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# Digitalization of mine operations: Scenarios to benefit in real-time truck dispatching

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ABSTRACT

One of the key factors in a profitable open-pit mine is the efficiency of the waste disposal system. Using GPS-technology, the truck-dispatching decisions can be made in real-time but the chosen strategy has a crucial role. Therefore, finding the optimal dispatching strategy for truck-shovel operations is extremely important. Dispatching strategies have been reported in the literature, but the comparison of these strategies is still missing. This paper illustrates the differences between the strategies by conducting a stochastic simulation study based on the data gathered from an actual mine. The findings underline the importance of the global vision in dispatching decisions.



## 1. Introduction

After another difficult year in 2014, the global thermal coal markets were faced with a backdrop of collapsing energy prices in 2015. Today, most mining companies attempt even harder to find intelligent services to improve the key areas of their operations [1–6]. General operational tasks of topsoil removal in open-pit mines include drilling and blasting, ore and waste loading, hauling and dumping, and various auxiliary services. The most important system, in terms of efficient material handling, is the truck-shovel operation. From the operational point of view, the crucial task is to decide how to allocate the truck-shovel resource in an efficient manner, since the large amounts of ore and waste must be delivered from the pit to their destinations through relatively long and steep haulage routes. Many prior research studies indicate that the transportation costs are relatively high, that is, 50–60% of the total operational cost of open-pit mines [7–12].

In the real world the system is complex: trucks must wait for the shovels to become available when the system is over-trucked and vice versa when the system is under-trucked. In most cases, operations require a high number of trucks to be assigned to shovels in order to maximize the production, and central dispatching approaches are typically used to minimize the queuing time. Previous research studies have addressed some problems of truck-shovel fleets in such a transportation system within different dispatching rules [2,8–11,13–23]. More recently, dynamic solutions to real-time fleets have been underlined. The use of the real-time fleet dispatching methods provides an advantage in the overall productivity of the mining system by ensuring the highest utilization of available trucks and shovels in the system at any given time. Many simulations with different algorithms for open-pit mining transportation systems are proposed to obtain the maximum efficiency of dispatching and routing [24–27]. Moreover, several areas that affect production are identified and these include: haul road conditions, the control systems, dispatching program, dispatching data management, as well as truck-shovel match factor techniques [28–29]. However, only few research papers on dispatching systems consider uncertainty [30–33], and there is no comparison to actual mine operations.

For more efficient real-time fleet management, it is important to take uncertainties into account. These uncertainties originate from, for instance, equipment faults or changing weather conditions, which cause variations in cycle times of truck-shovel operations. The objective of this work is to integrate a traffic simulation with uncertainties together with classical real-time truck dispatching strategies, that are widely used for solving fleet management problems in an open-pit mine. Based on extensive empirical data, collected from an open-pit mine, the empirical distributions of different activity times of truck-shovel cycle are used for finding a suitable parametric distribution for the simulation model as well as the right parameters. It is shown that the choice of the

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dispatching strategy has a significant impact on the performance of the mine. The simulation studies reveal that the differences in production figures under different dispatching strategies are remarkable.

The paper is organized as follows: Section 2 contains the formulation of the problem and discusses the real-time truck dispatching strategies. The research methodology and conceptual model are presented in Section 3 and the results are shown in Section 4. Finally, the theoretical and practical implications of the research are given in the discussion and conclusion part in Section 5, where the limitations of the study are also presented, and the future research suggested.

## 2. Problem formulation

The aim of this work is to provide a simulation framework incorporating the dynamic assignment problem and its relationship to truck-shovel fleet management. Real-time truck dispatching strategies are simulated to address which approach is the most effective for assigning truck-shovel pairs in order to maximize the productivity when uncertainties are taken into account.

### 2.1. Truck dispatching strategies

The purpose of optimizing a dispatching system is to maximize the productivity. The dispatching methods considered in this paper are partly based on minimizing the queuing time of trucks when waiting to be served by shovels. Consequently, if the lost time in queue is reduced, the utilization of trucks will increase. The above policy uses the concept of real-time truck dispatching strategies described below, for further details see References [11,31,33].

