

# **The Open Workshop on Decision-Based Design: Origin, Status, Promise, and Future**

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## **ABSTRACT**

The design perspective known as Decision-Based Design (DBD) has been under investigation via a web site-based workshop. During its first three years of operation, the Open Workshop focused on defining design from a DBD perspective and investigating the proper role of the DBD perspective on design. The workshop seeks to establish connections between theories in other disciplines, included and related to decision-making, and design. These relationships enrich our design theory foundations and provide insight for researchers. This paper summarizes the activities of the workshop as seen through the eyes of the organizers.

**Key Words:** Decision-Based Design, Open Workshop

## **1 The Origin: Why Decision Based Design?**

Decision-making is an essential aspect of design that cannot be ignored during the design process. Decision-Based Design (DBD) practitioners view design as a decision-making process that involves maximizing the value of a designed artifact to both the producer and the end-user. DBD processes emphasize making rational, value-based decisions, in a realistic setting [1, 2]. To

make appropriate decisions one must establish value systems to rank the expected outcomes of design decisions and incorporate uncertainty and risk handling in the predictions of those outcomes.

The National Science Foundation (NSF) supported the Open Workshop on Decision-Based Design and its effort to formalize, synthesize and advertise the decision-based perspective on design, one of many prominent design perspectives in our research community. The workshop engages design theory researchers via electronic and internet related technologies as well as face-to-face meetings in scholarly and collegial dialogue to establish a rigorous and common foundation for decision-based design. Workshop participants seek to determine the roles of decision-making, decision theories, and decision support tools in design theory research, education, and practice. Specifically, the Open Workshop's stated objectives are to:

- synthesize a sound theory of DBD,
- determine the proper role of decision-making in design,
- develop consensus on defining the DBD perspective,
- establish the role of DBD within design theory and methodology research,
- build a repository of foundational materials (e.g., a lexicon, case studies, references, text materials) that illustrate design as decision-making,
- establish a useful relationship between the DBD and theories in other science domains such as physics, mathematics, information and management science, and
- transfer decision support methods and tools into industry.

The creation of the special journal edition is one measure of the success of the Open Workshop. It has provided a forum for discussion of decision-based design and stimulated thinking on this topic. As primary organizers of this NSF workshop we present in this paper an overall picture of this Open Workshop by reviewing the status, promise, and future of the workshop activities. In Section 2, the strategies of conducting an open workshop via electronic and internet related technologies are reviewed. In Section 3, we provide an overview of the topics covered in each face-to-face meeting. In Section 4, a review of the issues relevant to the development of DBD theory is provided and their relevance to the papers collected in this special edition is established. This will serve as a road map for interested readers. Some open issues are raised in Section 5, and the paper is concluded in Section 6.

## 2 The Status: Successful Strategies for the Open Workshop

The Open Workshop on Decision-Based Design is in its third year of operation at: <http://www.eng.buffalo.edu/Research/DBD> (Figure 1). The term *open workshop* was coined during this undertaking to describe a web-based platform for interactive discussion for all interested parties. Like any conventional workshop, an open workshop is a conduit for dissemination of information. It is also a medium for collecting feedback on presented information and a forum for dialogue to synthesize new ideas. The architecture of an open workshop must include portals to both present information to and collect information from its audience. The DBD Workshop architecture has evolved into its present structure. The site is tailored to perform each workshop function. From the Open Workshop home Page in Figure 1 you can see links to the site areas disseminating information (“Position Papers,” “Reading List,”

and “Pedagogy”) and both disseminating and collecting information in the form of feedback (“Open Research Issues” and “Lexicon”).



