited. In W. Edwards, R. Miles, and D. von Winterfeldt (eds.). *Advances in decision analysis: From foundations to applications*. Cambridge; New York: Cambridge University Press. pp. 32-55. (RH2007).
- Keeney, R. (1982). Decision analysis: An overview. *Operations Research*, 30(5), 803-838. (RLK1982)
- Raiffa, H. (2007). Decision analysis: A personal account of how it got started and evolved. In W. Edwards, R. Miles, and D. von Winterfeldt (eds.). *Advances in decision analysis: From foundations to applications*. Cambridge; New York: Cambridge University Press. pp. 57-70 (HR2007)

Classics

- Raiffa, H. *Decision analysis*. (1968). Reading, MA: Addison-Wesley. (HR1968)
- Savage, J. (1954). *The foundations of statistics*. New York: Wiley. (JS1954)
- von Neumann, J. and Morgenstern O. (1947). *Theory of games and economic behavior*, 2nd Ed.. Princeton, NJ: Princeton University Press. (Appendix on expected utility theory). (vN&M1947)

Decisions under uncertainty and with multiple objectives (Session 2)

- Abbas, A. (2018) *Foundations of multiattribute utility theory*. New York, Cambridge University Press. (AA2018, Ch. 1-3).
- Howard, R. and Abbas, A. (2015). *Foundations of decision analysis*. New York, NY: Pearson. (RH&AA2015, Chapters TBD)
- Saaty, T. (2012). The seven pillars of the analytic hierarchy process. Multiple criteria decision making in the new millennium. In. T.L Saaty and L.G. Vargas (eds). *Models, methods, concepts, and applications of the analytic hierarchy process*. New York: Springer. pp. 26-40. (TS2012)

Uncertainty and Risk Analysis in Decision Theory (Session 3)

- Bedford, T. and Cooke, R. (2001). *Probabilistic risk analysis: Foundations and methods*. Cambridge, UK: Cambridge University Press. (B&C2001)
- Clemen, R. & Reilly, T. (2013). *Making hard decisions with DecisionTools* (3rd Ed.). New York: Cengage. (C&R2013)
- Clemen, R. and Reilly, T. (1999) Correlations and copulas for decision and risk analysis. *Management Science*, 45(2), 208-224. (C&R1999)

Wang, T. and Dyer, J. (2012). A copulas-based approach to modeling dependence in decision trees. *Operations Research*, 60(1), 225-242. (W&D2012)

Classics

DeGroot, M. (1970). *Optimal statistical decisions*. New York: Wiley. (DG1970)

Pratt, J., Raiffa, H. and Schlaifer, R. The foundations of decisions under uncertainty: An elementary exposition. *Journal of the American Statistical Association*, 59(306), 353-375. (PR&S1970)

Spetzler, C. and von Holstein, C. (1975). Probability encoding in decision analysis. *Management Science*, 22(3), 340-352. (S&vH1975)

Raiffa, H. and Schlaifer, R. (1961). *Applied statistical decision theory*. Cambridge, MA: Harvard University Press. (HR&RS1961)

Winkler, R. (2003). *An introduction to Bayesian inference and decision* (2nd ed.). Houston: Probabilistic Publishing. (RW2003)

Value of Information and Control (Session 4)

Clemen, R. & Reilly, T. (2013). *Making hard decisions with DecisionTools* (3rd Ed.). New York: Cengage. (C&R2013)

Howard, R.A. and Abbas, A. (2015). *Foundations of decision analysis*. New York, NY: Pearson. (RH&AA2015, Chapters TBD)

Single attribute utility (Session 5 and 6)

Abbas, A. (2018) *Foundations of multiattribute utility theory*. New York, Cambridge University Press. (AA2018, Ch. 4-6, 10).

Dyer, J. and Sarin, R. (1979). Measureable multiattribute value functions. *Operations Research*, 27(4), 810-822. (D&S1979)

Eisenfuehr, F., Weber, M., and Langer, T. (2010). *Rational decision making*. Heidelberg, Germany: Springer. (EW&L2010, Chapter10).

Krantz, D., Luce, R., Suppes, P., and Tversky, A. (1971). *Foundations of measurement, Volume I*. New York: Academic Press. (KLST1971, Chapters 1, 4).

von Winterfeldt, D. and Edwards, W. *Decision analysis and behavioral research*. New York: Cambridge University Press. (vW&E1986, Chapter 7)

Descriptive Theories of Decision Making Under Uncertainty (Session 7)

Kahneman, D. & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica*, 47(2), 263-291. (K&T1979)

Luce, R.D. & von Winterfeldt, D. (1994). What common ground exists for descriptive, prescriptive, and normative utility theories? *Management Science*, 40, pp. 263-279. (RDL&DvW 1998).

