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# *The Analyst's Bookshelf*

## **Review**

**MIECZYSLAW GREGORY BEKKER, *Introduction to Terrain-Vehicle Systems*, University of Michigan Press, Ann Arbor, Mich., 1969, 846 pages, \$27.50**

**T**HIS IS a fascinating and exciting book. It deals with a field that is still young, as far as scientific method is concerned; it applies the 'systems approach' constructively to integrate an impressive array of technical information; and it is written by the world's ranking expert in land locomotion (see Notes 1 and 2 below).

There is a particular pleasure in reading a volume by a single author that encompasses a whole field of technology, when the job is well done, as it is in this book. There is a continuity of thought and an organization and interrelation of content that rarely appear in a handbook assembled by a group of experts. As a field grows, there is a point of no return beyond which it escapes the ability of a single person to capture it adequately in a single volume. It is fortunate that DR. BEKKER has been able to devote the time to do this for land locomotion so satisfyingly and comprehensively, as, thanks in great part to his own efforts, the point of no return approaches.

The most difficult part of land locomotion is, of course, off-road travel, and considering that in the beginning there were no roads, it is remarkable that the science and engineering of off-the-road motion have developed so slowly. Yet the history of transportation and, in fact, the story of civilization is, to a great degree, a history of road building. Civilization has traditionally paused 'at the end of track.' The railroad opened 'trackless wildernesses' to man. Even movement by water has become increasingly tied to complex port facilities. And the eventual success of the helicopter came too late to prevent the critical dependence of modern air transport on acres of concrete runways.

When there is time, it is more cost-effective to build a road and simplify thereby the design of the vehicles that traverse it.

Yet there has always been a need for off-the-road locomotion. Armies would prefer not to be road-bound, but they must often choose between moving on foot or at a pace governed by their construction battalions. The farmer cannot pave his fields for his tractors and other agricultural equipment. Road building equipment must have some mobility before the roads they build come into being. These needs, important in each case to the operators, have constituted such a small fraction of the demands of transportation that over generations they have attracted limited effort, limited research, and even less research funding.

In spite of these limitations, the field of terramechanics has slowly acquired form and content. It is currently being stimulated by the need to apply what is known to movement on the ocean bottom and on the surface of extra-terrestrial bodies. In

Dr. Bekker's book we learn what is known, how we can apply this knowledge, and what must be done in the future.

Practitioners of operations research will take a special interest in this book, since the stimulus to integrate the existing knowledge on ground mobility and to undertake orderly and increased programs of research and development over the past decade and a half have been strongly influenced by the 'systems approach' of the Army's Operations Research Office and its interaction with the Army's in-house laboratories.

The book is divided into two major parts: Part I considers "The Terrain," and Part II considers "The Vehicle." Part II also shows by example how to proceed in an orderly fashion from mission to recommended vehicle design.

Part I presents the descriptors and measures by which terrain characteristics affecting locomotion are categorized, described, and quantified. We learn about the kinds of soil, mud, ice, and snow, and the experimental procedures and equipment for measuring their characteristics. Unlike a surfaced road or a rail, soil deforms under load; the vehicle sinks into it to varying degrees; some of the developed traction is consumed in displacement of the supporting material. Terrain is irregular. A vehicle traversing it rolls and pitches, the suspension is violently exercised, the frame deforms, the loading of individual wheels or tracks varies irregularly. Obstacles must be avoided, surmounted or pushed over. To swim across a canal or river requires overcoming the banks. Terrain composition, contours, and the distribution of obstacles must be described statistically, since one wants to know something of the probability that a vehicle of particular design will succeed in traversing unprepared terrain, the characteristics of which are known only approximately in advance.

All of these characteristics of terrain and many more are addressed in Part I, and what is known is summarized in charts, tables, and formulas. The geography ranges from the Northern United States to Southeast Asia to the Moon.

In Part II we learn how to configure vehicles to master the terrain. Beginning with the mission and concept of a vehicle, this part progresses through models of the soil-vehicle relation, dynamics of vehicle behavior, man-machine relation, performance models, and the final choice and basis of evaluation of a vehicle concept for a given mission and environment. The range of design parameters and their interrelations that characterize past and existing vehicle designs is summarized, and directions of improvement noted. Vehicle types considered range from the farmer's pea combine to the astronaut's lunar surface vehicle. Dr. Bekker shows clearly how far one can go using existing data and analysis, and where one must turn to experiment to validate a new design.

