

ISE 662 – Advanced Decision Theory

Units: 3

Term: Spring 2021

Location: VKC 201

Instructor: Ali E. Abbas

Office: OHE 310R

Office Hours: TBD

Contact Info: aliabbas@usc.edu

Teaching Assistant:

Office: TBD

Office Hours: TBD

Contact Info: TBD

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 evolution to date
- Understanding of the rationality principles of decision making
- Ability to develop prescriptive models of choices under uncertainty
- Ability to construct complex probability distributions and Bayesian revision algorithms, including conjugate distributions
- Ability to test decomposition forms of multiattribute utility models and to construct multiattribute value and utility models
- Understanding of the interplay between decision theory and game theory
- Understanding the relation between descriptive and normative modeling
- Awareness of the possible 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

Recommended preparation: Multivariate calculus; mathematical statistics; some knowledge of real analysis, measurement theory and functional equations preferred

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 comprehensive reading list is included below for instructors to choose.

Description and Assessment of Assignments

The class will be primarily in lecture format. Every other class will have an individual homework assignment. 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 in the form of a literature review or a research project proposal.

Grades

Grades will be assigned on the basis of class participation (10%), assignments (35%), project presentations (20%), and the final research proposal (35%).

Tentative Course Outline :

Class #	Topics	Readings	Assignments Due
1	<i>Class overview; history of decision theory from Bayes and Bernoulli to today; relationship to risk analysis and game theory; descriptive vs. prescriptive decision theory</i>	<i>RH2007, HR2007, vW&E1986 (Ch. 14), S&vW2004</i>	
2	<i>Rationality assumptions and axiomatic base of decision theory; decisions under uncertainty; decisions with multiple objectives; simplistic and flawed methods</i>	<i>AA2018 (Ch. 1-3), RH&AA2015 (Chapters TBD), vN&M1947 (Appendix), TS2012</i>	
3	<i>Uncertainty and risk analysis in decision theory: decision trees; expected value; prior and preposterior analysis, conjugate distributions, modeling joint distributions with copulas</i>	<i>C&R2013 (Chapters TBD), W&D2012, C&R1999, SH2007</i>	<i>Brief essay: Do you agree or disagree with the axioms of rationality and why?</i>
4	<i>Value of information, value of control, value of experimentation, Bayesian networks; discretization methods, analytical vs. simulation approaches</i>	<i>RH&AA2015 (Chapters TBD), C&R2013 (Chapters TBD)</i>	
5	<i>Single attribute utility theory 1; measurement theoretic foundation of utility and value functions; relationship between utility and value functions</i>	<i>KLS&T1971 (Chapters 1 and 4), vW&E1986(Ch. 7), AA2018 (Ch. 4-6, 10)</i>	<i>Analysis of a complex decision problem</i>
6	<i>Single attribute utility theory 2: Invariance conditions; functional equations; characterizing risk attitudes; implications of risk aversion</i>	<i>AA2018 (Ch. 13-17), D&S1979</i>	
7	<i>Descriptive theories of decision making under uncertainty: Prospect theory, rank and sign dependent utility theories, random utility models</i>	<i>K&T1979, TS&K1982 (Chapters TBD), RDL&vW1998, KET2004</i>	<i>Assessment of a utility function with two different methods</i>
8	<i>Discussion of research questions in decision theory: Presentations of research questions</i>		<i>2 research questions to be addressed in a research paper</i>
9	<i>Muliattribute utility theory 1: ordinal vs. cardinal value functions; conjoint measurement and difference measurement; model forms and functional equations</i>	<i>KLS&T (Ch. 6), vW&E, (Ch. 7), AA (Ch. 11-12), K&vW, 2007</i>	
10	<i>Muliattribute utility theory 2: Single and joint utility independence, additive and multiplicative models; more complex models based on functional equations</i>	<i>K&R1976 (Chapters TBD), AA2018 (Ch. 21-30), KLS&T1971 (Ch. 7)</i>	<i>Assessment of a multiattribute utility function</i>
	Spring Break		