- Train, K. E. (2009). *Discrete choice methods with simulation, 2nd ed.* Cambridge, UK; New York: Cambridge University Press. (KET 2009)
- Tversky, A. & Kahneman, D. (1981). The framing of decisions and the psychology of choice. *Science*, 211(4481), 453-458. (T&K1981)

Multiattribute Utility Theory (Sessions 8 and 9)

- Abbas, A. (2018). *Foundations of multiattribute utility.* New York, NY: Cambridge University Press. (AA2018, Chapters 4-9; 24-30)
- Fishburn, P. (1965). Independence in utility theory with whole product sets. *Operations Research*, 13(1), 28-45. (PF1965)
- Fishburn, P. (1970) *Utility theory for decision making.* New York: Wiley. (PF1970)
- Keeney, R. and Raiffa, H. (1976). *Decisions with multiple objectives.* New York: Wiley. (K&R1976, selected chapters)
- Keeney, R. and von Winterfeldt, D. (2007). Practical value models. In W. Edwards, R. Miles, and D. von Winterfeldt (eds.) *Advances in decision analysis: From foundations to applications.* Cambridge; New York: Cambridge University Press, pp.232-252. (K&vW, 2007)
- Krantz, D., Luce, R., Suppes, P., and Tversky, A. (2007). *Foundations of measurement, Volume I.* New York: Academic Press. (Chapters 1, 4, and 6). (KLS&T1971)
- von Winterfeldt, D. and Edwards, W. *Decision analysis and behavioral research.* New York: Cambridge University Press. (vW&E, Chapters 8-9).

Linking Decision Models with other Models for Decision Making (Session 11)

- Abbas, A.E. and Stipanovic, D.M. (2016). Achieving multiple objectives with limited resources: Using utility theory and control theory. In A.E. Abbas, M. Tambe, and D. von Winterfeldt. *Improving homeland security decisions.* New York: Cambridge University Press, pp. 427-444. (AA&DMS2016)
- Keefer, D. L.: and Kirkwood, C.W. Perspectives of decision analysis applications. In W. Edwards, R. Miles, and D. von Winterfeldt (eds). *Advances in decision analysis: From foundations to applications.* Cambridge; New York: Cambridge University Press. (Chapter 28, pp. 582-610) (K&K2007)
- Kleinmuntz, D.N. (2004). Resource allocation decisions. In W. Edwards, R. Miles, and D. von Winterfeldt (eds). *Advances in decision analysis: From foundations to applications.* Cambridge; New York: Cambridge University Press. (Chapter 20, pp. 400-418).
- Smith, J. & Keeney, R. (2005). Your money or your life: A prescriptive model for health, safety, and consumption decisions. *Management Science*, 51(9), 1309-1325. (S&K2005)
- von Winterfeldt, D. & Schweitzer, E. (1998). An assessment of tritium supply alternatives in support of the U.S. nuclear weapons stockpile. *Interfaces: An International Journal of the Institute for Operations Research and the Management Sciences*, 28(1), 92-112. (vW&S1998)

von Winterfeldt, D., Eppel, T., Adams, J., Neutra, R., & DelPizzo, V. (2004). Managing potential health risks from electric powerlines: A decision analysis caught in controversy. *Risk Analysis*, 24, pp. 1487-1502. (vWEAND 2004).

Game Theory (Sessions 12 and 13)

Bo, A. and Tambe, M. (2017). Stackelberg security games: Basics and applications. In A.E. Abbas, M. Tambe, and D. von Winterfeldt (eds.). *Improving homeland security decisions*. New York: Cambridge University Press, pp. 485-507. (B&T2017)

Dutta, P.K. (1999). *Strategies and games: Theory and practice*. Cambridge, MA: MIT Press. (PKD1999)

Garcia, R. & von Winterfeldt, D. (2016) Defender-attacker decision tree analysis to counter terrorism. *Risk Analysis*, 36(8), 1-14. (G&vW2016)

Kiekintveld, C. and Jain, M. (2017) Basic solution concepts and algorithms for Stackelberg security games. In A. Abbas, M. Tambe, and D. von Winterfeldt. *Improving homeland security decisions*. New York: Cambridge University Press, 508-537. (K&J2017)

Merrick J, Parnell, G. (2011). A comparative analysis of PRA and intelligent adversary methods for counterterrorism risk management. *Risk Analysis*, 31(9), 1488–1510. (M&P2011)

Sebenius, J.K. (2007). Negotiation analysis: Between decisions and games. In W. Edwards, R. Miles, and D. von Winterfeldt (eds). *Advances in decision analysis: From foundations to applications*. Cambridge; New York: Cambridge University Press,. pp. 469-488. (JKS2007).