Particularly important is the chapter on "Selecting Vehicle Concepts for a Given Mission and Environment." Here Dr. Bekker shows by example how one balances analysis, judgment, and experience in the practical business of coming up with a recommended design for a specified mission. Systems analysis and engineering in vehicle design—whether air, sea, or land, often tend to pursue independent objectives; Dr. Bekker shows how they can be integrated.

Part II concludes with a stimulating discussion of the future course of terramechanics.

The mysticism of the road will always be with us, as well as its cost-effective reality. Tolkien's hobbit, Bilbo, in the *Fellowship of the Ring* said

The Road goes ever on and on  
... and I must follow, if I can.

But where there are no roads, we must turn to Bekker. And there are no roads on the Moon ... yet.

HERBERT K. WEISS  
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#### NOTES

1. One of the many honors conferred upon DR. BEKKER for his work in Terramechanics is Sweden's Royal Military Technical Association Medal for Professional Achievement.

2. Although *Introduction to Terrain-Vehicle Systems* is complete in itself, for the essential nucleus of a library on land locomotion, one should also have Dr. Bekker's prior two volumes, *Theory of Land Locomotion, the Mechanics of Vehicle Mobility*, University of Michigan Press, Ann Arbor, 1956, and *Off-the-Road Locomotion, Research and Development in Terramechanics*, University of Michigan Press, Ann Arbor, 1960. To 'dig deeper'—*Terrain Vehicle Systems* contains over fifty pages in its bibliography.

#### **Books Received**

JULIUS S. ARONOVSKY, *Progress in Operations Research, Volume III: Relationship between Operations Research and the Computer*, John Wiley & Sons, New York, N.Y., 1969, 571 pages, \$18.75. Number 16 in ORSA's Progress-in-Operations-Research series.

ROBERT U. AYRES, *Technological Forecasting and Long-Range Planning*, McGraw-Hill Book Co., New York, N.Y., 1969, 255 pages, \$12.50.

PAUL W. BACHMAN, *Research for Profit: The Problem, The Solution, A Case History*, The Ronald Press Co., New York, N.Y., 1969, 205 pages, no price.

LIPMAN BERS and members of the Committee on Support of Research in the Mathematical Sciences, *The Mathematical Sciences: A Report*, National Academy of Sciences, Washington, D.C., 1968, 270 pages, \$6.00 (paper).

LEO BREIMAN, *Probability and Stochastic Processes, with a View toward Applications*, Houghton Mifflin Co., Boston, Mass., 1969, 336 pages, \$9.50.

HARVEY BROOKS AND OTHERS, *Technology: Processes of Assessment and Choice*, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., July, 1969, 177 pages, 75 cents. A report of the ad hoc Panel on Technology Assessment of the Committee on Science and Public Policy of the National Academy of Sciences to the Committee on Science and Astronautics of the U.S. House of Representatives.

ELWOOD S. BUFFA, *Modern Production Management, Third Edition*, John Wiley & Sons, New York, N.Y., 1969, 809 pages, \$10.95.

