Multiple Criteria Decision Making, Multiattribute Utility Theory: Recent Accomplishments and What Lies Ahead

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Purpose of Presentation

This talk is based on a recent paper the six of us wrote. The paper is an update of an article five of us published in Management Science in 1992. The areas of Multiple Criteria Decision Making (MCDM) and Multiattribute Utility Theory (MAUT) continue to be active areas of management science research and application. This paper extends the history of these areas and discusses topics we believe to be important for the future of these fields.
Contents

• Introduction
• Our decision-making framework
• Bibliometric analysis of MCDM/MAUT
• Contributions since our 1992 paper
• Areas for future research
• Conclusions
Important developments

1. Use of the Internet has exploded
2. Substantial growth in applications of MCDM/MAUT
3. The importance of MCDM/MAUT has been recognized in professional journals
4. The importance of behavioral aspects has grown
5. DEA has grown in importance and its relationship to MOLP has been explored
6. EMO has emerged as a new field with strong ties to MCDM
7. Heuristics have become more important
8. MCDM/MAUT has begun to penetrate many new areas of research and applications
Our decision-making framework

• We assume a DM who chooses one (or a subset) of a set of alternatives evaluated on the basis of two or more criteria or attributes. The feasible set of solutions may be either small and finite (as in choice problems) or large and perhaps infinite (as in design problems). Uncertainty may be involved.

• Conceptually, we may assume that a DM acts to maximize a utility or value function that depends on the criteria or attributes. In cases of uncertainty, the problem is typically to maximize the expected value of a utility function.

➢ We believe that an important part of MCDM/MAUT is the support of decision making in a broader sense. MCDM/MAUT methods are intended to help a DM think about the problem as part of the decision-making process.

➢ The DM may be an individual or a group
Two Categories of Problems

• There are two categories of MCDM/MAUT problems: multiple criteria discrete alternative problems and multiple criteria optimization problems
  ➢ Examples of discrete alternative problems include choosing the location for a new airport, selection of a computer network, choice of a drug rehabilitation program, and identifying which nuclear power plant to decommission.
  ➢ Examples of optimization problems include river basin planning, energy planning, engineering component design, portfolio selection, and R&D project selection
Further Differences

• In addition to differences in the feasible sets of alternatives, there are other differences between multiple criteria discrete alternative and multiple criteria optimization problems.
  ➢ One is that discrete alternative problems are more likely to be modeled with uncertain values for the attributes or criteria, than multiple criteria optimization problems.
  ➢ Another difference is in the way utility or value functions are taken into account.
• Because of different problem types, different families of approaches have evolved for solving discrete alternative problems and multiple criteria optimization problems.
Bibliometric Analysis of MCDM/MAUT

• We have conducted a basic bibliometric study of MCDM/MAUT using the ISI database. The ISI database covers over 8650 journals. It found 6910 MCDM/MAUT publications covering years 1970-2007.

• We report basic statistics regarding how our fields have developed based on variations of the following key words: multiple criteria decision, multiattribute utility, multiple objective programming/optimization, goal programming, Analytic Hierarchy Process, evolutionary/genetic multiobjective, and vector optimization.
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<td>France</td>
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<td>South Korea</td>
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TABLE 2: Sub-topical Areas

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<td>Computer science and AI</td>
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<tr>
<td>Management and business</td>
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<td>Applied mathematics, interdisc.</td>
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<td>Manufacturing engineering</td>
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<td>Economics</td>
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<td>Civil Engineering</td>
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<td>Computer science and IS</td>
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<td>Energy and water resources</td>
<td>267</td>
<td>3.9%</td>
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Publication History: Area of Research

- AHP
- Goal Programming
- EMO
- MAUT
- Math Programming
- French School
- Vector Optimization
12 most cited MCDM/MAUT ISI articles

<table>
<thead>
<tr>
<th></th>
<th>Title</th>
<th>Journal/Conference</th>
<th>Year</th>
<th>Citations</th>
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<tbody>
<tr>
<td>1.</td>
<td>YAGER RR: On Ordered Weighted Averaging Aggregation Operators in Multicriteria Decision-Making</td>
<td>IEEE ON SYSTEMS MAN AND CYBERNETICS 18 (1)</td>
<td>1988</td>
<td>551</td>
</tr>
<tr>
<td>2.</td>
<td>GEOFFRION AM: Proper Efficiency and Theory of Vector Maximization</td>
<td>J. OF MATHEMATICAL ANALYSIS AND APPLICATIONS 22 (3)</td>
<td>1968</td>
<td>424</td>
</tr>
<tr>
<td>3.</td>
<td>GEOFFRION AM, DYER JS, and A. FEINBERG: An Interactive Approach for Multicriterion Optimization</td>
<td>MANAGEMENT SCIENCE 19</td>
<td>1972</td>
<td>337</td>
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<tr>
<td>5.</td>
<td>ZITZLER E, THIELE L: Multiobjective Evolutionary Algorithms</td>
<td>IEEE TRANSACTIONS ON EVOLUTIONARY COMPUTATION 3 (4)</td>
<td>1999</td>
<td>317</td>
</tr>
<tr>
<td>6.</td>
<td>ZIONTS S, WALLENIUS J: Interactive Programming Method for Solving the Multiple Criteria Problem</td>
<td>MANAGEMENT SCIENCE 22 (6)</td>
<td>1976</td>
<td>263</td>
</tr>
<tr>
<td>8.</td>
<td>BENAYOUN R. et al: Linear Programming with Multiple Objective Functions</td>
<td>MATHEMATICAL PROGRAMMING 1</td>
<td>1971</td>
<td>247</td>
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<tr>
<td>9.</td>
<td>ZAHEDI F.: The AHP – A Survey</td>
<td>INTERFACES 16 (4)</td>
<td>1986</td>
<td>241</td>
</tr>
<tr>
<td>12.</td>
<td>DYER JS, SARIN RK: Measurable Multiattribute Value Functions</td>
<td>OR 27 (4)</td>
<td>1979</td>
<td>167</td>
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</tbody>
</table>
Decision Support Applications of MCDM/MAUT