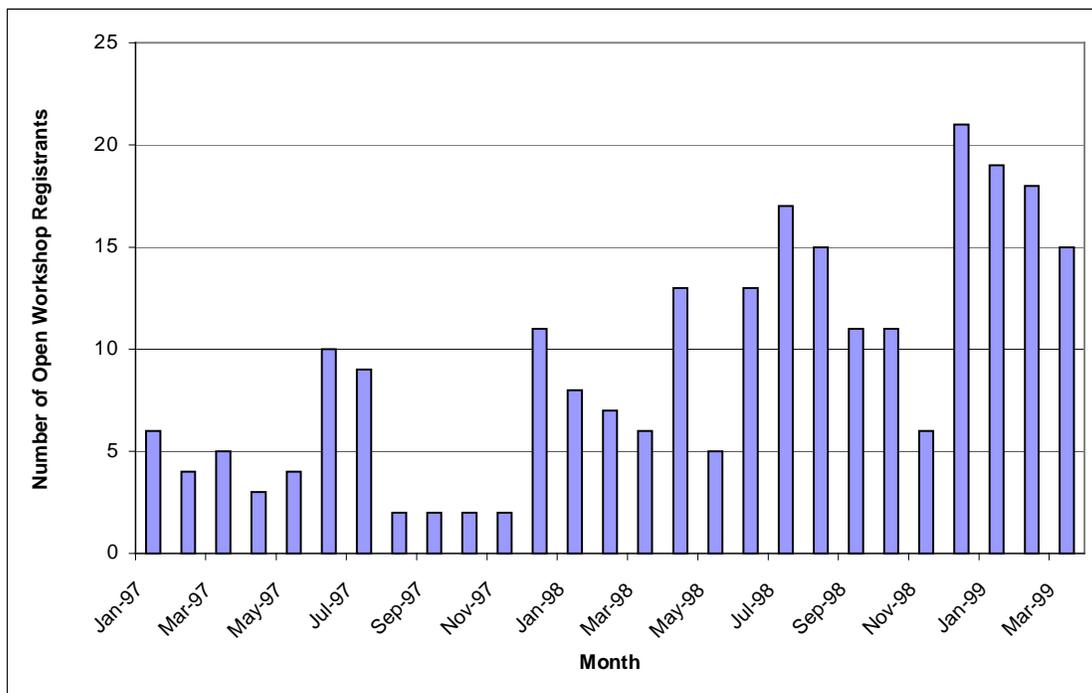
Figure 1 Home Page of The Open Workshop on Decision-Based Design (DBD)

There are two fundamental challenges to establishing a successful open workshop. The first challenge is attracting participants. The second is establishing meaningful collegial dialogue that furthers the objectives of the workshop. Our experience with these challenges is discussed in this section.

## 2.1 Open Workshop Participants

Word of the Open Workshop has been spread by recruitment of potential participants by workshop organizers and sponsors. Once launched, the web presence of the workshop creates an audience of its own. The off-line activities of the workshop registrants also generate curiosity about the workshop.

Interest in the DBD Open Workshop has increased steadily since its launch in 1997. In the charts below, the increasing interest is presented. The number of registrants per month is plotted in Figure 2 for the past two years. From March 1997 to April 1999, we have had over 4000 'hits' to the site. We have over 225 registrants in the workshop. Table 1 summarizes the demographics of our registrant base. This description does not include at least 60 academic institutions represented in the workshop.