Classics

von Neumann, J. and Morgenstern O. (1947). *Theory of games and economic behavior* (2nd ed.). Princeton, NJ: Princeton University Press. (Appendix on expected utility theory). (vN&M1947)

Luce, R.D. and Raiffa, H. (1957). *Games and decisions: Introduction and critical surveys*. New York: John Wiley and Son. (L&R1958)

Behavioral decision research (Sessions 14)

Bond, S., Carlson, K., & Keeney, R. (2008). Generating objectives: Can decision makers articulate what they want? *Management Science*, 54(1), 56-70. (BC&K2008)

Gilovich, T. Griffin, D. and Kahneman, D. (Eds.). (2002) *Heuristics and biases: The psychology of intuitive judgement*. Cambridge; New York: Cambridge University Press. (TG&K2002)

Kahneman, D., Slovic, P, and Tversky, A. (Eds.). (1982) *Judgement under uncertainty: Heuristics and biases*. Cambridge; New York: Cambridge University Press. (KS&T1982)

- Kahneman, D. and Tversky, A. (Eds.). (2000) *Choices, values, and frames*. Cambridge; New York: Cambridge University Press. (K&T2000)
- Keeney, R. (2002). Common mistakes in making value trade-offs. *Operations Research*, 50, 935-945. (RLK2002)
- Montibeller, G. & von Winterfeldt, D. (2015). Cognitive and motivational biases in decision and risk analysis. *Risk Analysis*, 35(7), 1230-1251. (M&vW2015)
- Tversky, A. & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, 185(4157), 1124-1131. (T&K1974)
- Tversky, A. & Kahneman, D. (1981). The framing of decisions and the psychology of choice. *Science*, 211(4481), 453-458. (T&K1981)
- von Winterfeldt, D. (1998). On the relevance of behavioral decision research for the practice of decision analysis. In J. Shanteau, B. Mellers, and D. Schum (eds.) *Decision research from Bayesian approaches to normative systems: Reflections on the contributions of Ward Edwards*. Norwell, MA: Kluwer, 133-149. (DvW1986)
- Wakker, P. (2010). *Prospect theory: For risk and ambiguity*. Cambridge; New York: Cambridge University Press. (PW2010)

Statement on Academic Conduct and Support Systems

Academic Integrity:

The University of Southern California is a learning community committed to developing successful scholars and researchers dedicated to the pursuit of knowledge and the dissemination of ideas. Academic misconduct, which includes any act of dishonesty in the production or submission of academic work, comprises the integrity of the person who commits the act and can impugn the perceived integrity of the entire university community. It stands in opposition to the university's mission to research, educate, and contribute productively to our community and the world.

All students are expected to submit assignments that represent their own original work, and that have been prepared specifically for the course or section for which they have been submitted. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s).

Other violations of academic integrity include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), collusion, knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university. All incidences of academic misconduct will be reported to the Office of Academic Integrity and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

For more information about academic integrity see [the student handbook](#) or the [Office of Academic Integrity's website](#), and university policies on [Research and Scholarship Misconduct](#).

Please ask your instructor if you are unsure what constitutes unauthorized assistance on an exam or assignment, or what information requires citation and/or attribution.

Students and Disability Accommodations:

USC welcomes students with disabilities into all of the University's educational programs. The Office of Student Accessibility Services (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at osas.usc.edu. You may contact OSAS at (213) 740-0776 or via email at osasfrontdesk@usc.edu.

Support Systems:

[Counseling and Mental Health](#) - (213) 740-9355 – 24/7 on call

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

[988 Suicide and Crisis Lifeline](#) - 988 for both calls and text messages – 24/7 on call

The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week, across the United States. The Lifeline is comprised of a national network of over 200 local

crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services (though the previous 1 (800) 273-8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

[Relationship and Sexual Violence Prevention Services \(RSVP\)](#) - (213) 740-9355(WELL) – 24/7 on call
Free and confidential therapy services, workshops, and training for situations related to gender- and power-based harm (including sexual assault, intimate partner violence, and stalking).

[Office for Equity, Equal Opportunity, and Title IX \(EEO-TIX\)](#) - (213) 740-5086
Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

[Reporting Incidents of Bias or Harassment](#) - (213) 740-5086 or (213) 821-8298
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

[The Office of Student Accessibility Services \(OSAS\)](#) - (213) 740-0776
OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.

[USC Campus Support and Intervention](#) - (213) 740-0411
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

[Diversity, Equity and Inclusion](#) - (213) 740-2101
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

[USC Emergency](#) - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

[USC Department of Public Safety](#) - UPC: (213) 740-6000, HSC: (323) 442-1200 – 24/7 on call
Non-emergency assistance or information.

[Office of the Ombuds](#) - (213) 821-9556 (UPC) / (323-442-0382 (HSC)
A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

[Occupational Therapy Faculty Practice](#) - (323) 442-2850 or otfp@med.usc.edu
Confidential Lifestyle Redesign services for USC students to support health promoting habits and routines that enhance quality of life and academic performance.