• The business world has become more competitive and less predictable, accentuating the importance of effective decision making and the use of decision support tools. The DSSs that are widely used are user friendly and often employ spreadsheets, such as Excel, at least for data entry.

• The following web pages provide examples of MCDM/MAUT software applications:
  http://www.decisionarium.tkk.fi/,
  http://faculty.fuqua.duke.edu/daweb/dasw.htm/,
  http://www.logicaldecisions.com/,
  http://www.krysalis.co.uk/index.html/,
Decision Support Applications of MCDM/MAUT -- continued

- The invention of the Internet has created a need for additional decision support (in a distributed or even a environment). Many scholars have implemented their favorite MCDM/MAUT procedures on the Internet.
- Decision support is also available for consumers online (for example, Active Decisions discussed below) and for decision conferencing. Advances in MAUT methods to support decision conferencing have been facilitated by the increases in readily available computing power. See Keefer et al. (2004), the work by Phillips et al. (http://www.catalyze.co.uk/), and the work by Hämäläinen et al. (http://www.decisionarium.tkk.fi/)
Behavioral Considerations

- Behavioral issues have not received a great deal of attention by MCDM/MAUT researchers in recent years,
  - Biases in the elicitation of weights (Keeney, 2002, Delquie, 1993,
  - Issues related to the design of value trees and the selection of
  - Matheson and Matheson (2007) discuss organizational issues
  - Special issue of JORS (Vol. 57, Issue 7, 2006) on problem
Robustness Considerations

Generally speaking, robustness refers to the ability of a solution

• Hogarth et al. (2005) provide a recent example of this work for
• For examples of MCDM robustness research, see Kouvelis and
• Interesting work on rough sets, based on Pawlak’s original idea
• Furthermore, many interval-valued methods provide robust
Role of Heuristics

Heuristics have become more important in recent
• Multiple objective combinatorial optimization
  ➢ Simulated annealing, tabu search, and local search
• Evolutionary procedures (EA)
  ➢ Despite prior advances, multiple criteria optimization
Role of Heuristics – Evolutionary

- Starting with an initial population, an EA updates the population.
- The goal is to converge on a diverse final population of solutions.
Other Computer Related Topics

Machine learning and knowledge discovery
• Knowledge Discovery, Preference Modeling:
• Preference learning from a sample of past decisions
New Application Areas of MCDM/MAUT

• DEA

• Negotiation Science

• e-Commerce: Multi-Attribute Auctions and Shopping

• Geographic Information Systems

• Engineering Applications
Data Envelopment Analysis (DEA)

- Charnes and Cooper conducted the pioneering
- Joro, Korhonen and Wallenius (1998) developed a
  - One of the basic differences is the radial projection
Negotiation Science

- The literature on negotiation and group decision making is
- Raiffa (1982) is a pioneer in this field. For a more recent
- Ideas and tools have been picked eclectically from
Geographic Information Systems (GIS)

• Many real-world spatial planning and management
  ➢ The GIS technology offers unique capabilities for
  ➢ MCDM/MAUT, on the other hand, offers useful tools
e-Commerce: Multi-Attribute Auctions and

- Geoffrion and Krishnan (2001) have summarized the
  - Multiattribute online auctions, in particular procurement
    ✓ A central problem is elicitation of auction owner’s preferences
  - Comparison shopping agents
    ✓ Sophisticated shopping agents, incorporating buyer’s
Engineering Applications

- MCDM/MAUT is used in many fields of engineering. Often, however,
  - Examples of scholarly applications include river basin development
- See the SAL web-page for several MCDM/MAUT applications
- See Coello and Lamont (2004) for EMO applications
- See Hobbs and Meier (2000) for an extensive coverage of the use
- Sophisticated applications of MAUT have appeared in the
Areas for Future Research

• The penetration of MCDM/MAUT concepts to the
• In conclusion, we identify several other areas with
Areas for Future Research - continued

- **Decision Support in a Distributed Environment**
  - For example, what is a user?
- **Quadratic and Stochastic Programming**
- **Usefulness of Dotted Representations of**
- **Evolutionary Multi-Objective Optimization**
  - Collaborative efforts between EMO and MCDM/MAUT
- **Challenges from Practice**
Conclusions

We believe that the conclusions of Dyer et al. (1992) are still
- The Internet will continue to provide challenges for the
- The role of transitivity will erode, the status of axiomatizing
- The interactive/visual mode will become standard
- We also envision that several subfields which developed