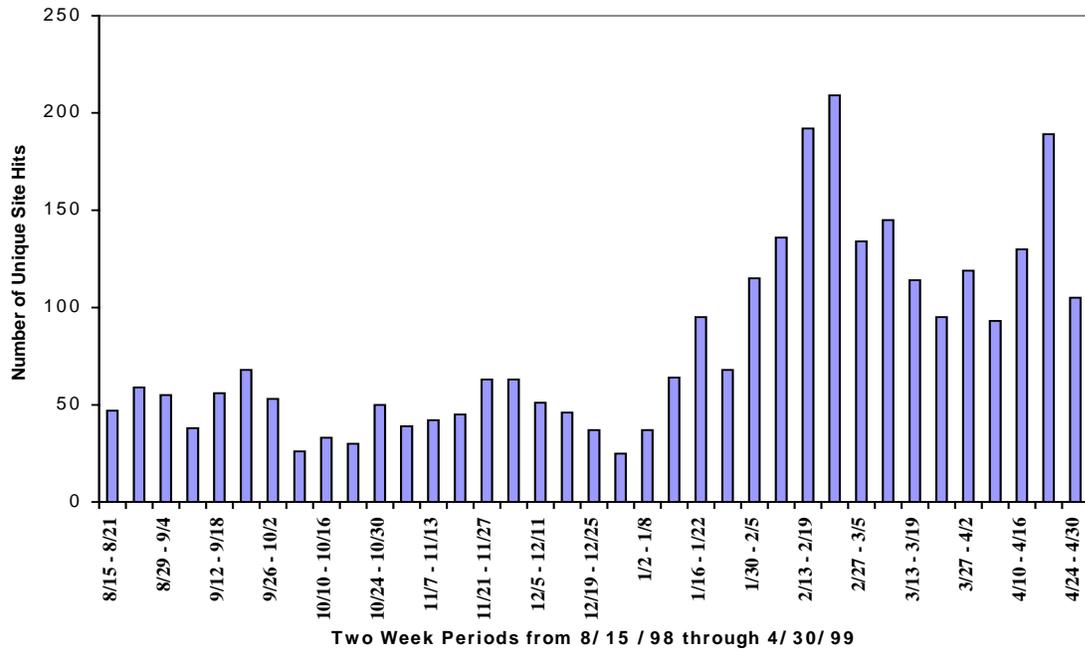


**Figure 2 Number of Registrants**

**Table 1 Open Workshop Registrant Demographics**

<b>Countries</b>		<b>Business Enterprises</b>	<b>Other Non-Academic Organizations</b>
Canada	England	Xerox, Armstrong World Industries,	NASA
Argentina	Denmark	Siemens, Lockheed-Martin,	NIST
Mexico	Finland	Bath Iron Works Corporation, Ford,	NRC-Canada
India	Egypt	Boeing, Cerprobe,	David Taylor Research
Bulgaria	Brazil	Small Systems Company,	Center - U.S. Navy
Hungary	Germany	United Technologies Corporation,	Idaho National
Croatia	Australia	WABA, Inc., SRI International,	Engineering &
Greece	Hong Kong	Otis Elevator, Kimball International,	Environmental Lab
China	Taiwan	Product Development and Research	Sandia Laboratories
Japan	Yugoslavia	Center, Gensym Corporation,	
Sweden	Thailand	AVACO Consultants, Philips	
Korea	USA	Honourcode, Inc,	

A pure count of number of website “hits” is not an accurate metric for judging the popularity of a website because it may include repeat visitors. A more sophisticated performance measure is data of the number of new host machines that contact the website as determined from contacting IP addresses. In Figure 3, the number of hits from different machines per two-week period is plotted for the last eight months. These statistics do not include multiple hits from the same machine. This graph illustrates how many different sites accessed the workshop. As can be seen, this number has increased significantly over the last eight months.



**Figure 3 Number of Different Sites per Week**

## 2.2 Establishing Fruitful Dialogue

The open workshop dialogue is organized around a core of foundational research questions. These are refined through the thread of the web discussion and reflection on that discussion. The workshop website includes a set of message boards (see example in Figure 4) to promote and record registrant dialogue. Each message board is devoted to a single question. The website has a different discussion board for each question. New questions and issues can be raised and new message boards can be created in addition to these.

Current questions under discussion are:

- What are the key activities designers perform in the design process?
- What are the advantages and limitations of a Decision-Based Design approach to a design process?

- What is the role of decision-making in design in general, and in the approach you use in design?
- How can an underlying science of design and lexicon of design be developed? What should it look like?
- What are the issues of coordination and collaboration in distributed design?
- How do we teach design effectively?

The manner in which research topics are developed and added to the website is discussed in the review of face-to-face meetings in Section 3.

