Department of Systems Engineering

George Mason University

SYST 302: Systems Methodology and Design II #1

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Outline

- System Definitions and Concepts
- Course Overview and Schedule
- Models in Decision Making

System Definitions and Concepts

- **A system is a set of interconnected components working together toward some common objectives**
  - **Agrees with our intuitive understanding of a *physical system* such as an electrical circuit, a computer system, a transportation system, and a communication system**
  - **When change in time, it's called a *physical dynamical system (PDS).***
- **An ordered and comprehensive assemblage of facts, principles, or rules**
  - **Agrees with the concept of a system as a mathematical abstraction**
  - **Serves as a model for real system phenomena**

System Engineering

- Mission: to design a PDS that behave in a desired manner
  - understand the physical laws
  - develop mathematical models
  - study system behavior
  - system design and implementation
- Systems Engineering Core Courses
  - SYST 101: Understanding systems engineering
  - SYST 201: Systems Modeling I: mathematical foundation
  - SYST 202: Systems Modeling II: static and dynamic systems
  - SYST 203: Systems Modeling Lab: hand on experience (MATLAB)
  - SYST 301: Systems Methodology and Design I
    - » systems requirement analysis and architecture specification
  - SYST 302: Systems Methodology and Design II
    - » quantitative techniques for modeling and evaluating designs

Scope of Course

- **Systems Analysis Tools**
  - Decision Analysis
  - Optimization Techniques
  - Probabilistic Analysis
  - Queuing Theory
  - Markov Chain
  - Control Techniques
- **Operational Feasibility**
  - Design for Reliability
  - Design for Maintainability
  - Economic Feasibility

Course Outline

• Wk#1 Course Introduction/Decision under Risk	Chap 7
• Wk#2 Economic Models and Evaluation	Chap 8
• Wk#3 Probability Concept and Analysis	Appendix B
• Wk#4 Probabilistic Analysis	Handouts
• Wk#5 Mid-term 1: Chap. 7, 8, Appendix B, Handouts	
• Wk#6 Optimization - Theory	Chap 9
• Wk#7 Queuing Theory and Analysis	Chap 10
• Wk#8 Spring Recess	
• Wk#9 Queuing Theory and Analysis	Chap 10
• Wk#10 Mid-term 2: Chap. 9, 10	
• Wk#11 Control Concepts and Techniques	Chap 11
• Wk#12 Reliability: Concept and Design	Chap 12
• Wk#13 Markov Chain for Reliability Analysis	Handouts
• Wk#14 Maintainability: Concept and Design	Chap 13
• Wk#15 Design and Life-Cycle Cost Analysis	Chap 17
• Wk#16 Final Exam: Chap. 11, 12, 13, 17	

Assignments and Grading

- Grading
  - Weekly Assignments (30%)
  - Mid-Term Exam I (20%)
  - Mid-Tram Exam II (20%)
  - Final Exam (30%)
- Course Materials
  - Required texts: Blanchard and Fabrycki., Systems Engineering and Analysis, Prentice Hall, 3rd. Ed., 1998.
  - Lecture Notes
  - Other References

Models in Decision Making

- **Motivation**
  - Efficient use of limited resource
  - Searching for better alternatives
- **Issues**
  - Limiting factors (constraints)
  - Measures for comparing alternatives
  - Risk and uncertainty
- **Models**
  - Physical (globe, airplane)
  - Analog (LSI design)
  - Schematic (process flow chart, Petri net)
  - Mathematical (system dynamic equation)

Decision Evaluation Function

- **Operation**
  - $E = f(X, Y);\ g(X, Y) \le C$
  - *E:* **effectiveness**, *X*: **controllable,** *Y*: **uncontrollable**
- **Procurement**
  - $E = f(X, Y_d, Y_i);\ g(X, Y_d, Y_i) \le C$
  - *X*: **quantity,** *Yd*: **source dependent**
  - *Yi*: **source independent parameters**
- **Design Optimization**
  - $E = f(X, Y_d, Y_i);\ g(X, Y_d, Y_i) \le C$
  - *X*: **design variable**
  - *Yd*: **design dependent parameters**
  - *Yi*: **design independent parameters**

Decision Evaluation Matrix

$$
\begin{array}{c|cccc}
 & H_1 & H_2 & \cdots & H_n \\
\hline
A_1 & E_{11} & E_{12} & \cdots & E_{1n} \\
A_2 & E_{21} & E_{22} & \cdots & E_{2n} \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
A_m & E_{m1} & E_{m2} & \cdots & E_{mn}
\end{array}
$$