D. B. CANDLIN, *O&M—A Management Service*, Pergamon Press, Oxford, England, 1969, 222 pages, \$3.25 (paper).

ROBERT L. CHARTRAND AND OTHERS, *Systems Technology Applied to Social and Com-*

- munity Problems, Subcommittee on Employment, Manpower, and Poverty of the Committee on Labor and Public Welfare, United States Senate, June 1969, 487 pages, no price. A report prepared by the Science Policy Research Division, Legislative Reference Service, Library of Congress.
- KONG CHU, *Quantitative Methods for Business and Economic Analysis*, International Textbook Co., Scranton, Pa., 1969, 391 pages, \$8.95.
- FREDERICK E. CROXTON, DUDLEY J. COWDEN, AND BEN W. BOLCH, *Practical Business Statistics, Fourth Edition*, Prentice-Hall, Englewood Cliffs, N.J., 1969, 462 pages, \$9.95.
- RALPH DEUTSCH, *Systems Analysis Techniques*, Prentice-Hall, Englewood Cliffs, N.J., 1969, 490 pages, \$13.50.
- HANS-DIETER DEPPE *Bankbetriebliches Wachstum: Funktionalzusammenhänge und Operations Research in Kreditinstituten*, C. E. Poeschel Verlag, Stuttgart, W. Germany, 1969, 310 pages, DM 48.
- J. L. DOLBY, V. J. FORSYTH, AND H. L. RESNIKOFF, *Computerized Library Catalogs: Their Growth, Cost, and Utility*, The MIT Press, Cambridge, Mass., 1969, 174 pages, \$10.00.
- MARTIN EISEN, *Introduction to Mathematical Probability Theory*, Prentice-Hall, Englewood Cliffs, N.J., 1969, 559 pages, \$12.95.
- IVAN D. ERTEL AND MARY LOUISE MORSE, *The Apollo Spacecraft: A Chronology, Volume I (through November 7, 1962)*, Scientific and Technical Information Division, Office of Technology Utilization, National Aeronautics and Space Administration, 1969, available from the Superintendent of Documents, US Government Printing Office, Washington, D.C., \$2.50 (paper).
- JAY W. FORRESTER, *Urban Dynamics*, The MIT Press, Cambridge, Mass., 1969, 299 pages, \$12.50.
- J. K. FRIEND AND W. N. JESSOP, *Local Government and Strategic Choice*, Sage Publications, 275 S. Beverly Drive, Beverly Hills, California, 1969, 320 pages, \$12.50.
- SAUL I. GASS, *Linear Programming, Third Edition*, McGraw-Hill Book Co., New York, N.Y., 1969, 374 pages, \$14.50.
- PAUL S. GREENLAW AND MICHAEL P. HOTTENSTEIN, *PROSIM: A Production Management Simulation*, International Textbook Co., Scranton, Pa., 1969, 264 pages, \$4.25 (paper).
- JAMES M. GRIMWOOD AND BARTON C. HACKER (with PETER J. VORZIMMER), *Project Gemini—Technology and Operations: A Chronology*, Scientific and Technical Information Division, Office of Technology Utilization, National Aeronautics and Space Administration, 1969, 326 pages, available from the Superintendent of Documents, US Government Printing Office, Washington, D.C., \$2.75 (paper).
- GENE K. GROFF AND JOHN F. MUTH, *Operations Management: Selected Readings*, Richard D. Irwin, Homewood, Ill., 1969, 446 pages, \$8.65 (paper). An anthology of 33 essays.
- ROBERT W. GRUBBSTRÖM, *Market Cybernetic Processes*, Almqvist & Wiksell, Stockholm, Sweden, 1969, 358 pages, 56 Swedish Kroner.
- SILVIU GULIAȘU, *Aplicații ale Teoriei Informatiei: Sisteme Dinamice, Sisteme Ciberneticice*, (Applications of Information Theory: Dynamical Systems, Cybernetic Sys-

