SYSTEMS ENGINEERING RESEARCH CENTER

GEORGETOWN UNIVERSITY
McCourt School of Public Policy

(ART-005)

Policy Portfolios to Enhance the STEM Talent Pipeline

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ANNUAL SPONSOR RESEARCH REVIEW

Overview

- Objectives
- Stakeholders
- Example Policy Interventions
- Delivery Mechanisms
- Uncertainties
- Decision Attributes
- Overall Formulation
- Elements & Information Needed
- Case Study
- Managing Uncertainties
- Summary

Objectives of WRT-1042

- Formulate alternative policy portfolios to enhance the STEM talent pipeline for both the DoD workforce and the US workforce more broadly
- Provide a means for stakeholders to interactively create and explore alternative policies and portfolios of policies

Stakeholders

- Potential and existing STEM students
- Educational institutions offerings STEM programs
- Industry employers
- DoD employers
- A super-stakeholder that decides the relative importance of other stakeholders' preferences

Example Policy Interventions

- General Examples
  - Grants – If you intend to do X, you are granted $Y
  - Support – If you are doing X, you get $Y to pay for support
  - Incentives – If you accomplish X, you get $Y in student debt relief
  - Reimbursement – Institution is paid for delivering X if Y is achieved
- Specific Instances
  - Financial incentives to increase STEM student retention
  - Investing in adoption of advanced educational technologies
  - Supporting alliances among K-12, community colleges and industry
  - Improving the performance of K-12 to produce STEM-ready graduates

Delivery Mechanisms

- Communicate – let people know about policies
- Educate – show how to take advantage of policies
- Incentivize – provide payment for enrolling
- Invest – provide capital to create offerings & support services
- Regulate – require institutional participation

Potential Uncertainties

- Workforce needs that would not be met without interventions
- Efficacy of interventions vs. costs of interventions
- Efficacy of mechanisms vs. costs of mechanisms
- Distributions of number of successes
  - Cost of intervention = n x cost/person – pay for everybody
  - Returns on investment = n x p – returns only on successes