A_i: alternative H_j: hypothesis

Assumptions:

1. **All viable alternatives and hypotheses have been considered**
2. **Hypotheses are mutually exclusive and independent**
3. **Hypotheses are uncertain**

Decision with Certainty

	H
A_1	E_1
A_2	E_2
$\vdots$	$\vdots$
A_m	E_m

$$Select\ \ A_i \Rightarrow \max_i \{E_i\}$$

Issues:

1. Quantitative vs. Qualitative (eg., relative preference)
2. Other measures (time, market share, etc.)
3. Rating nonquantifiable alternatives (expert opinion)

Decision under Risk

Probabilities are assigned to each future state (hypothesis)

	$SW(0.2)$	$HW(0.3)$	$SW+HW(0.5)$
$(1) S_i H_o$	100	100	400
$(2) S_o H_i$	-200	150	600
$(3) S_i H_i$	0	200	500
$(4) S_{io} H_{io}$	100	300	200
$(5) S_o H_o$	-400	100	200

Remarks:

1. Probabilities assigned are relative
2. Decision criterion is needed for making choice
3. Eliminated dominated alternatives (e.g., (5))

Decision Criteria

- **Aspiration Level (desired)**
  - ex: min profit 400, max loss 100.
  - decision are (1) or (3)
- **Most Probable Future**
  - SW+HW is most probable
  - decision is (2)
- **Expected value**
  - (1) 250, (2) 305, (3) 310, (4) 210
  - decision is (3)
- **Issues**
  - no one "best" decision, it depends on the criterion
  - hypothesis (future) probabilities may not be obtainable

Decision under Uncertainty

No probability is assigned to each future state (hypothesis)

	SW	HW	$SW + HW$
(1)	100	100	400
(2)	− 200	150	600
(3)	0	200	500
(4)	100	300	200

Criteria:

1. ***Laplace principle: principle of insufficient reason***
   prob = 1/n and compare the expected values
2. **Maxmin**
3. **Maxmax**

$$\max_i \{\min_j E_{ij}\}, \max_i \{\max_j E_{ij}\}$$

Hurwicz Criterion

$$\max_i \left[(1-\alpha)\{\min_j E_{ij}\} + \alpha\{\max_j E_{ij}\} \right];\ 0 \le \alpha \le 1$$

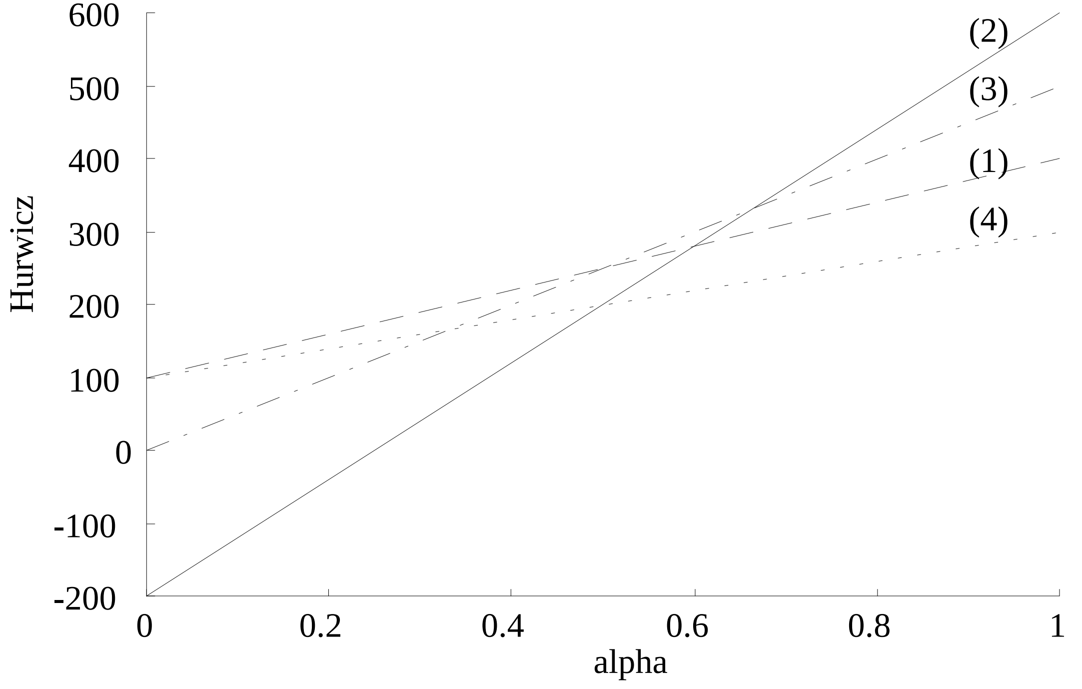
$$\begin{matrix} \min_j E_{ij} & \max_j E_{ij} \\ \begin{bmatrix} 100 \\ -200 \\ 0 \\ 100 \end{bmatrix} & \begin{bmatrix} 400 \\ 600 \\ 500 \\ 300 \end{bmatrix} \end{matrix} \begin{cases} 100(1-\alpha)+400\alpha = 100+300\alpha & (1) \\ -200(1-\alpha)+600\alpha = -200+800\alpha & (2) \\ 0(1-\alpha)+500\alpha = 500\alpha & (3) \\ 100(1-\alpha)+300\alpha = 100+200\alpha & (4) \end{cases}$$

