Empirical Model Building and Response Surface.

George E. P. BOX and Norman R. DRAPER New York: Wiley, 1987 ISBN 0-471-81033-9. 669 pp. $99.95

Response Surface Methodology.

Raymond H. MYERS and Douglas C. MONTGOMERY New York: Wiley, 1995 ISBN 0-471-58100-3. 700 pp. $64.95

Response Surfaces.

A. I. KHURI and John A. CORNELL, 2nd Edition New York: Dekker, 1996 ISBN 0-8247-9741-8. 510 pp. $75

The original response surface methodology (RSM) is typically attributed to Box and Wilson (1951). The first book on RSM (Myers 1971) did not appear until 1971, however. Here I review three recent books on RSM. Although there are many outstanding practitioners and researchers in this field, it is probably fair to say that the authors of these books have dominated the RSM history in many ways. Each individual has contributed a significant amount of original work, and all are esteemed teachers, writers, and researchers. Each could have written an eminent RSM textbook individually, if so desired. Given such a background, it is not surprising that all three books are well written and provide much insight into RSM. Here I attempt to address the issue of which book may fit you best.

Table 1 summarizes the tables of contents of these three books: Box and Draper (BD), Myers and Montgomery (MM), and Khuri and Cornell (KC). It is clear that all three books share common themes: a basic empirical model-building tool, such as least squares fitting; first-order model and design, notably two-level factorials; concepts of steepest ascent and more complicated second-order model and design; and the exploration of maxima for optimum condition.

But a close look at Table 1 indicates that these three books are different in that each contains special topics that the others do not. Chapters 8 and 12–14 in BD are unique: they include transformation, variance/bias lack of fit, and optimal design. They also present ridge analysis in much detail (Chaps. 10 and 11). MM and KC address some important subjects such as Taguchi's method and mixture experiments. MM also covers evolutionary operation (EVOP) in Chapter 13. Apart from Chapters 9 and 11 that have been covered by MM, several chapters in KC are unique: multiple response problems (Chap. 7), block effects (Chap. 8), and nonlinear response surfaces (Chap. 10). Bear in mind that these are relatively new research subjects—more advanced techniques may be possible in the near future. Overall, BD is a "classical" RSM bible, suitable for researchers and practitioners, but lacks recent results on some important subjects, such as multiple responses, quality improvement, and screening experiments (e.g., projectivity in Box and Tyssedal 1996). MM is an excellent book for practitioners, although it does not discuss the theoretical developments of certain subjects as deeply as the other two books do. KC has two parts: the first for a general audience (Chaps. 1–5) at an introductory level, and the second (Chaps. 6–12) at a higher level with many research problems. The second part covers some important recent research results useful for the practitioners, but requires some knowledge of matrix algebra.

BD and KC strike a balance between real applications and theoretical developments, whereas MM attempts to lower the theoretical level to make the book more readable to their target audiences—a difficult task for which MM did an excellent job.

Table 2 summarizes some other features of the three books, specifically:

- Bibliography. BD uses 42 pages to list 937 selected references; MM has 7 pages with 135 references; and KC has 13 pages with 260 references. KC also lists relevant references at the end of each chapter. This allows the reader to find relevant references in an efficient manner. Although there is a much overlap among the books in the reference lists, it is interesting to note that there are also many references cited by only one of the three books.

- Statistical tables. BD provides four statistical tables: normal, t, chi-squared, and F. MM provides none, and KC provides two: t and F. I tend to believe that the four tables in BD are essential. They do not take up too much space, and yet are really handy when one needs them.

- Appendices. All three books emphasize the methodology and concepts using illustrative real data, with more difficult theories given in appendixes. Readers can easily learn the concepts without going through the complicated theoretical derivations, but can catch those theoretical aspects from the appendixes, if so desired. Such an aim has been well achieved. BD has 28 appendices spread over different chapters. MM has 10 appendices at the end of the book; and KC has a total of five appendices given in Chapters 2, 3, and 8. This distribution more or less reflects the writing styles of these authors.

- Exercises. BD appears to have the richest problem set—many real data problems as well as classroom type homework problems. Moreover, solutions are provided at the end of the book. MM provides some real data problems, but more of the classroom-type homework problems; no solutions are given. KC has a good set of exercises, but only a small number (typically six questions per chapter, but some chapters have none); solutions are given.