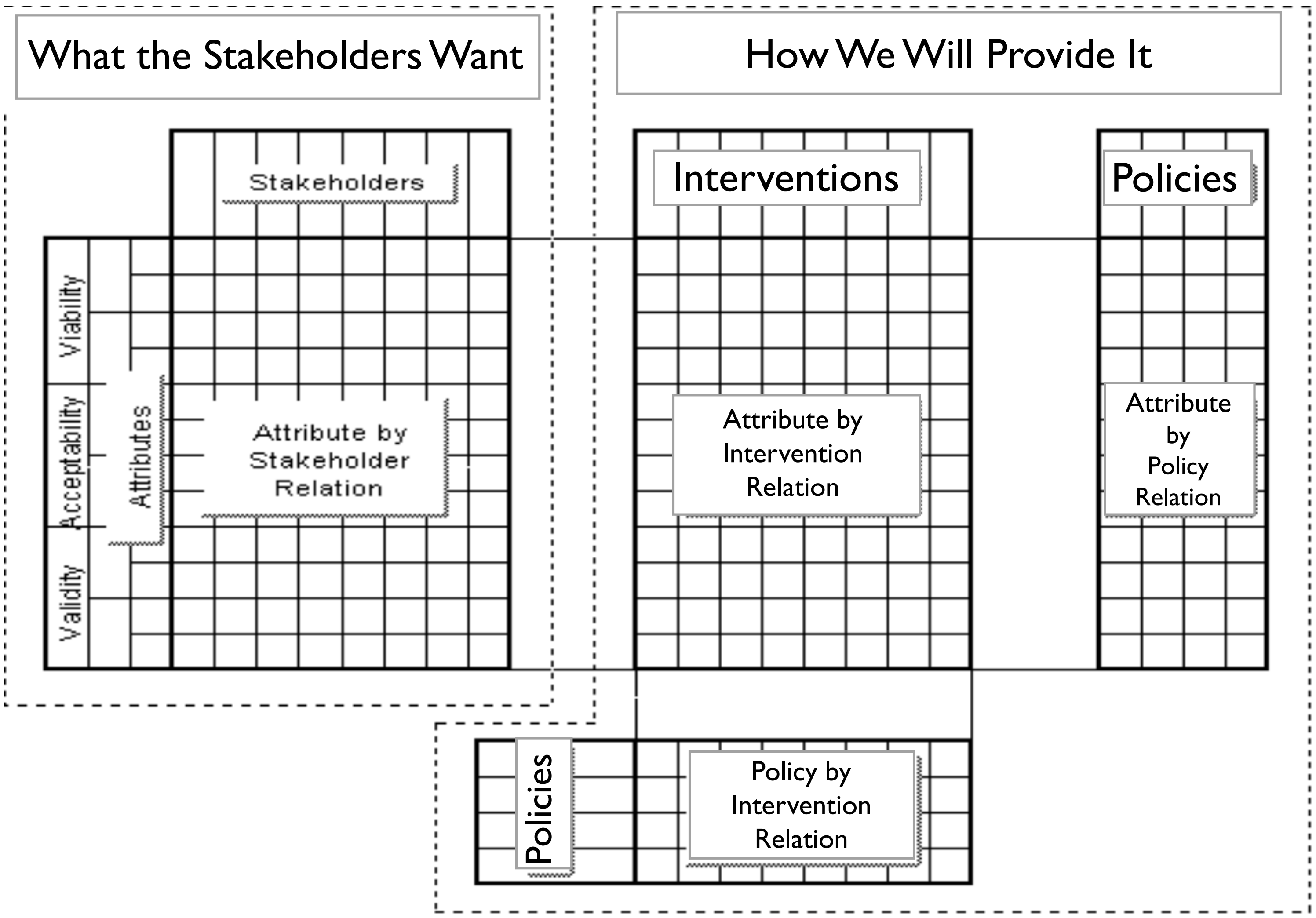
Binomial Distribution

- Mean = np
- Variance = np(1-p)
- $f(x) = (N!/X!(N-X)!)p^x(1-p)^{n-x}$ where x = 0, 1, 2, …., n

Decision Attributes

- STEM graduates over time
- STEM program enrollment over time
- STEM employment opportunities over time
- STEM employment compensation over time
- STEM employment tax revenues, with multiplier, over time
- STEM policy portfolio costs over time
- Net Present Value (NPV) of attributes could be used to collapse over time
- Discount rate for NPV is likely to vary by stakeholder
- Attributes with longer times to emerge will have lower NPV than those faster

Overall Formulation



Formulation Elements	Information Needed
Stakeholders	
Potential and existing STEM students	Utility functions & weights across attributes
Educational institutions offerings STEM programs	Utility functions & weights across attributes
Industry employers	Utility functions & weights across attributes
DoD employers	Utility functions & weights across attributes
Sponsor (R&E) is a super-stakeholder	Utility functions & weights across stakeholders
Policy Interventions	
• Grants – If you intend to do X, you are granted $Y	Costs of intervention; likely adoption
• Support – If you are doing X, you get $Y to pay for support	Costs of intervention; likely adoption
• Incentives – If you accomplish X, you get $Y in student debt relief	Costs of intervention likely adoption
• Reimbursement – Institution is paid for delivering X if Y is achieved	Costs of intervention; likely adoption
Delivery Mechanisms	
• Communicate – let people know about policies	Costs of mechanism; likely effectiveness
• Educate – show how to take advantage of policies	Costs of mechanism; likely effectiveness
• Incentivize – provide payment for enrolling	Costs of mechanism; likely effectiveness
• Invest – provide capital to create offerings & support services	Costs of mechanism; likely effectiveness
• Regulate – require institutional participation	Costs of mechanism; likely effectiveness
Uncertainties	
• Workforce needs that would not be met without interventions	Uncertainty of work force needs
• Efficacy of interventions – in terms of cost per increased workforce unit	Uncertainty of costs per 1000 graduates
• Efficacy of mechanisms -- in terms of cost per increased workforce unit	Uncertainty of costs per 1000 graduates
Decision Attributes	
• STEM graduates over time	Projections of attribute over time
• STEM program enrollment over time	Projections of attribute over time
• STEM employment opportunities over time	Projections of attribute over time
• STEM employment compensation over time	Projections of attribute over time
• STEM employment tax revenues, with multiplier	Projections of attribute over time
• STEM policy portfolio costs over time	Projections of attribute over time

Case Study of Retention Policies

- Four Policies
    1. Better Students
    2. Student Support
    3. Process Redesign
    4. Support & Process
- Stakeholders
    - Potential and Existing STEM students
    - Educational Institutions
    - Employers
    - DoD

