NETWORK PLANNING PROBLEMS IN MINING EXPORT SUPPLY CHAINS

NATASHIA BOLAND*

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EXTENDED ABSTRACT. Australia's current boom in mineral exports is achieved only as a result of the work of a complex logistics system. The logistics challenge is particularly acute for minerals such as coal and iron ore, that need to be blended to make a final product having a balance of characteristics. Product specifications are usually achieved by blending ore extracted from different parts of a mine, or from different mines in the same area, serviced by the same logistics system. This system takes mineral extracted from mines, and transports it from the mine site to a terminal, usually by train, but sometimes by truck. In some regions, such as the Pilbara, the rail system is dedicated to the mining operation, but in others, such as the Hunter Valley, it is shared with other freight and even passenger rail. Blending is often carried out at the terminal, either by combining train loads of material from different sources in a common stockpile, which is then loaded onto the ship as a final product, or by loading material from several stockpiles onto the ship to create the final product. Material handling at the terminal usually requires the use of a sequence of critical pieces of machinery: dump stations for unloading trains, stacking machinery for loading material onto a stockpile, reclaiming machinery for removing material from the stockpile, and ship loaders for transferring the material onto the ship, all connected by conveyors.

Planning problems arise in this system in a number of ways. Clearly to operate the system involves the interaction of many sequencing and scheduling decisions. Sometimes these decisions are made "on the fly", but often sophisticated advance planning and disruption management processes underpin the operation. Maintenance and equipment refurbishing decisions which require scheduling of specialized or scarce equipment/personnel, usually need to be planned sometime in advance. However a crucial question for today's miners is capacity expansion. The net present value of Australia's mineral wealth is driving miners to seek to extract and export mineral resources at ever greater rates. This is driving capacity expansion projects, improving existing infrastructure and building new infrastructure, to service increasingly hungry markets. Making decisions about what infrastructure to expand, when, is thus an important planning activity.

So where do networks come in? They can arise in a number of ways. In many respects, one could view the supply chain as a network in which minerals flow over time. Each piece of tail track, each piece of handling equipment, each part of the stockyard, that the mineral moves over, could be treated as an arc in a network, with copies for each point in time. Since minerals from different sources, at different points in time, may have different characteristics that are important for blending, one could expect the flow to be multicommodity, potentially with time windows associated

*School of Mathematical and Physical Sciences, The University of Newcastle, Callaghan, NSW 2308, Australia, supported by the ARC and the Hunter Valley Coal Chain Coordinator P/L under ARC Linkage Grant LP0990739.

with the supply and demand of each commodity. Stockpiling could be modelled as storage at nodes. We thus can view the system as a dynamic multicommodity flow problem with storage at nodes. Indeed, a model such as this is used in our current research to calculate capacity of a supply chain under a given maintenance schedule, where maintenance closes off, or reduces, the capacity of (one or more) arcs for a particular period. We also overlay this with an optimization procedure to re-schedule maintenance tasks so as to maximize total capacity over time.

For operational considerations, this model is likely to be too simplistic, and ignores critical equipment such as trains. Do the "track arcs" actually exist at any point in time? Only if there is a train scheduled on it at that time! This leads to scheduling problems that could be viewed as network design problems, where one simultaneously needs to decide which arcs are available in the network, and what the flow through the network is, so as to optimize some objective. Time-space networks can be particularly helpful when considering rail scheduling operations.

Network design models can similarly be used to consider capacity expansion decisions. By overlaying arc expansion variables over the dynamic multicommodity flow model, one can seek budget-constrained designs that maximize throughput of the system, for example.

These ideas highlight some of the planning concepts in mining export supply chains, and the possible roles of networks. Of course, ensuring resulting models are fit for purpose, and can be solved, throws up significant research challenges.