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OPTIMISING THE OPERATIONAL ENERGY EFFICIENCY OF AN OPEN-PIT COAL MINE SYSTEM

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Mining companies are increasingly being challenged to improve energy efficiency, as a method of reducing both the cost and environmental impact of their operations. This thesis addresses this issue by investigating the operational energy efficiency of open-pit coal mining. The presented approach uses integrated mathematical programming and metaheuristics to model and optimise operational decisions of mine systems in order to support operators in making energy-efficient decisions.

Open-pit coal mining methods are reviewed to select the most common subsystems that represent the primary operation and energy consumption, excavation and haulage, stockpile, processing plant and belt conveyor. Due to the apparent lack of operations research literature modelling mine energy efficiency, production system literature is drawn upon by considering an open-pit coal mine as a continuous flow production system. A literature review of production system energy efficiency and how it relates to mine operations is conducted to identify the most important factors to consider in operational models of mines—asset usage and planning. Integrated modelling is introduced as an effective way of considering all the relevant subsystems and factors together.

Using these findings, a framework for creating an integrated model of an operating open-pit coal mine is proposed along with a process for applying the framework and model to new mines with considerations about practical limitations such as existing bottlenecks and data availability. These contributions enable the modelling of subsystems independently and employ the continuous flow production system analogy to connect them via material flow connections on their boundaries to build a single

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integrated model that can be 'hooked up' in various manners to represent a wide variety of mines. The objective function of the integrated model is represented as the sum of the individual energy consumption of each subsystem, so that whole-of-mine energy consumption is optimised.

This framework is then used to formulate an integrated mixed integer linear programming (MILP) model of the four subsystems. The most sophisticatedly modelled subsystem, the excavation and haulage subsystem, is modelled using an equipment-allocation formulation based on the majority of recent work in the area [3, 6–8]. Less complex, material balance based formulations, based on [2, 4, 9], were used for the processing plant, stockpile and conveyor belt to suit the available data for the case study and remain general enough to be applicable to other mines. The results of this initial modelling applied to a case study are presented in [5].

Analysis of this first model identified accuracy issues with the equipment allocation based formulation of the excavation and haulage subsystem. To overcome these, an innovative scheduling formulation of the subsystem is developed, improving upon the similar work of [1]. However, the complexity of the improved model means exact methods are unable to provide solutions for practical-sized problems. An innovative hybrid solution technique that uses exact methods solving the first MILP model to aid both tabu search and simulated annealing metaheuristics running in parallel is developed so that good-quality solutions can be found in reasonable time for practical use.

A case study is conducted of an open-pit coal mine in South East Queensland, Australia. Comprehensive sensitivity analysis is presented to verify and validate that the model and solution technique provide valuable opportunities for supporting energy-efficiency improvements both at the case-study mine and for open-pit coal mines in general. Thorough discussion of how the model can support short-, medium- and long-term decision making is presented, including a conceptual design of a decision support software tool.

The full text of the thesis can be downloaded at http://eprints.qut.edu.au/95087.

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