MIP-based heuristics for a mining multi-site planning problem

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1 Introduction

This research addresses an integrated production, inventory and transport planning problem taking place at a multi-site, multi-product logistics network. The addressed problem is a realistic problem taking place at mining supply chain of a world's leading company in the phosphate market. Traditional planning approaches often plan supply chain issues separately or sequentially. Thus, local or sequential planning usually leads to sub-optimal solutions [2, 1]. One of the main objectives of this work is to investigate the benefits of integrating decisions in a complex multi-level supply chain structure on one side. One the other side, our objective is to mimic and compare some traditional planning approaches, based on sequential decomposition of the logistics system, in order to reveal some interesting managerial insights and to provide a clearer picture of the functioning of the global industrial system.

This work proposes an integrated production, inventory and transport planning model that address some of the complexity and particularity of the mining industry. We model this problem as a mixed-integer linear program (MIP) that finely represents real world constraints and characteristics, and propose several heuristic approaches to solve large scale instances with tactical time horizon. A computational study based on real-world instances test and compares the performance of the proposed heuristic methods.

2 Integrated optimisation

Our industrial problem is modelled as a multi-level lot sizing problem. The proposed modelling integrates in one model the following aspects : (i) multi-level, multi-product capacitated production problem ; (ii) multi-level, multi-product capacitated inventory problem ; (iii) single railway train transport problem with time windows constraints. In addition to the classical issues of multi-level lot-sizing problems, this modelling address further aspects related to the structural specifications of mining activity and to continuous production processes. The objective is to hierarchically satisfy deterministic demand, minimize the total number of switch-offs of production units, and minimize total operational costs (variable production cost, start up cost, inventory, and transport). On a large realistic set of instances, we demonstrate the benefit of integrating decisions in terms of improving demand satisfaction rates, increasing resource performance and efficiency, and minimizing global operational costs.

Although the proposed integrated modelling is able to solve to optimality small and medium instances, it requires important computational times to solve some large scale instances. Thus, given the industrial context one the most important issues to consider remains finding a good quality solution in a reasonable computation time. Otherwise, the industrial manager is ready to sacrifice optimally in return for good feasible solutions in acceptable times. In this context, we propose several efficient solution methods that provide good quality solutions in a reasonable computation times.

3 Sequential optimisation

3.1 Relax and fix heuristic

We propose a Relax and fix heuristic to solve this integrated problem. This approach consists in a hybridization of an optimisation method and a strategy of horizon decomposition. Its main idea is based on decomposing the global, complex, problem into several reduced sub-problems using a horizon decomposition strategy, then iteratively solve the obtained mixed integer problems. The horizon decomposition idea is straightforward. The integer variables set is partitioned into three disjunctive sets. At each iteration, only the variables of one of these sets are maintained as integer. Whereas the variables of the other sets are either fixed or relaxed. This horizon decomposition strategy is very advantageous as it considerably reduces the problem binary variables and constraints, which reduces its complexity and consequently reduces the computational time required to solve it.

We evaluate the quality and performance of the proposed method and prove that allows to obtain good quality solutions with a gap between 0.00% and 0.10%, within a reasonable CPU time.

3.2 Top down & Bottom up heuristics

Also, this research proposes two sequential approaches that reproduces two classical planning approaches : pull-flow and push flow approaches. These heuristics are respectively named : Top down and Bottom up heuristics. These approaches decomposes the integrated problem two sequential problems : distribution and multi level lot sizing. Then, top down heuristic optimizes hierarchically distribution then lot sizing problem. While bottom up heuristic optimizes lot sizing then distribution problem. These procedures considerably reduce the integrated problem complexity which allows to considerably reduce computation time. Thus, one of their disadvantages is their incapacity to solve some instances. Finally, we conducted several computational experiments that revealed some important managerial insights related to the system behavior to meet the demand.

4 Conclusion

In this work we studied a real multi-site, multi-product production storage planning problem integrated with a transportation problem where final product transportation is carried out on a single railway with time window restrictions. The problem takes place at real mining industrial logistics system. The problem is modelled as a multi-level lot sizing problem integrated to train transport with time windows. To solve the problem, this research proposes an integrated modelling and several heuristic procedures. Computational experiments demonstrates that the proposed methods allows to obtain good quality solutions within reasonable computation time.

Références

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