

## Regular Article

# An Optimization for Ore Blending Schedules Using Mathematical Programming Methods

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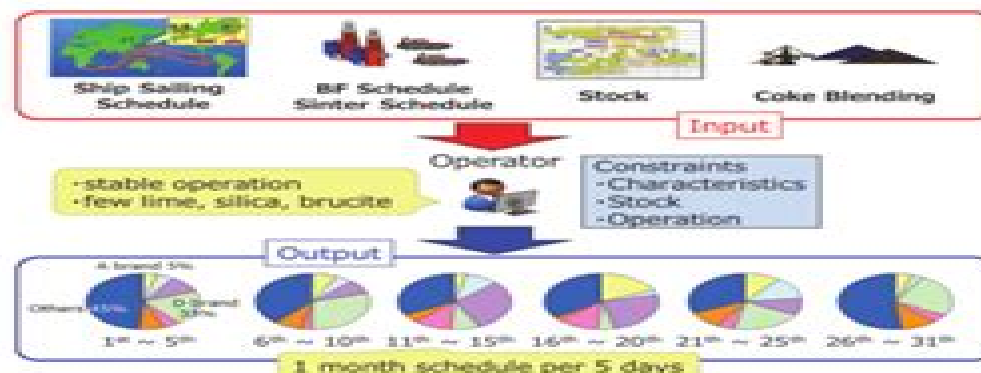
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**Abstract:** We have developed an optimal scheduling method for raw material operations aiming the raw materials cost reduction. In this paper, we report optimization approaches to minimize the cost of ore blending in steel works.

The ore blending problem is to make schedules for the purpose of cost minimization under several constraints such as the stock in yards, ingredients in sintered ore. When formulating as a mathematical model, nonlinearity exists in this problem and make it complicated. However, this problem has characteristic that becomes a linear problem by fixing several key variables as constants. To overcome the nonlinearity, we developed our original Hybrid model that was a combination of Particle Swarm Optimization (PSO) and Linear Programming method (LP). We applied PSO to search the best way of fixing key variables, and obtained blending schedules by solving LPs. Our Hybrid model searched wide area effectively, and derived the solution within 2 minutes. Numerical experiments indicated a cost reduction of secondary materials by 1%.

**Keywords:** ore blending; mathematical programming; optimization; linear programming; meta heuristics; particle swarm optimization; multi-point search method.



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# Mathematical Programming Methods

**James Killen**



## **Mathematical Programming Methods:**

Mathematical Programming Methods G. Zoutendijk, 1976 Theory of linear programming The simplex method Numerical aspects of the simplex method Other methods for linear programming Special structures Post optimal analysis Decomposition and partitioning methods Integer and mixed integer linear programming Theory of nonlinear programming General principles of a method of feasible directions Direction generators Linear programming and the methods of feasible directions Unconstrained optimization Quadratic programming Linearly constrained nonlinear programming General nonlinear programming

**Mathematical Programming** S. M. Sinha, 2005-01-01 Mathematical Programming a branch of Operations Research is perhaps the most efficient technique in making optimal decisions It has a very wide application in the analysis of management problems in business and industry in economic studies in military problems and in many other fields of our present day activities In this keen competitive world the problems are getting more and more complicated and efforts are being made to deal with these challenging problems This book presents from the origin to the recent developments in mathematical programming The book has wide coverage and is self contained It is suitable both as a text and as a reference A wide ranging all encompassing overview of mathematical programming from its origins to recent developments A result of over thirty years of teaching experience in this field A self contained guide suitable both as a text and as a reference

Methods and Models in Mathematical Programming S. A. MirHassani, F. Hooshmand, 2019-12-09 This book focuses on mathematical modeling describes the process of constructing and evaluating models discusses the challenges and delicacies of the modeling process and explicitly outlines the required rules and regulations so that the reader will be able to generalize and reuse concepts in other problems by relying on mathematical logic Undergraduate and postgraduate students of different academic disciplines would find this book a suitable option preparing them for jobs and research fields requiring modeling techniques Furthermore this book can be used as a reference book for experts and practitioners requiring advanced skills of model building in their jobs

Mathematical Programming Methods for Geographers and Planners James Killen, 2021-11-30 Originally published in 1983 this was the first text to offer an in depth treatment of mathematical programming methods explained from first principles It considers all the major programming techniques and fully explains key terms illustrates theories with detailed examples and shows how the various skills are applied in practice It will be invaluable in both the academic world and to policy formulators and planners who make extensive use of the methods described

*Computational Mathematical Programming* Klaus Schittkowski, 2013-06-29 This book contains the written versions of main lectures presented at the Advanced Study Institute ASI on Computational Mathematical Programming which was held in Bad Windsheim Germany F R from July 23 to August 2 1984 under the sponsorship of NATO The ASI was organized by the Committee on Algorithms COAL of the Mathematical Programming Society Co directors were Karla Hoffmann National Bureau of Standards Washington U S A and Jan Teigen Rabobank Nederland Zeist The Netherlands