- tems), Editura Academiei Republicii Socialiste România, Bucharest, Roumania, 1968, 350 pages, 17 lei.
- GILBERT HELMBERG, *Introduction to Spectral Theory in Hilbert Space*, John Wiley & Sons, New York, N.Y., 1969, 360 pages, \$19.50.
- R. HENN AND H. P. KÜNZI, *Einführung in die Unternehmensforschung, I & II*, Springer-Verlag, Berlin, W. Germany, 1968, 168 and 209 pages, no prices.
- DIETER HOCHSTÄDTER, *Stochastische Lagerhaltungsmodelle*, Springer-Verlag, New York, N.Y., 1969, 269 pages, \$4.50.
- BARTOW HODGE AND ROBERT N. HODGSON, *Management and the Computer in Information and Control Systems*, McGraw-Hill Book Co., New York, N.Y., 1969, 313 pages, \$13.50.
- L. P. HYVÄRINEN, *Information Theory for Systems Engineers*, Springer-Verlag, New York, N.Y., 1968, 212 pages, \$3.80.
- PHILIP B. JORDAIN, *Condensed Computer Encyclopedia*, McGraw-Hill Book Co., New York, N.Y., 1969, 621 pages, \$14.50.
- JOHN F. KAIN, H. M. KOLSEN, N. C. STOKES, AND S. C. JOY, *The Economics of Road and Road Transport*, Commonwealth Bureau of Roads, Melbourne, Australia, 1968, 64 pages, no price (paper).
- WILLIAM F. KELLY, *Management through Systems and Procedures: The Total Systems Concept*, John Wiley & Sons, New York, N.Y., 1969, 568 pages, \$13.95.
- A. A. KOR BUT AND J. J. FINKEL'STEIN, *Diskretnoe Programirovanie*, (Discrete Programming), Izdatel'stvo "Nauka," Glavnaja Relakcija Fiziko-Matematicheskoi Literatury, Moscow, Soviet Union, 1969, 368 pages, 1 ruble 27 kopecks.
- BERNHARD KORTE AND WALTER OBERHOFER, *Ein univariablen ökonomisches Analyse und Prognosemodell*, Westdeutscher Verlag, Köln, W. Germany, 1968, 72 pages, no price (paper).
- H. W. KUHN AND G. P. SZEGÖ, editors, *Mathematical Systems Theory and Economics*, vols. I and II, Springer-Verlag, Berlin, Germany, 1969, 498 pages, \$8.50 for both volumes (paper). Proceedings of an International Summer School held in Varenna, Italy, June 1-12, 1967.
- HENRY F. LANDE, *How to Use the Computer in Business Planning*, Prentice-Hall, Englewood Cliffs, N.J., 1969, 205 pages, \$19.95.
- ODD LANGHOLM, *Full Cost and Optimal Price: A Study in the Dynamics of Multiple Production*, Universitetsforlaget, Box 142, Boston, Mass. 02113, 1969, 87 pages, \$6.00.
- J. A. LARKIN, *Work Study*, McGraw-Hill Book Co., New York, N.Y., 1969, 256 pages, \$9.95.
- T. H. LEE, G. E. ADAMS, AND W. M. GAINES, *Computer Process Control: Modeling and Optimization*, John Wiley & Sons, New York, N.Y., 1968, 400 pages, \$14.95.
- LEON LIVOVSKI, *Circuite cu Contacte de Relee*, (Relay Contact Circuits), Editura Academiei Republicii Socialiste România, Bucharest, Roumania, 1968, 251 pages, 9.50 lei (paper). In Roumanian with an English summary.
- DAVID G. LUENBERGER, *Optimization by Vector Space Methods*, John Wiley & Sons, New York, N.Y., 1969, 344 pages, \$13.95.

- EUGENE LUKACS, *Stochastic Convergence*, D. C. Heath Co., Boston, Mass., 1969, 152 pages, \$6.95.
- JOHN R. MCGIBONY, *Principles of Hospital Administration, 2nd Edition*, G. P. Putnam's Sons, New York, N.Y., 1969, 608 pages, \$12.95.
- OLVI L. MANGASARIAN, *Nonlinear Programming*, McGraw-Hill Book Co., New York, N.Y., 1969, 236 pages, \$12.50.
- JAMES C. T. MAO, *Quantitative Analysis of Financial Decisions*, The Macmillan Co., New York, N.Y., 1969, 639 pages, \$10.95.
- L. B. M. MENNES, JAN TINBERGEN, AND J. GEORGE WAARDENBURGH, *The Element of Space in Development Planning*, North-Holland Publishing Co., Amsterdam, Holland, 1969, 354 pages, \$15.00.
- ROBERT G. MURDICK, *Business Research: Concept and Practice*, International Textbook Co., Scranton, Pa., 1969, 240 pages, \$3.95 (paper).
- THOMAS H. NAYLOR AND JOHN M. VERNON, *Microeconomics and Decision Models of the Firm*, Harcourt, Brace & World, New York, N.Y., 1969, 496 pages, \$10.00.
- JAMES J. O'BRIEN, *Scheduling Handbook*, McGraw-Hill Book Co., New York, N.Y., 1969, 617 pages, \$18.50.
- JOSEPH A. PANICO, *Queuing Theory: A Study of Waiting Lines for Business, Economics, and Science*, Prentice-Hall, Englewood Cliffs, N.J., 1969, 214 pages, \$7.95.
- WILLIAM S. PETERS, editor, *Readings in Applied Statistics*, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1969, 384 pages, \$5.95 (paper).
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- LOUIS A. PIPES AND SHAHEN A. HOVANESSIAN, *Matrix-Computer Methods in Engineering*, John Wiley & Sons, New York, N.Y., 1969, 345 pages, \$12.95.
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- LUCAS PUN, *Introduction to Optimization Practice*, John Wiley & Sons, New York, N.Y., 1969, 319 pages, \$14.95.
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- ALAIN SCHÄRLIG, *Localisation Optimale et Théorie des Graphes*, Librairie Droz, Geneva, Switzerland, 1969, 164 pages, 26 Swiss francs (paper).
- ROBERT E. SCHELLENBERGER, *Managerial Analysis*, Richard D. Irwin, Homewood, Ill., 1969, 477 pages, \$13.35.
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- HILARY L. SEAL, *Stochastic Theory of a Risk Business*, John Wiley & Sons, New York, N.Y., 1969, 244 pages, \$14.95.