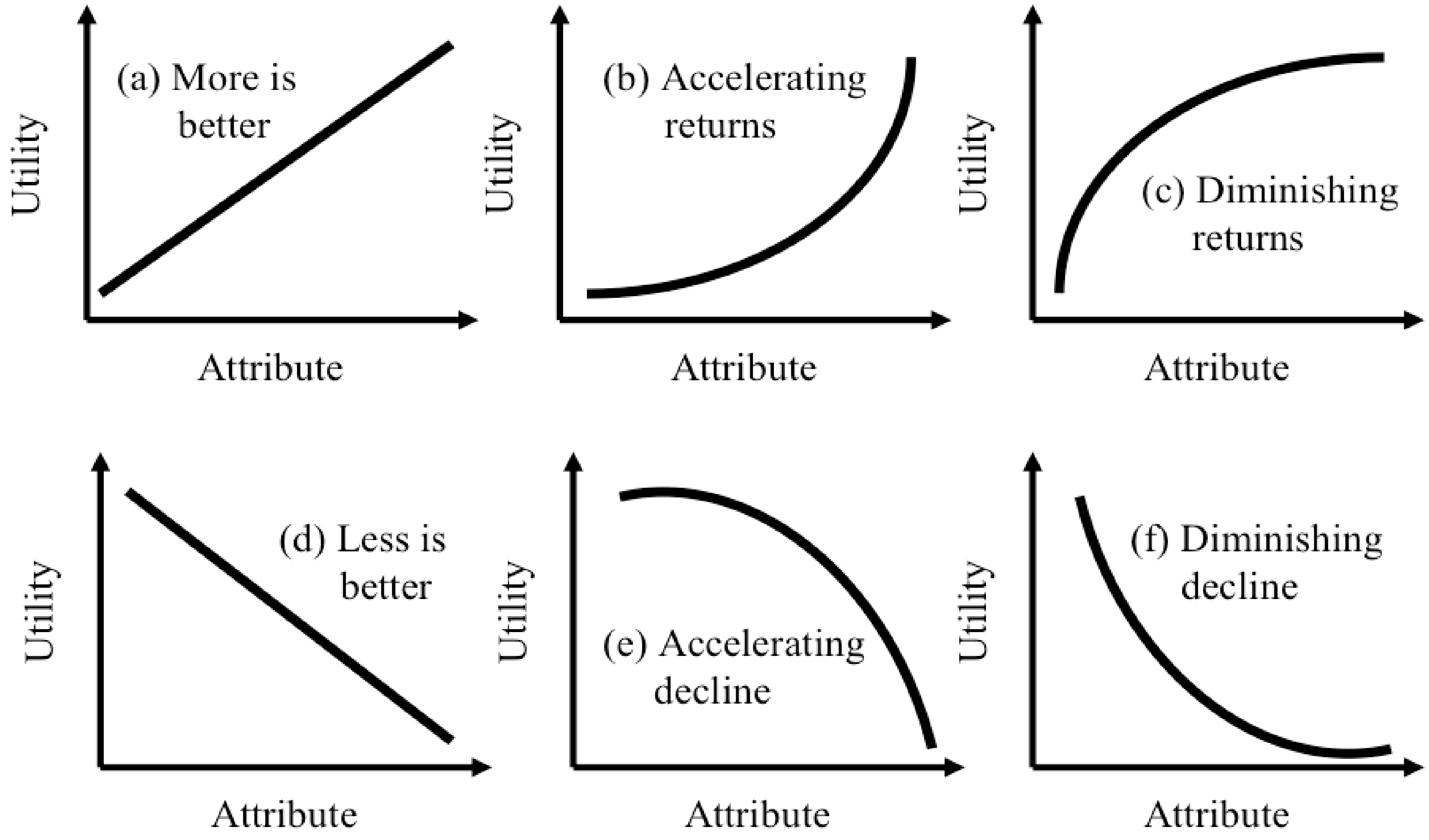
Student Support & Process Redesign

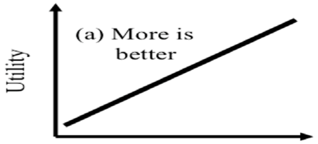
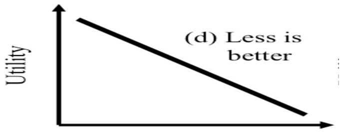
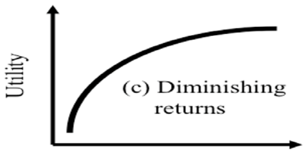
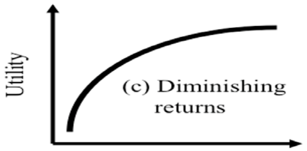
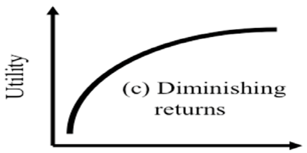
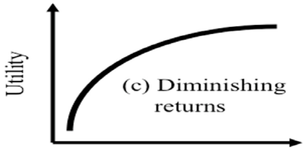
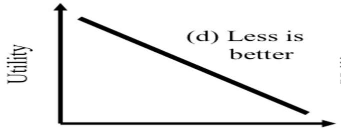
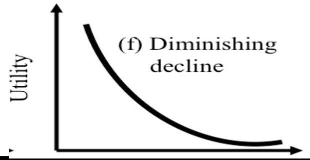
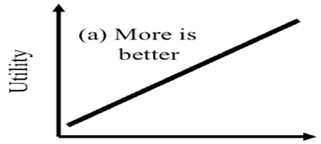
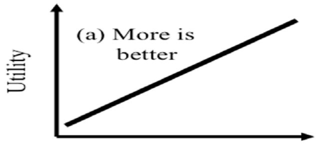
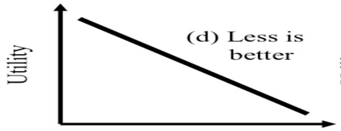
- Student Support
  - Remedial Courses