Ninety participants coming from about 20 different countries attended the ASI and contributed their efforts to achieve a highly interesting and stimulating meeting Since 1947 when the first linear programming technique was developed the importance of optimization models and their mathematical solution methods has steadily increased and now plays a leading role in applied research areas The basic idea of optimization theory is to minimize or maximize a function of several variables subject to certain restrictions This general mathematical concept covers a broad class of possible practical applications arising in mechanical electrical or chemical engineering physics economics medicine biology etc There are both industrial applications e g design of mechanical structures production plans and applications in the natural engineering and social sciences e g chemical equilibrium problems christollography problems

Mathematical Programming Methods for Geographers and Planners James Killen, 1983

Mathematical Programming for Operations Researchers and Computer Scientists Holzman, 1981-06-01 This book covers the fundamentals of linear programming extension of linear programming to discrete optimization methods multi objective functions quadratic programming geometric programming and classical calculus methods for solving nonlinear programming problems

**Interior Point Methods of Mathematical Programming** Tamas Terlaky, 1996-09-30 One has to make everything as simple as possible but never more simple Albert Einstein Discovery consists of seeing what every body has seen and thinking what nobody has thought Albert S ent\_Gyorgy The primary goal of this book is to provide an introduction to the theory of Interior Point Methods IPMs in Mathematical Programming At the same time we try to present a quick overview of the impact of extensions of IPMs on smooth nonlinear optimization and to demonstrate the potential of IPMs for solving difficult practical problems The Simplex Method has dominated the theory and practice of mathematical programming since 1947 when Dantzig discovered it In the fifties and sixties several attempts were made to develop alternative solution methods At that time the principal base of interior point methods was also developed for example in the work of Frisch 1955 Caroll 1961 Huard 1967 Fiacco and McCormick 1968 and Dikin 1967 In 1972 Klee and Minty made explicit that in the worst case some variants of the simplex method may require an exponential amount of work to solve Linear Programming LP problems This was at the time when complexity theory became a topic of great interest People started to classify mathematical programming problems as efficiently in polynomial time solvable and as difficult NP hard problems For a while it remained open whether LP was solvable in polynomial time or not The breakthrough resolution of this problem was obtained by Khachijan 1989

Mathematical Programming Methods in Structural Plasticity D. Lloyd Smith, 1990-05-18 Civil engineering structures tend to be fabricated from materials that respond elastically at normal levels of loading Most such materials however would exhibit a marked and ductile inelasticity if the structure were overloaded by accident or by some improbable but naturally occurring phenomenon Indeed the very presence of such ductility constitutes an important safety provision for large scale constructions where human life is at risk In the comprehensive evaluation of safety in structural design it is therefore unrealistic not to consider the effects of ductility

This book sets out to show that the bringing together of the theory and methods of mathematical programming with the mathematical theory of plasticity furnishes a model which has a unifying theoretical nature and is entirely representative of observed structural behaviour. The contents of the book provide a review of the relevant aspects of mathematical programming and plasticity theory together with a detailed presentation of the most interesting and potentially useful applications in both framed and continuum structures: ultimate strength and elastoplastic deformability, shakedown and practical upper bounds on deformation measures, evolutive dynamic response, large displacements and instability, stochastic and fuzzy programming for representing uncertainty in ultimate strength calculations. Besides providing a ready fund of computational algorithms, mathematical programming invests applications in mechanics with a refined mathematical formalism rich in fundamental theorems which often gives additional insight into known results and occasionally lead to new ones. In addition to its obvious practical utility, the educational value of the material thoroughly befits a university discipline.

Evaluating Mathematical Programming Techniques J. M. Mulvey, 2012-12-06     *Progress in Mathematical Programming* Nimrod Megiddo, 2012-12-06. The starting point of this volume was a conference entitled Progress in Mathematical Programming held at the Asilomar Conference Center in Pacific Grove, California, March 1-4, 1987. The main topic of the conference was developments in the theory and practice of linear programming since Karmarkar's algorithm. There were thirty presentations and approximately fifty people attended. Presentations included new algorithms, new analyses of algorithms, reports on computational experience and some other topics related to the practice of mathematical programming. Interestingly, most of the progress reported at the conference was on the theoretical side. Several new polynomial algorithms for linear programming were presented: Barnes, Chopra, Jensen, Goldfarb, Mehrotra, Gonzaga, Kojima, Mizuno, Yoshise, Renegar, Todd, Vaidya, and Ye. Other algorithms presented were by Betke, Gritzmann, Blum, Gill, Murray, Saunders, Wright, Nazareth, Vial, and Zikan. Cottle. Efforts in the theoretical analysis of algorithms were also reported: Anstreicher, Bayer, Lagarias, Imai, Lagarias, Megiddo, Shub, Lagarias, Smale, and Vanderbei. Computational experiences were reported by Lustig, Tomlin, Todd, Tone, Ye, and Zikan. Cottle. Of special interest, although not in the main direction discussed at the conference, was the report by Rinaldi on the practical solution of some large traveling salesman problems. At the time of the conference, it was still not clear whether the new algorithms developed since Karmarkar's algorithm would replace the simplex method in practice. Alan Hoffman presented results on conditions under which linear programming problems can be solved by greedy algorithms.

