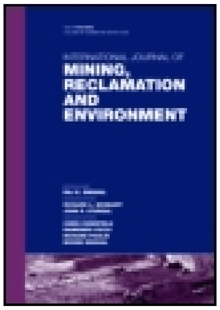

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Truck dispatching in an open pit mine

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Truck dispatching in an open pit mine

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ABSTRACT: In an open pit mine operated by trucks and shovels, the trucks should be dispatched from the crusher to the shovels in such a way that the productivity of trucks and shovels in maximized while maintaining a rational production plan as well as obtaining target grades and other objectives with small variations at the entrance to the concentrator.

To solve the dispatching problem we present a three step approach. First we select shovel locations with a man-machine interactive system. This step combines operator expertise and linear programming optimisation. In the second step, we establish an optimal strategy (production plan) for a certain period of time by solving a network problem with non-linear costs associated with estimates of trucks' and shovels' waiting times and the quality objectives. The solution gives, for each shovel, the best access paths, the trucks' and shovels' estimated waiting times and an estimate of the number of trucks loaded per unit of time. In the last step we dispatch each truck in real-time by solving an assigment problem, taking into account the next 15 trucks, which are becoming available for dispatching in order to get a series of dispatches which will realize the optimal strategy.

1 INTRODUCTION

The final stage of the production in an open pit mine, after the drilling and blasting, consists of two closely related activities namely: the loading of the materiel - ore and waste - by the shovels onto the trucks and the transportation by the trucks of this materiel to the proper dumping point - ore crushers or waste dumps. The planning and control of this final stage of production involve two distinct, however closely related, managerial activities namely: the determination of how much and from where each shovel should produce, and the decision of to which shovel the next free (empty) truck should be sent to pick up materiel.

The determination of how much and from where each shovel should produce is the subject of a planning activity, which is the last in a chain of planning decisions. It begins with the final pit contour planning and continues with the long, medium and short term planning closer and closer to the production stage. The last planning decision is the very short term planning, also called the operational plan and is the plan to be executed immediately during the next period of time.

The decision of which shovel the next free (empty) truck should be sent to, is the truck dispatching. The decision of the truck dispatching should execute the operational plan as well as possible. This is not an easy task: the trucks become available for new dispatches at variable intervals depending on their immediate past history. The optimal dispatch decisions depend on the next foreseeable future.

The two activities - operational planning and truck dispatching - must be solved in an integrated manner as there are many links between them. The operational planning is in this respect a short term strategic plan and sets the scene for the optimal operation, which subsequently is to be reproduced by the truck dispatching. Together they form what is called optimizing software for truck dispatching. It can be of various depths and sophistication. [White] [Soumis] Dispatch procedures without integration of these activities do not approach optimum and may under some circumstances be counterproductive.

2 THE DEEP THREE-STEP PLANNING AND DISPATCHING PROCEDURE

The system described in this paper produces the truck dispatches at the end of a three-step procedure. An important objective for the development of the planning procedure is that it must be user-friendly, flexible and transparent. It

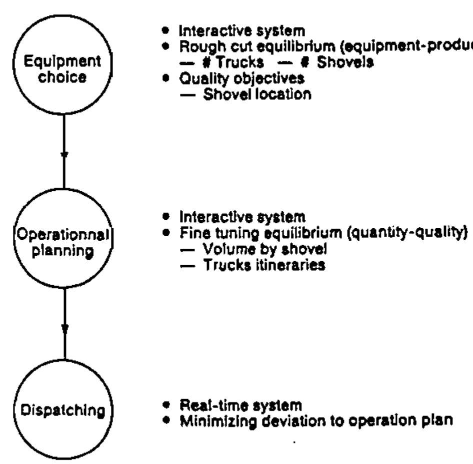

Figure 1. Three step procedure

was found that an efficient way of finding the operational plan was to subdivide the planning in two steps: one which produces an initial good but rough cut solution. This solution then orients the search for the final operational plan which is the second step.

2.1 The equipment plan

In the first step of the planning the available shovels' locations and their production rates are determined for the available number of truck by mixed integer programming. The objective is maximal production under the obediance of quality constraints while considering the shovels' restricted possibility of movements to get at the

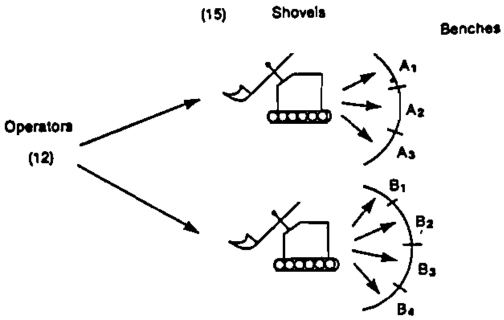

Figure 2. Shovel location

various grades - a little to either side on the bench where the shovel is located presently (and possibly but with difficulty one bench up or one bench down). In order to render the calculation time efficient - mixed integer programming can easily become very time consumming - an initial count of the number of feasible combinations of shovel locations and production rates is carried out. The operator will then know the time it would