Class #	Topics	Readings	Assignments Due
	<i>Spring Break</i>		
11	<i>Linking decision models to other models; multi-attribute models and optimization; portfolio analysis with resource constraints; simulation and decision models</i>	<i>vW&S1998, DNK2004, AA&DMS2016, S&K2005</i>	
12	<i>Game theory 1: Distinctions and similarities between game theory and decision theory; overview of types of games; cooperative, non-cooperative, and adversarial games</i>	<i>PKD1999 (Chapters TBD), M&P2011</i>	<i>Progress report on research papers, annotated literature review</i>
13	<i>Game theory 2: Introduction to security games; Stackelberg games; Nash solution and randomization; negotiation analysis</i>	<i>B&T2017, K&J2017, KET2004, KKS2007</i>	
14	<i>Behavioral decision research: The prescriptive-descriptive distinction; heuristics and biases in probability and utility judgments that are relevant to decision analysis</i>	<i>T&K1974, K&T1979, TS&K1982 (Chapters TBD), M&vW2015</i>	<i>Solution to a Stackelberg security problem</i>
15	<i>Presentations of research papers</i>		<i>Powerpoint version of research papers</i>
<i>Final</i>	<i>Final research papers due</i>		

Selected Supplementary Readings for Advanced Decision Theory

(Instructors will select supplementary readings from this list)

History and Overview of the Class (Session 1)

- Edwards, W. Miles, R., and von Winterfeldt, D. (eds.) (2007). *Advances in decision analysis: From foundations to applications*. Cambridge; New York: Cambridge University Press. (MvWE, 2007)
- 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)
- Smith, J. & von Winterfeldt, D. (2004). Decision analysis in management science. *Management Science*, 50(5), 561-574. (S&vW)
- von Winterfeldt, D. and Edwards, W. (1986). *Decision analysis and behavioral research*. New York: Cambridge University Press. (vW&E1986, Ch.

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).
- Eisenfuehr, F., Weber, M., and Langer, T. (2010). *Rational decision making*. New York: Springer. (EW&L 2010, Chapters 1-2)
- 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)

- Hora, S. (2007) Eliciting probabilities from experts. In W. Edwards, R. Miles, and D. von Winterfeldt (eds.), *Advances in decision analysis: From foundations to applications*. Cambridge; New York: Cambridge University Press. (SH2007)
- 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)
- Winterfeldt, D., Kavet, R., Peck, S., Mohan, M., & Hazen, G., (2012). The value of environmental information without control of subsequent decisions. *Risk Analysis*, 32(12), 2113-2132. (vWKPM&H2012)

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 Pres., 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 Conduct:

Plagiarism – presenting someone else’s ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Part B, Section 11, “Behavior Violating University Standards” policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct, <http://policy.usc.edu/scientific-misconduct>.

Support Systems:

Student Counseling Services (SCS) – (213) 740-7711 – 24/7 on call

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

National Suicide Prevention Lifeline – 1 (800) 273-8255

Provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week. www.suicidepreventionlifeline.org

Relationship and Sexual Violence Prevention Services (RSVP) – (213) 740-4900 – 24/7 on call

Free and confidential therapy services, workshops, and training for situations related to gender-based harm. engemannshc.usc.edu/rsvp

Sexual Assault Resource Center

For more information about how to get help or help a survivor, rights, reporting options, and additional resources, visit the website: sarc.usc.edu

Office of Equity and Diversity (OED)/Title IX Compliance – (213) 740-5086

Works with faculty, staff, visitors, applicants, and students around issues of protected class. equity.usc.edu

Bias Assessment Response and Support

Incidents of bias, hate crimes and microaggressions need to be reported allowing for appropriate investigation and response. studentaffairs.usc.edu/bias-assessment-response-support

The Office of Disability Services and Programs

Provides certification for students with disabilities and helps arrange relevant accommodations. dsp.usc.edu

Student Support and Advocacy – (213) 821-4710

Assists students and families in resolving complex issues adversely affecting their success as a student EX: personal, financial, and academic. studentaffairs.usc.edu/ssa

Diversity at USC

Information on events, programs and training, the Diversity Task Force (including representatives for each school), chronology, participation, and various resources for students. diversity.usc.edu

USC Emergency Information

Provides safety and other updates, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible. emergency.usc.edu

USC Department of Public Safety – UPC: (213) 740-4321 – HSC: (323) 442-1000 – 24-hour emergency or to report a crime.

Provides overall safety to USC community. dps.usc.edu