- T. P. SHERMAN, *O&M in Local Government*, Pergamon Press, Oxford, England, 1969, 274 pages, \$4.75 (paper).
- C. STAFFURTH, editor, *Project Cost Control Using Networks*, The Operational Research Society and The Institute of Cost and Works Accountants, London, England, 1969, 92 pages, 16 shillings.
- SAUL STIMLER, *Real-Time Data-Processing Systems: A Methodology for Design and Cost/Performance Analysis*, McGraw-Hill Book Co., New York, N.Y., 1969, 269 pages, \$13.50.
- J. TEGHEM, J. LORIS-TEGHEM, AND J. P. LAMBOTTE, *Modèles d'Attente M/G/1 et GI/M/1 à Arrivées et Services en Groupes*, Springer-Verlag, New York, N.Y., 1969, 57 pages, \$1.50 (paper).
- EDWARD TOMESKI, *The Executive Use of Computers*, The Macmillan Co., New York, N.Y., 1969, 160 pages, \$1.50 (paper).
- R. IAN TRICKER, *Management Information Systems: An Annotated Bibliography*, The General Educational Trust of the Institute of Chartered Accountants in England and Wales, 56-66 Goswell Rd., London E.C.1, England, 1969, 127 pages, 10 shillings (paper). Annotated bibliography of 196 books and a listing of 369 papers, plus references to the relevant journals and bibliographical services.
- LUCIEN VALLERY, *Application du Calcul Statistique au Contrôle des Produits*, Editions Eyrolles, 61 boulevard Saint-Germain, Paris 5<sup>e</sup>, France, 134 pages, 22 francs (paper).
- LAWRENCE A. WALSH, *Physical Distribution*, McGraw-Hill Book Co., New York, N.Y., 1969, 128 pages, \$2.12 (paper).
- F. WEINBERG AND C. A. ZEHNDER, editors, *Heuristische Planungsmethoden*, Springer-Verlag, New York, N.Y., 1969, 93 pages, \$2.00 (paper).
- RALPH A. WILLOUGHBY, editor, *Proceedings of the Symposium on Sparse Matrices and their Applications*, International Business Machines Corp., Box 218, Yorktown Heights, New York, 1969, 206 pages, no price (paper).
- SIDNEY J. YAKOWITZ, *Mathematics of Adaptive Control Processes*, American Elsevier Publishing Co., New York, N.Y., 1969, 174 pages, \$11.00.
- WILLARD I. ZANGWILL, *Nonlinear Programming: A Unified Approach*, Prentice-Hall, Englewood Cliffs, N.J., 1969, 372 pages, \$12.50.

### Notes

**P**OLICY SCIENCES: *Policy Analysis, Systems Approaches, and Decisionmaking*, a new quarterly journal, will appear in 1970 under the Editorship of E. S. QUADE. According to its prospectus, it "will provide a forum for the developing interest in the application of structured rationality, systematic analysis, and interdisciplinary knowledge to problems of public policy. It will include applied studies analyzing specific problem areas, theoretic studies on the methods, content, and problems of the policy sciences, and papers dealing with the policy sciences as a subject for