  - Individual Tutoring
  - Expert Advising
  - Staff Training
- Process Redesign
  - Loosening Prerequisite Constraints
  - Modularizing Course Structure
    - Ten 4-hour modules vs. 40 hours of traditional instruction
    - Credits earned module by module, not course by course
    - Selected modules also offered online
  - Online Courses to Eliminate Class Size Limits

Attributes

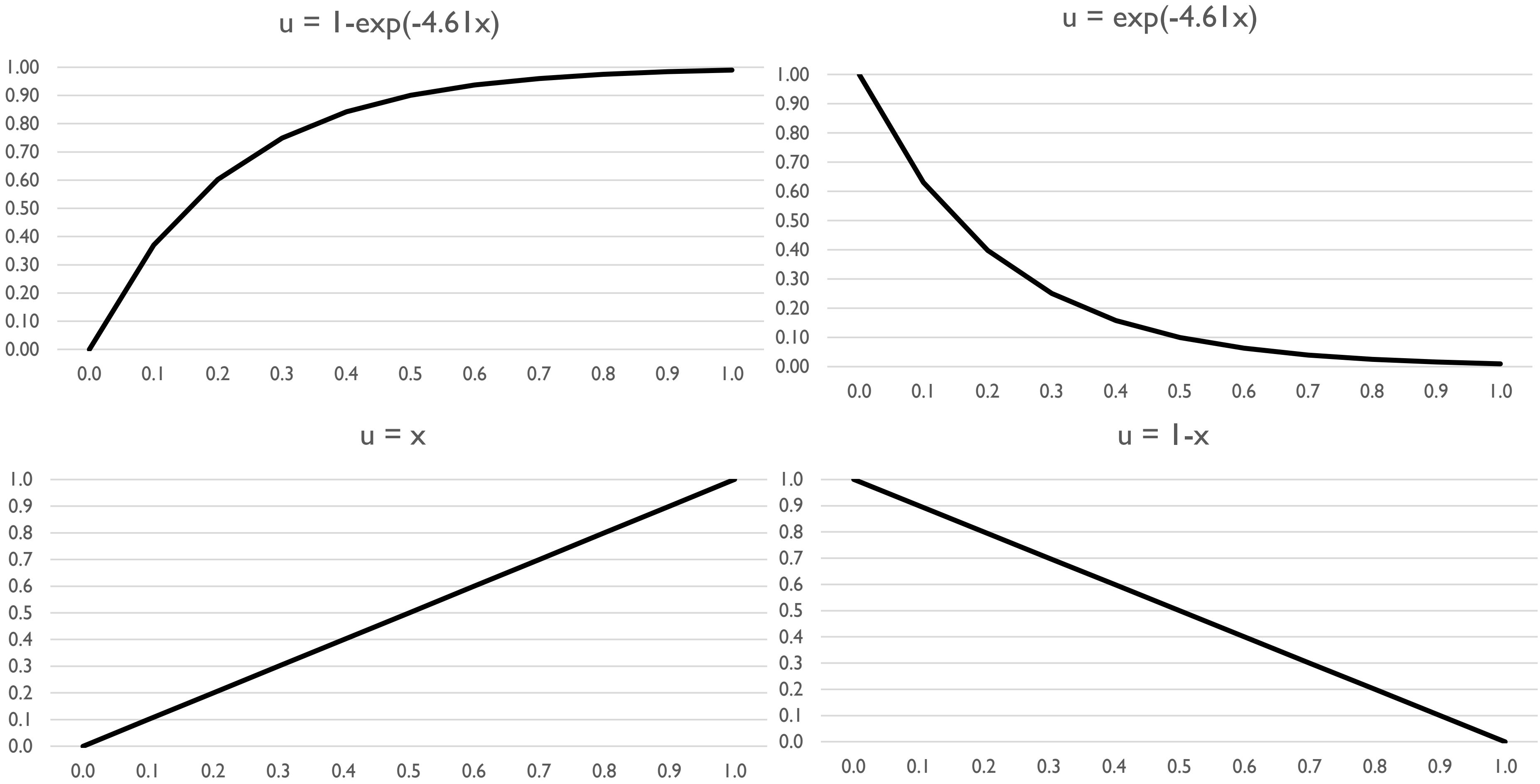
- Acceptance rate
- Retention rate
- Graduation rate
- Faculty time
- Institutional costs
- Net STEM talent
- Net policy costs