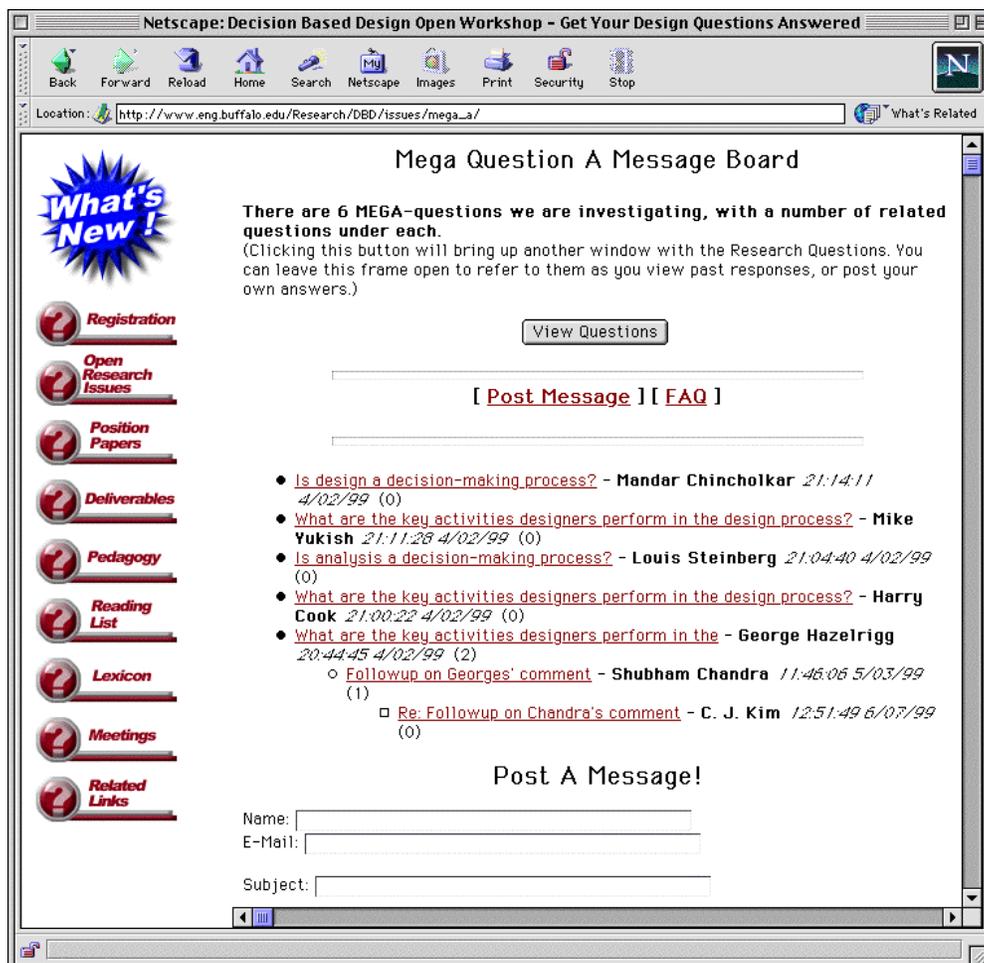


Figure 4 Open Workshop's Message Board for Mega Question A

### 3 The Status: DBD Open Workshop's Supporting Face-to-Face Meetings

Engaging the audience in online participation is a critical challenge in maintaining a viable open workshop. Workshop dialogue must be sparked and kept relevant. In a conventional workshop setting, these tasks are performed by a talented discussion leader. An open workshop requires a different approach. Workshop participants perform facilitation tasks at periodic meetings called *Face-to-Face Meetings*.

The Open Workshop's Face-to-Face meetings are attended by groups of registrants and guest researchers and hosted by the workshop organizers. At the time of this publication, seven face-to-face meetings have been held to supplement, plan, and direct the open workshop and the 8<sup>th</sup> Meeting is in the planning stages. Ten to twenty participants are invited to each meeting. Selection is based on a position paper addressing the views of searching a science base for engineering design theories and methods in general and decision-based design in particular. These meetings are usually attached to the major conferences in design fields. Over 25% of the Open Workshop registrants have participated in at least one face-to-face meeting.

Each of our face-to-face meetings has supported our workshop in several ways:

- Introduced new members to the workshop goals;
- Provided a forum for real-time discussion;
- Allowed us to assess the effectiveness of our web site and develop participation strategies;
- Identified sets of open research questions to guide our web dialogue and investigation; and,
- Engaged in the web discussion by posting responses research questions.

A synopsis of topics discussed at the Open Workshop's Face-to-Face Meetings is given in Table

2. Based on these meetings and the dialogues and repository on the website, we have identified a handful of promising issues relevant to the development and application of DBD Theory.

