Multiple Criteria Decision Support in Engineering Design

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With 83 Figures

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Dedicated to Dong-Ling, Indi, Lin and Sree for all their support whilst this book was taking shape.

FOREWORD

This book is an important step forward towards making design an objective process in which decisions can be rationally accounted for. That does not mean that the creativity, the skill, the humanity, and the challenging fun of designing is to be lost. It does mean that design decision makers can be more confident that their design solutions have been well matched to the needs and contraints which represent the ambitions of all their potential customers and, indeed, any who will come into contact with the resulting product.

When designing mighty systems such as large commercial aircraft, for example, it is easy to feel a sense of awe that people can be transported swiftly over large distances in comfort and safety in a massive structure depending on the most demanding technology. It is also easy to forget that it is a flying compromise in many dimensions. It must satisfy (or, preferably, delight) the passengers, the flight crew, the cabin crew, the baggage handlers, the maintainers, the airline which owns it or the leasing agency which owns it. Air trafffic controllers will want it to fit well into their expectations. Those living near the airports it uses will have an interest in its noise and smell. Society at large will have demands and feelings which will extend over fuel consumption, safety, ease of disposal... and so on. All this is too important to be left to the unprovable decisions of specialists working, quite possibly, in isolation from one another. We have moved into an era when all the conflicts and compromises in such an extensive design task, involving huge technical and human systems, need sound, analytical balancing, rendering the decisions effective, logical, and traceable... in an economically short time.

For some ten years I have been fascinated by the way in which Professor Pratyush Sen has taken his constructive and probing approach to Multiple Criteria Decision Making (MCDM) as a means of handling these problems. It is a major component of the work of the highly successful Engineering Design Centre at the University of Newcastle. In my roles as Design Co-ordinator for the Science and Engineering Research Council and, later, as Design Consultant to the Engineering and Physical Sciences Research Council I have been privileged to witness Professor Sen and his group develop, extend, and implement the ideas. He has much to tell us; and there is still more to come as he continues his researches and applies them across the whole industrial spectrum.

Those of us who have practised engineering design know only too well that designing is about trying to obtain the best solution to the problem, *taking everything into consideration.* In other words, to design is to optimise. In this book Professor Sen and his worthy co-author Dr.J.B.Yang have clearly laid out the procedures to do just that. It is an admirable text to help designers. Its approach takes design into the realms of managerial decision making in a way most of us could not have dreamed possible only a few years ago. This, for me, really is Computer Aided Design.

Professor Peter Hills
President, Institution of Engineering Designers
June 1998

Preface

Decision making, in general, and engineering decision making, in particular, often involve the balancing of multiple, potentially conflicting requirements. Classical optimisation deals with these problems by taking the most important requirement as the objective function and the remainder as constraints.

This still leaves the problem of potentially irreconcilable requirements and the usual approach employed to solve this problem is to relax the thresholds of the constraints until feasible solutions emerge. However, there is an alternative body of methods that take a different view. These deal with multiple criteria problems as they appear and employ a range of processes that clarify the consequences of the underlying trade-offs between criteria in configuring alternative solutions. The aim is to use the conflict resolution process as a creative activity. It is in this context that this book has been written. However, two fortunate events have contributed to its actual writing.

Firstly, the setting up of the Engineering Design Centre (EDC) at Newcastle University in 1990 with funding from the Engineering and Physical Sciences Research Council (EPSRC) allowed the first author to assemble a group of researchers under him to continue to more rigorously pursue his personal research interests in the important area of Multiple Criteria Decision Making (MCDM) in engineering design. This was as a part of the overall research portfolio of the EDC. Dr.Yang, the co-author of this book, joined the research group on MCDM in 1991 and worked within this group until 1995 when he left the Newcastle EDC. By the time he left he had made an impressive contribution to the development of the methodological base that is reported in Chapters 3 and 4. Although both authors had a strong research interest in MCDM before the formation of the EDC, the four and a half years together helped to produce a body of work that has proved to be of wide applicability both within the EDC and without.

The second fortunate set of circumstances that has helped this book is the issue of topicality. MCDM as a formal body of methodology has evolved into a discipline in its own right over the last quarter of a century and has now reached a level of maturity that merits its formal adoption in many decision making situations. This provided the technical impetus for sharing some of our experiences with potential users.

Given the personal backgrounds of the authors and the context of the EDC it seemed natural to develop the methodological base as a decision support environment primarily for engineering design. The examples of engineering design decision making used in the text are often drawn from the domain of marine technology which is the base department of the first author. They have been presented in a sufficiently generic manner, however, so as not to pose any difficulties for the average reader, we hope.

The production of the work has also benefited from direct and indirect contributions from several students and research associates from the Decision Support Group at the EDC which the first author leads. In particular thanks are due to David Todd, Tri Achmadi, Raj Subramani, Zhengfu Rao, Peter Meldrum and Jaime Scott. David, in particular, has assisted with the production aspects of all the technical chapters and with technical material for Chapter 5. Both authors also wish to acknowledge the numerous technical discussions held with a large number of interested users of the methodologies. They are too numerous to name but it is a pleasure to acknowledge that their implicit contributions have helped to clarify some of our own thinking in several of the areas. The authors are also grateful for the excellent word processing and editing assistance from Kathleen Heads.

Finally, both authors would like to thank their families for the forbearance, understanding and support during the anti-social hours that had to be kept at times during the writing of this book.

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