Typical Utility Functions



	STEM Students	Institutions	Employers	DoD
Acceptance Rate				
Retention Rate				
Graduation Rate				
Faculty Time				
Institution Costs				
Net STEM Talent				
Net Policy Costs				

Utility Functions



Attribute Levels	Better Students	Student Support	Improved Process	Support & Process
Acceptance Rate	Low	Moderate	Moderate	High
Retention Rate	High	Moderate	Moderate	High
Graduation Rate	High	Moderate	Moderate	High
Faculty Time	Low	Moderate	Moderate	High
Institution Costs	Moderate	Moderate	Moderate	High
Net STEM Talent	High	Moderate	Moderate	High
Net Policy Costs	Low	Moderate	Moderate	High

Stakeholders Utility Functions

- Attributes levels are the same for all stakeholders
  - High = 0.9 or 0.7
  - Mod = 0.5
  - Low = 0.1 or 0.3
- Utility functions vary across stakeholders – see slides 16 & 17
  - Students value retention and graduation rates (AR, RR, GR)
  - Institutions value faculty time and institutional costs (AR, RR, GR, FT, IC)
  - Employers value net STEM talent (ST)
  - DoD values net STEM talent and net policy costs (ST, PC)

Multi-Stakeholder, Multi-Attribute Utility Model

The utility function of stakeholder i across the N attributes is given by

$u_i = u(x_{1i}, x_{2i}, \ldots, x_{Ni}) = u(\mathbf{x}_i)$ (1)