$\alpha = 0$ Extremely conservative

$\alpha = 1$ Extremely aggressive

Hurwicz Criterion

$$\max_i \left[(1-\alpha)\{\min_j E_{ij}\} + \alpha\{\max_j E_{ij}\} \right];\ 0 \le \alpha \le 1$$



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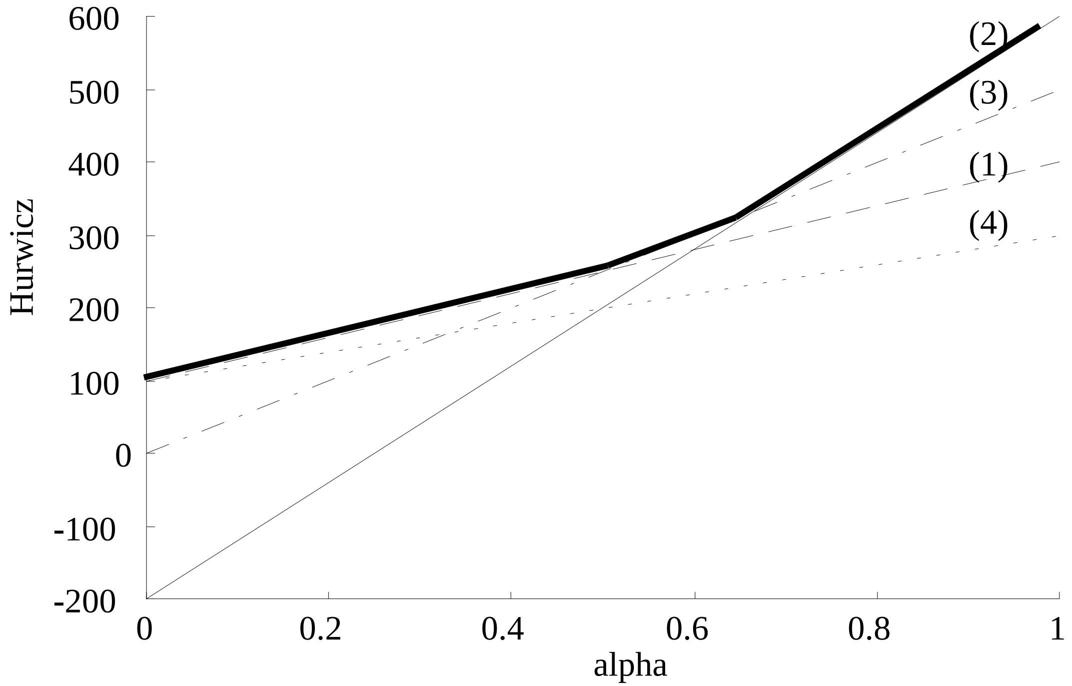
$$\max_i \left[(1-\alpha)\{\min_j E_{ij}\} + \alpha\{\max_j E_{ij}\} \right];\ 0 \le \alpha \le 1$$



Optimal Decisions:

$$\alpha \le \tfrac{1}{2} \Rightarrow (1);\ \tfrac{1}{2} \le \alpha \le \tfrac{2}{3} \Rightarrow (3);\ \tfrac{2}{3} \le \alpha \le 1 \Rightarrow (2)$$