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Janusz Kacprzyk, Polish Academy of Sciences, Warsaw, Poland
e-mail: kacprzyk@ibspan.waw.pl

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Christina N. Burt · Louis Caccetta

Equipment Selection for Mining: With Case Studies

Springer

Christina N. Burt
Department of Mathematics
and Statistics
The University of Melbourne
Parkville, VIC
Australia

Louis Caccetta
Department of Mathematics
and Statistics
Curtin University
Bentley, WA
Australia

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Preface

The mining industry contributes significantly to the health of the worlds' economy. Indeed, the total annual revenue generated by the industry worldwide has exceeded \$500 billion US for the past 6 years. Over this time, the net profit margins have decreased from 25% in 2010 to 4% in 2016. The significant global economic uncertainty together with declining trends in average ore grades, declining market prices, increasing mining costs, and the complex regulatory, environmental and safety restrictions in which the industry must operate is contributing to this decline in profitability. Consequently, the economic viability of the modern-day mine is very highly dependent on careful planning and management. This, of course, presents enormous opportunities for the application of cutting-edge optimisation technology. Optimisation techniques have been successfully applied to resolve a number of important problems that arise in the planning and management of large and complex mines. Applications that are well documented include ore-body modelling and ore reserve estimation, optimal pit design, optimal production schedules, optimal blends, effective equipment selection, utilisation and maintenance, efficient mine site rehabilitation and a range of transport and logistics issues. This book focusses on the important truck–loader selection problem.

The truck–loader selection problem is that of selecting a fleet of trucks and loaders for use in extracting ore and waste throughout the life of the mining operation. The cost of the truck and loader fleet has been estimated as being up to 55% of the total cost of the operation making the purchasing and maintaining the correct combination of trucks and loaders critical to the economic viability of a mining operation. For a new mining operation, setting up the initial fleet requires a large purchase of trucks and loaders for the removal of ore and waste as specified in the mine plan. The effective management of this fleet requires continual changes to this fleet as the mine plan progresses. Note that fleet equipment has a life cycle of around three to five years, whilst the life of the mine may well exceed 50 years. Prior to our work, the methods used for determining the trucks and loaders to use in a mining operation largely relied on the experience of specialist consultants with computational methods usually restricted to the use of spreadsheets and/or simulation. Due to the complexity of the problem, only a small subset of the possible combinations of trucks and loaders may be considered for selection using these methods. The application of accurate mathematical modelling and cutting-edge optimisation techniques, where the optimisation is done over all possible truck and loader combinations, clearly leads to better cost savings whilst ensuring effective choices of equipment.

Our objective in this book is to present a comprehensive account of the mathematical based computational models that have been developed for determining the optimal truck–loader selection strategy for use in a large and complex mining operation. Our models not only give the optimal selection of trucks and loaders but also give the optimal allocation of the trucks and loaders. This book is organised into the following two parts: *Background and Methodology*; *Optimisation Models and Case Studies*.

The first part, *Background and Methodology*, consists of four chapters. Chapter 1 defines the equipment selection problem in surface mining and presents an introduction and relevant background to the area including some basic concepts. Chapter 2 provides a brief review of the methodology that is used in the mining industry for determining truck cycle times, equipment costs and various productivity measures for trucks and loaders. An important productivity measure is that of match factor which was first defined half a century ago. Of the available optimisation models, linear and integer programming models are the most capable for capturing the decision variables and comprehensively describing the complex relationships that exist between the various factors that arise in the equipment selection and more generally in engineering asset management equipment systems. In addition, these models are capable of handling the big and complex data sets that arise in real mines. The chapter also gives a brief overview of linear and integer programming. Chapter 3 gives a detailed literature review of the equipment selection problem in surface mining as well as the closely related equipment selection problem for the construction industry. A number of related problems are also discussed such as network design, hub location, scheduling and allocation. Models and solution procedures are reviewed. As mentioned above, match factor is an important productivity measure. Prior to our work, this measure was restricted to homogeneous fleets, and thus, applications with heterogeneous fleets were not addressed. In Chap. 4, we present our work which extends the match factor concept to more general fleets and provides an effective equipment performance measure.

The second part of our book, *Optimisation Models and Case Studies*, consists of six chapters. These chapters detail the bulk of our research on equipment selection in mining that we have carried out over a number of years. We begin by detailing the case studies that we will use in the models developed in the subsequent chapters. The case studies were provided by our industry partner. Our focus is on two case studies. The first is a simple mine with a few mining locations and 9 periods (each having one-year duration). The second case study is of a more complex mining operation having many locations with 13 periods (each having one year duration). This case study had pre-existing equipment, and this is the first time such equipment has been considered. All data are presented. In developing our mixed-integer linear programming (MILP) models, we start, in Chap. 6, by considering the simple case study of a mine having a single location and a single truck route. The objective is to determine a purchase and salvage policy for trucks and loaders that minimises the cost materials handling over a multiple period schedule. The resulting model is tested on industry data and proven to be very effective. In Chap. 7, we develop an effective MILP model for a more complex mining operation that has multiple locations and multiple periods. Pre-existing equipment and heterogeneous fleets are catered for. In addition to providing the equipment selection policy over the life of the mine, our model also gives the optimal equipment allocation. Our models are tested on two case studies. As these are large applications, we developed a pre-processing procedure and a separation algorithm to improve the tractability. These tests establish the effectiveness of our model. In our work, we accounted for equipment cost through utilised hours. Unfortunately, in real operations, equipment is not always utilised to full capacity and so the cost depends on the age of the equipment, whilst the utilisation of equipment is usually based on equipment cost. This codependency of age and utilisation is an issue and can lead to inferior solutions. In Chap. 8, we consider this issue and present a MILP model that accounts for equipment utilisation for a single location multi-period mine. Our model is successfully tested on our real case studies. We extend these notions in Chap. 9 by presenting a method for determining the cost of the equipment that accounts for utilisation. This forms the first attempt at addressing this important and difficult problem. We conclude our book with a discussion of future research directions in Chap. 10.

The bulk of the material in this book was developed over a number of years, whilst we were engaged in a Research and Development project with RioTinto. We gratefully acknowledge their support and in particular the enormous help of our collaborators Palitha Welgama and Leon Fouché. The contents of many of the chapters are from joint research publications.

Parkville, Australia Christina N. Burt
Bentley, Australia Louis Caccetta
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