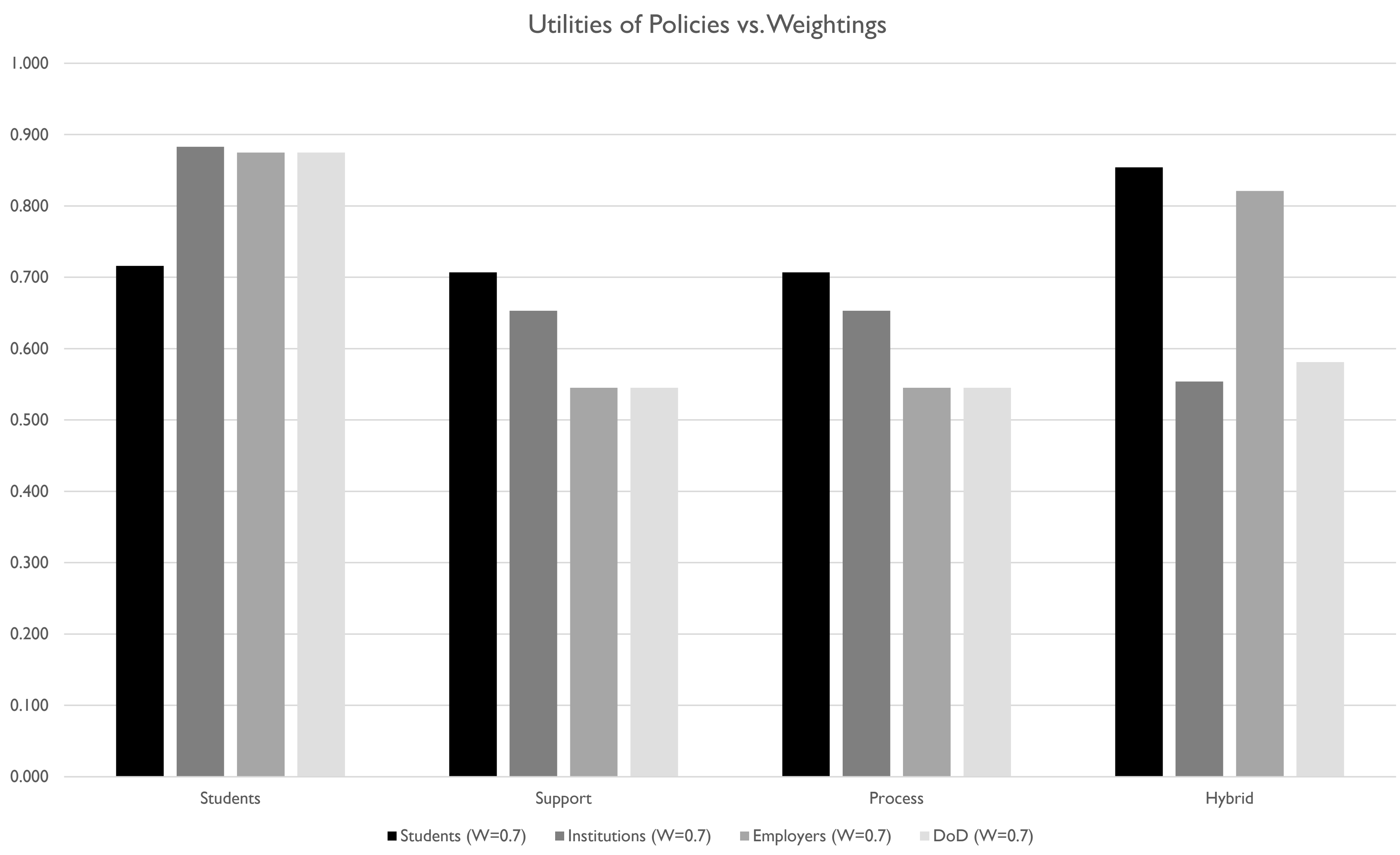
where the bold **x** denotes the vector of attributes.

The utility of an alternative across all M stakeholders is given by

$U = U\,[u(\mathbf{x}_1), u(\mathbf{x}_2), \ldots, u(\mathbf{x}_M)]$ (2)

Notes:

- The appropriate forms of these functions vary by the assumptions one is willing to make. When there are many attributes, a weighted linear from is usually the most practical.
- The weights in equation (1) reflect how much a particular stakeholder cares about the attribute being weighted. It is quite common for most stakeholders to only care about a small subset of the overall set of attributes. Those for which they do not care receive weights of zero.
- The weights in equation (2) reflect the extent to which the overall decision maker or decision process cares about particular stakeholders. For example, is the student the most important stakeholder or do institutional finances drive the decision? These weights are usually subject to considerable sensitivity analyses.


Utilities of Policies vs. Weightings
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
Students
Support
Process
Hybrid
Students (W=0.7)
Institutions (W=0.7)
Employers (W=0.7)
DoD (W=0.7)

Observations

- Recruiting better **Students** is preferred by all stakeholders other than students
  - Yields better STEM graduates
  - Requires less investment
- **Hybrid** (student support + process improvement) is preferred by students and is a close second for employers
  - Provides success opportunities to more students
  - Requires institutions and DoD to invest
- **Support** or **Process** by itself yields only moderate returns: this assumption warrants careful reconsideration