*Introduction to Mathematical Programming* N. K. Kwak, Marc J. Schniederjans, 1987. This text presents current and classical mathematical programming techniques at an introductory level. It provides case problems to stimulate interest and is aimed for undergraduate courses in management science, operations, and decision research, and applied mathematics.

**Mathematical Programming Techniques** Nirmal Singh Kambo, 1984     **Modern Mathematical Methods of Optimization** Karl-Heinz Elster, 1993-11. Light will be thrown on a variety of problems concerned with the construction and

analysis of optimization models equilibrium models of mathematical economy modern numerical optimization methods and software methods of convex programming optimal with respect to complexity polynomial algorithms of linear programming decomposition of optimization systems modern apparatus of nonsmooth optimization models and methods of discrete programming

**Optimization Methods and Mathematical Programming Using MATLAB** Scientific Books, 2016-01-08 This book begins by introducing the MATLAB environment and the structure of MATLAB programming Below it is developed especially the Optimization Toolbox that includes algorithms for solving multiobjective problems non linear minimization with boundary conditions and restrictions minimax optimization semi infinitely constrained minimization and linear and quadratic programming A wide range of exercises are included illustrating techniques such as linear programming quadratic programming non linear least squares and the solution of non linear equations These topics are augmented with examples that put into practice the most widely used optimization methods

Mathematical Programming in Statistics T. S. Arthanari, Dr. Yadolah Dodge, 1981 Linear regression analysis Generalized inverses in linear statistical models Theory of testing statistical hypotheses Sampling Design and analysis of experiment Cluster analysis

Evaluating Mathematical Programming Techniques J. M. Mulvey, 1982-05 2 APL 3 5 Dyadic functions such as  $x \cdot r$   $\max$   $\min$  and  $e \log$  operate on scalars and extend to arrays in a systematic manner Two array arguments of a function must have the same shape ie vectors must have the same number of elements matrices must have the same number of rows and columns If one argument of a function is a scalar it is applied to each element of the other argument

Monadic functions such as  $\text{signum}$   $\text{ceil}$   $\text{floor}$   $\text{int}$   $\text{le}$   $\text{ge}$   $\text{lt}$   $\text{gt}$   $\text{and}$   $\text{or}$  operate on arrays and produce results with the same shape as the argument

Relational functions follow the same rules The result is 1 for true 0 for false

Theory and Application of Mathematical Programming Gautam Mitra, 1976 What is mathematical programming Equivalent linear programming problems and the simplex method Some ancillary features of the simplex method The revised simplex method Computational refinements and extensions within the context of the revised simplex method Duality properties of linear programs and post optimal analysis Integer and mixed integer linear programs Formulating mathematical programming models linear programming integer programming and nonlinear programming by extending linear programming techniques The general mathematical programming problem lagrange and kuhn tucker multipliers Convex quadratic programming its application and its solution by the use of kuhn tucker theory Linear programming quadratic programming theory of games and the fundamental problem algebra and combinatorics of pivot theory for such problems

**Programming and Mathematical Method** Manfred Broy, 2012-12-06 The Summer School in Marktoberdorf 1990 had as its overall theme the development of programs as an activity that can be carried out based on and supported by

a mathematical method In particular mathematical methods for the development of programs as parts of distributed systems were included Mathematical programming methods are a very important topic for which a lot of research in recent years has been carried out In the Marktoberdorf Summer School outstanding scientists lectured on mathematical programming methods The lectures centred around logical and functional calculi for the specification refinement verification of programs and program systems Some extremely remarkable examples were given Looking at these examples it becomes clear that proper research and teaching in the area of program methodology should always show its value by being applied at least to small examples or case studies It is one of the problems of computing science that examples and case studies have to be short and small to be presentable in lectures and papers of moderate size However even small examples can tell a lot about the tractability and adequacy of methods and being able to treat small examples does at least prove that the method can be applied in modest ways Furthermore it demonstrates to some extent the notational and calculational overhead of applying formal methods

*Some Notes and Ideas on Mathematical Programming Methods for Structural Optimization* Fred Moses, 1967

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