**Table 2 Face-to-Face Meeting Synopsis**

<b>Date, Location, and Affiliation</b>	<b>Focus and Work Accomplished</b>
<p><b>1<sup>st</sup> Meeting:</b> November 22<sup>nd</sup>-23<sup>rd</sup>, 1996 Atlanta, Georgia</p>	<p>Position Paper Presentations <u>Small Group Discussion Topics:</u>  <ul style="list-style-type: none"> <li>◇ Philosophy of DBD</li> <li>◇ Research Methodology and Ontology</li> <li>◇ Design Education</li> </ul> </p>
<p><b>2<sup>nd</sup> Meeting:</b> January 10<sup>th</sup>-11<sup>th</sup>, 1997, Seattle, WA NSF Design and Manufacturing Grantees 1997 Site</p>	<p><u>Small Group Discussion Topics:</u>  <ul style="list-style-type: none"> <li>◇ What is DBD and What is Not?</li> <li>◇ Taxonomy</li> <li>◇ Reading List and Workshop Strategy</li> </ul> </p>
<p><b>3<sup>rd</sup> Meeting:</b> April 5<sup>th</sup>-6<sup>th</sup>, 1997, Kissimmee, FL 38<sup>th</sup> AIAA/ASNE/ASCE/AHS/ASC SDM Conferences 1997 Site</p>	<p>Unveiled Web Site <u>Small Group Discussion Topics:</u>  <ul style="list-style-type: none"> <li>◇ Engaging Researchers in Web Dialogue</li> <li>◇ Maintaining Progress</li> </ul> </p>
<p><b>4<sup>th</sup> Meeting:</b> September 13<sup>th</sup>-14<sup>th</sup>, 1997 Sacramento, CA ASME DETC'97 Site</p>	<p><u>Small Group Discussion Topics:</u>  <ul style="list-style-type: none"> <li>◇ Supporting DBD Education</li> <li>◇ Lexicon</li> <li>◇ Sparking Web Dialogue</li> </ul> </p>
<p><b>5<sup>th</sup> Meeting:</b> January 5<sup>th</sup> 1998 Monterrey Mexico NSF Design and Manufacturing Grantees 1998 Conference Site</p>	<p><u>Small Group Discussion Topics:</u>  <ul style="list-style-type: none"> <li>◇ Supporting DBD Education</li> <li>◇ Lexicon</li> <li>◇ Website Effectiveness</li> </ul> </p>
<p><b>6<sup>th</sup> Meeting:</b> September 12<sup>th</sup> 1998, Atlanta, GA ASME DETC'98 Site</p>	<p>Guest Speakers on Economics, Decision Theory, and Cognitive Engineering Poster Session <u>Small Group Discussion Topics:</u>  <ul style="list-style-type: none"> <li>◇ Risk and Uncertainty</li> <li>◇ Complimentary Theories</li> <li>◇ Website Effectiveness</li> </ul> </p>
<p><b>7<sup>th</sup> Meeting:</b> January 1999 Long Beach, CA NSF Design and Manufacturing Grantees 1999 Conference Site</p>	<p>Guest Speaker on Risk Management <u>Small Group Discussion Topics:</u>  <ul style="list-style-type: none"> <li>◇ Open Research Issues</li> <li>◇ Role of Optimization in DBD</li> <li>◇ Where Do We Go From Here?</li> </ul> </p>
<p><b>8<sup>th</sup> Meeting:</b> September 12<sup>th</sup> 1999, Las Vegas, NV ASME DETC'99 Site</p>	<p>Planned Guest Speakers on Rank Aggregation Paradox, and a DBD Tool Kit <u>Small Group Discussion Topics:</u>  <ul style="list-style-type: none"> <li>◇ Future Format</li> </ul> </p>

#### 4. The Promise: Issues Relevant to the Development of DBD Theory

Every perspective on design is built from a rich body of knowledge. DBD is different only in that the body of knowledge is coalescing at the present time. This special edition includes papers in a sampling of key DBD topic areas under active research. These topics can be classified into the following major categories that represent the common research interests from DBD researchers and practitioners. We provide here a brief review of these topics and point out their relevance to those papers collected in this special edition.

##### Design Lexicon

To develop a theory of DBD, it is important to establish a commonly accepted design lexicon that can serve as a basis for communication among DBD researchers. The paper by A. Messac and W. Chen on “The Engineering Design Discipline: Is its Confounding Lexicon Hindering its Evolution?” is an invitation paper to the engineering design research community to examine the current state of the engineering design lexicon. In their paper, the authors expose common confounding situations that routinely occur in everyday use of the engineering design lexicon. They point out that the current state of engineering design lexicon has constituted a hindrance to the continued scholarly development of the engineering design discipline and therefore the broad community involvement in addressing this problem is important. Readers who are interested in contributing their views can participate in the discussion through web at <http://www.eng.buffalo.edu/Research/DBD/>.

### Theoretical Foundations of DBD

To qualify the DBD theory on an axiomatic basis, there is a need to identify its fundamental principles that are rooted in scientific domains such as mathematics, economics, and decision theory. The paper “A Toolkit for Decision-Based Design Theory” by B. Allen is a contribution to this effort. The author focuses on the basic theoretical questions of how to formulate a general decision-based model of engineering design so that mathematically rigorous results can be obtained regarding a set of conditions within the framework of DBD. The view of considering feasible options of product designs and production technologies as the point set topology should be of interest to readers.