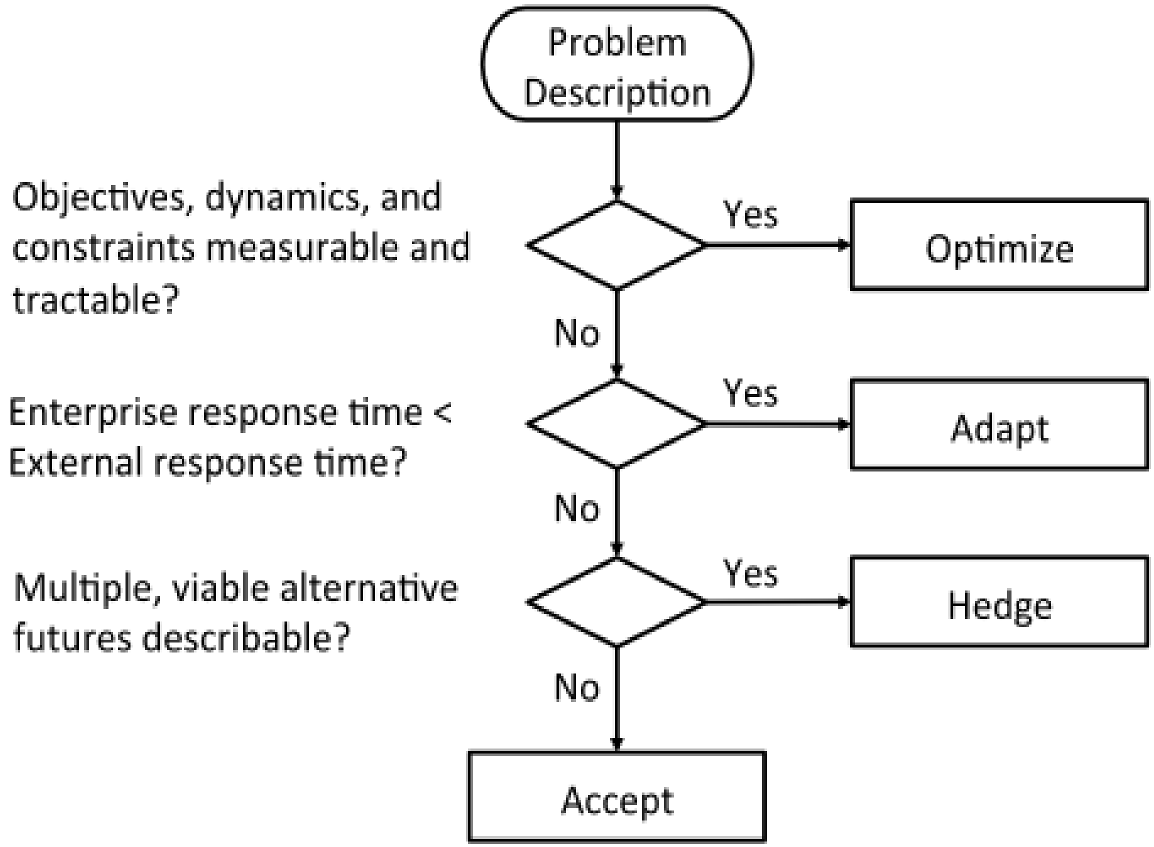
Managing Uncertainties

- Nature of Uncertainties
- Strategies for Managing Uncertainties
- Strategies vs. Uncertainties
- Application to STEM Policies

Nature of Uncertainties

- Student Retention (Case Study)
  - Student Support – Extent, Effectiveness & Costs Uncertain
    - Remedial Courses, Individual Tutoring, Expert Advising, Staff Training
  - Process Redesign – Extent, Effectiveness & Costs Uncertain
    - Loosening Prerequisite Constraints, Modularizing Course Structure, Online Courses to Eliminate Class Size Limits, Student Monitoring System
- Other Policies of Interest
  - Invest in adoption of educational technologies
  - Potential alliances among K-12, community college & industry
  - Increase K-12 production of "STEM-ready" students

Strategies for Managing Uncertainties



Strategies vs. Uncertainties

Requirements Uncertainty	Not Feasible	Possibly Feasible	Fully Feasible
Definitely Required	Hedge Via Partnership	Hedge Via R&D Investment	Optimize Educational Capability
Possibly Required	Hedge Via Partnership	Hedge Via R&D Investment	Adapt If Requirement Emerges
Not Required	Accept Current Situation	Accept Current Situation	Archive for Potential Later Use

Technology & Cost Uncertainties

Application to STEM Policies

- **Optimize** retention investments
  - Target population and needed interventions are clear
  - Incentives for co-investments likely successful
- **Adapt** to trends in educational technology
  - Exploit rather than invest
  - Focus on accessibility & efficiencies
- **Hedge** potential alliances among K-12, community college & industry
  - Many alternative scenarios
  - Wide range of barriers and hurdles
- **Accept** the state of K-12 education
  - Extremely uncertain
  - Highly expensive

Summary

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