(1) The 1-truck-for-*n*-shovels approach (Greedy heuristic), illustrated by Fig. 1, is the strategy which is most commonly used in mining operations. A truck operator asks for a new assignment and *n* possible shovels where the truck could be sent are considered. The choice of the shovel which the truck is assigned for depends on the skills or logical operating procedure of a dispatcher, who typically follows one of the heuristic methods presented in Table 1. The truck is sent to the shovel which offers the highest potential. Typically this strategy is implemented based on the single-stage approach.

(2) The *m*-trucks-for-1-shovel method is based on the multi-stage approach: truck dispatching decisions will be made by taking into account the *m* next trucks to dispatch, considering one shovel at a time. More specifically, the shovels are first sorted according to a priority scheme based on how much they are behind their production schedule. Subsequently, the dispatcher assigns the best truck (under the chosen measure) to the shovel that is first on the priority list, see Fig. 1.

(3) The *m*-trucks-for-*n*-shovels method is based on the multi-stage approach: the dispatcher simultaneously considers *m* forthcoming trucks and *n* shovels, and the requesting truck is assigned for the most suitable shovel, based on forecasted availability of trucks and shovels. Only the truck that has submitted the request is assigned. This is illustrated in the rightmost panel of Fig. 1. In this strategy *m* should be greater than or equal to *n*.

### 2.2. Process properties

The study is carried out at PT. Kitadin Tandung Mayang's East Kalimantan production site based on a concession of mine rated at up to three million tonnes of coal per annum with a total movement of overburden of fifty million bank cubic meter (bcm) using a fleet of 115 machines. The production of the mine varies significantly from month to month and the production rate between shifts fluctuates independent of the working day even if the quantity of trucks and shovels remain the same. It is of great interest to determine which truck dispatching strategy gives the maximal

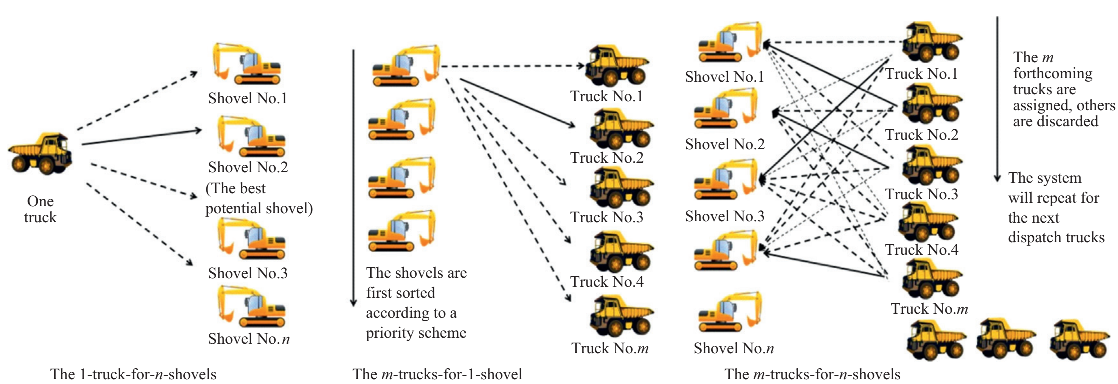


**Fig. 1.** Real-time truck dispatching strategies.

**Table 1**
Heuristic truck dispatching methods.

| Method | Key objectives | Assignment |
|---|---|---|
| Minimizing shovel waiting time (MSWT) | To maximize the utilization of both trucks and shovels | An empty truck is assigned to the shovel with the longest idle time or to the shovel that is expected to be idle first |
| Minimizing truck cycle time (MTCT) | To maximize the total tonnage productivity | An empty truck is assigned to the shovel that allows the shortest truck cycle time |
| Minimizing truck waiting time (MTWT) | To maximize the utilization of a shovel by minimizing truck waiting time | An empty truck is assigned to the shovel in which the loading operation starts first |
| Minimizing shovel saturation and coverage (MSC) | To minimize a shovel operating waiting time | An empty truck is assigned to shovel at equal time intervals to keep shovels non-idle |