- Target audience. The books' Prefaces give insight into their intended readerships: BD: "The experimenter frequently faces the task

Table 1. Summary of Contents

Chapter	BD	MM	KC
1	Introduction	Introduction	Introduction
2	Graduation Function	Building Empirical Models	Matrix Algebra
3	Least Squares	Two-Level Factorials	First-Order Model and Design
4	Two-Level Factorials	Two-Level Fractional Factorials	Second-Order Model and Design
5	Blocking and 2^{k-p} Designs	Steepest Ascent	Optimum Condition
6	Steepest Ascent	Analysis of Response Surface	IMSE Criterion
7	Second-Order Model	Design for Response Surface-I	Multiple Response
8	Transformation	Design for Response Surface-II	Block Effects
9	Exploration of Maxima	Miscellaneous Topics	Mixture Experiment
10	Ridge System-I	Taguchi's Robust Design	Nonlinear Response Surface
11	Ridge System-II	Mixture Experiment	Taguchi's Method
12	Empirical/Theoretical Models	More on Mixture	Additional Topics
13	Variance, Bias and Lack of Fit	EVOP	
14	Variance-Optimal Design		
15	Practical Choice		

Table 2. Further Comparisons of BD, MM, and KC

	BD	MM	KC
Bibliography	42 pages; 937 references	7 pages; 135 references	13 pages; 260 references
Statistical tables	4	0	2
Appendixes	28	10	5
Exercises	Many real data problems	Classroom-type problems	Good quality but small number
(with solutions)	Yes	No	Yes
Target readers	Advanced undergraduates and graduates	Undergraduates; practitioners	Graduates
Use as a textbook	Yes	Yes	Yes
Related books	Box, Hunter, and Hunter (1978)	Myers (1971)	Myers (1971)

of exploring the relationship between some response y and a number of predicted variables x." MM: "The text is written to emphasize methods that are useful in industry and that we have found to be helpful in our consulting experience; however, some of the underlying theory is developed so that reader will gain an understanding of the assumptions and conditions necessary to apply the methodology." KC: "This book is intended for research workers and students, at advanced undergraduate and graduate levels, both in the fields of statistics and other related areas." If I were the instructor, I would choose MM for an undergraduate course, BD for a graduate course, and KC for undergraduate/graduate students working in RSM area. For nonacademic (e.g., industrial) readers, MM is the best fit for those who do not have a graduate degree in Statistics; BD is best for those who do. KC is most appropriate for those who are interested in certain subjects in depth. These suggestions are based more or less on the books' mathematical levels.

- Related books. BD can be viewed as a follow-up to the work of Box, Hunter, and Hunter (1978). MM has some overlaps with the books by Myers (1971) and Montgomery (1991); some chapters are close to work of Box et al. (1978) and Cornell (1990). The first edition of KC is meant to replace Myers (1971); with a new structure and added subjects, the second edition is clearly an improvement (see Mason 1997).

In summary, these three books are clearly the best books in RSM that I have seen. Ownership of these three books is a professional necessity. If your budget is tight and buying all three books is not possible, hopefully these comments and comparisons will aid your decision. It is so tempting to add that BD is the only book that uses alphabetical order for the authorship.

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REFERENCES

Box, G. E. P., Hunter, W. G., and Hunter, J. S. (1978), *Statistics for Experimenters*, New York: Wiley.

Box, G. E. P., and Tyssedal, J. (1996), "Projective Properties of Certain Orthogonal Arrays," *Biometrika*, 83, 950–955.

Box, G. E. P., and Wilson (1951), "On the Experimental Attainment of Optimum Conditions," (with discussion), *Journal of the Royal Statistical Society*, Ser. B, 12, 1–45.

Cornell, J. A. (1990), *Experiments With Mixtures*, New York: Wiley.

Mason, R. L. (1997), Book review of *Response Surfaces* (2nd ed.) by Khuri and Cornell, *Journal of Quality Technology*, 29, 362–364.

Myers, R. H. (1971), *Response Surface Methodology*, Boston: Allyn and Bacon. Reprint 1976, Ann Arbor, MI: Edwards Bros.