### Decision-Based Design Models – Normative vs. Descriptive Approaches

Researchers consider the use of decision theory in design as both descriptive and normative. An approach is considered to be descriptive in nature when used to model the way that human designers make decisions. Normative approach, on the other hand, prescribes the methodology (such as utility theory) to ensure that a chosen design is the most preferred by a designer. Two papers are collected in this special issue on the roles of normative and descriptive approaches in creating decision-based design models. In the paper “The Decision Support Problem Technique: Integrating Descriptive and Normative Approaches”, by M. Marston, J. Allen, and F. Mistree, an interpretation of normative and descriptive approaches in DBD is provided. The authors consider the use of both approaches important and present the compromise Decision Support Problem as the technique that can be used to integrate the two approaches. In the paper

“Decision Model Development in Engineering Design” by X. Tang and S. Krishnamurty, three different preference elicitation perspectives, implicit and explicit articulation of priorities using normative and descriptive points of view, are presented. The authors emphasize the fundamental characteristics of normative theories such as value theory and expected utility theory, and also introduce an alternative deductive reasoning based descriptive approach in a multiattribute utility theory framework.

#### Uncertainties in Engineering Design:

As uncertainty is inevitable in engineering design, DBD theory is expected to provide a framework for analysis of uncertainty and risk and the support of decision making under these conditions. Researches in this category need to address fundamental issues relating to the inclusion of quantitative estimation of uncertainty in design model and the estimation of the global impact of uncertainty sources on confidence in the design. We include in this special edition a review paper written by L. Chen on “Treatment of Uncertainties in Decision-Based Design Optimization”. The author classifies uncertainty into different types and provides a review of existing theories that support decision making under various types of uncertainty.

#### Multicriteria Decision-Making in Decision-Based Design:

No matter whether a design involves decisions by a single decision-maker or efforts from multiple disciplines, multiple system attributes often need to be considered. How the tradeoff analysis between multiple attributes is conducted at the system level will have a significant impact on the success of the product in the global market place. We included in this edition two

papers that deal with the generation of Pareto Sets in decision-based design. In the paper on “An Approach to Facilitate Decision Tradeoffs in Pareto Solution Sets” by E. Kasprzak and K. Lewis, an approach to constructing Pareto sets based on discretization of the design space and polynomial approximations is presented. A new method is developed to alleviate the need to choose weights when negotiating the decision tradeoffs within the Pareto set. A method for mapping the Pareto solution into the design space is also illustrated. In the paper on “Pareto Sets in Decision-Based Design” by R. Balling, the methods for generating Pareto sets using genetic algorithms are described. Recommendations are made for developing tools to further assist decision-makers in selecting the best design option from the set of design alternatives identified from the Pareto set.

## 5 The Future: Open Research Issues

The development of DBD theory is far from its completion. There are many open research issues need to be addressed. We would like to raise several open issues here for future discussions:

1. *Should normative and descriptive approaches both be considered in the development of decision-based design models or only the normative approaches be considered?*
2. *In multiattribute decision-making, under conditions of both certainty and uncertainty, what are the fundamental principles one should follow when developing a utility function? What set of axioms is most relevant to studying and modeling decision-making in design?*

3. *How does the decision-based perspective on design impact the generation of an option space of initial design solutions?* In considering this space at the beginning of a problem, usually no attempt is made to weed out solutions that are high-risk or that have negative consequences. That being the case, the creation of this option space seems *not* to be the result of a strict DBD process. Yet, the generation of an option space requires *many* decisions. This leads to the next open research question.
4. *Are there activities in the design process that are decision activities but do not require the same type of decision-making as that used for a selecting a final design -- which necessarily involves values, uncertainty, and risk assessment?*
5. *The challenge of modeling individual vs. group preferences and individual vs. group rationality.* It is well known that group preferences are difficult if not impossible to construct and that individual rationality does not always align with group rationality. How can group decision-making benefit from examining individual vs. group rationality and their effects on product and process effectiveness? Can group rationality be determined from individual preferences?
6. *Keeping decisions and the results of these decisions (products, systems, processes) robust and open to change, adapt, and evolve with minimal rework, reformulation, and additional decision making.* How can flexibility be designed not only into products, systems, and processes, but the actual decisions underlying the design process?

## 6 Conclusion

The Open Workshop on Decision-Based Design has succeeded in focusing research efforts. A DBD presence has been established not only nation wide, but internationally. There is an acute and increasing awareness of the relevance of DBD to studying design and the corresponding research issues. We have also shown that it is possible to engage a number of researchers in dialogue by holding an open workshop on a web site. Certainly it is a challenging task that demands active monitoring but the results can be stunning. The breadth and complexity of the previous editorial questions reminds us that many areas remain in the quest to establish a rigorous foundation for decision-based design perspective.

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