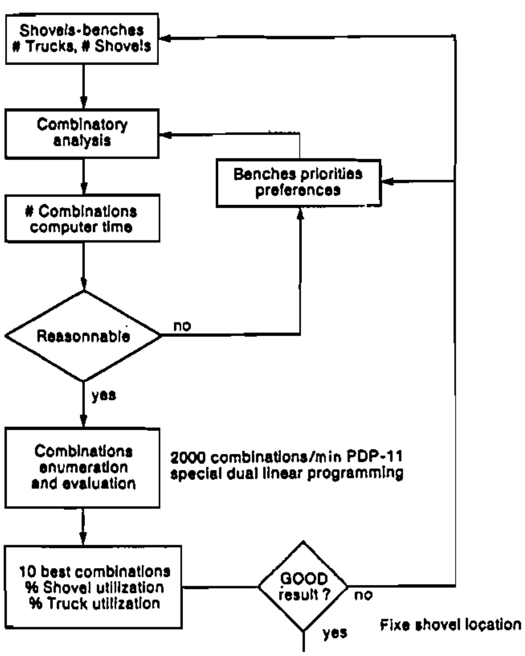

Figure 3. Interactive procedure for equipment choice

take to find a solution. If this time is too long he will fix some variables, possibly shovel locations, and call for a new count of combinations before letting the program proceed with the optimization. This solution determines the best locations of the least flexible equipment, the shovels, and forms the basis for the search in the second step for the final solution of the operationel plan, which is concerned with the trucks, the more flexible equipment.

2.2 The operational plan

The scope has now been narrowed and the further planning can take into account the parameters which permit the finetuning. As the optimal truck dispatching only can be obtained from an optimal

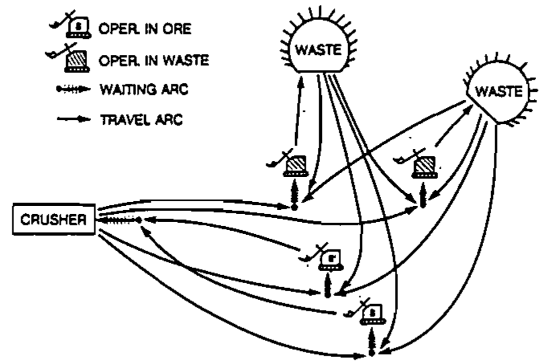

Figure 4. Network problem for operational plan

but above all from a feasible plan it is of far most importance to build as much realism into this step of the planning as possible. The optimization procedure is non-linear programming. It uses the given number of trucks and the shovel locations which are known to generate a solution already. It selects the optimal truck itineraries between shovels and dumping points and finds the shovel productions, expressed as truck rates for each shovel.

The non-linear objective function combines 3 factors: the differences between shovel production objectives and computed shovel productions, and between available truck hours and computed truck hours, which include trucks' waiting times. The third factor is some penalty function for deviation of the computed production blend from the desired grade and some other quality properties. The trucks' waiting times are functions of the level of

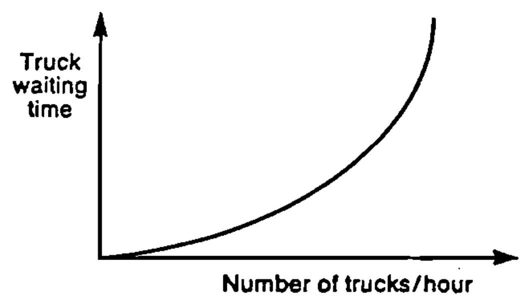

Figure 5. Truck waiting time according to shovel activity

activity of the shovels. These functions have been obtained from realistic operations research models of waiting time by means of an adjustment to the queuing theory. The penalty for grade deviations have been obtained from experimental work, which

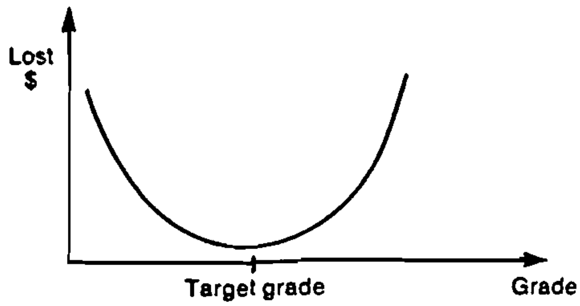

Figure 6. Loss of recovery according to deviation from target grade

shows the loss of recovery when the ore grade deviates from the setpoint. As an important objective of the operational plan is to be as realistic as possible, we therefore emphazise on the importance of the inclusion of these two operations research models, which both are based on long experiences of open pit operations. If the waiting times are not forecasted in a realistic way the operational plan would overestimate the capacity, not only of the whole operation but also of each shovel individually, and the solution would have severe imbalances inbuilt already from the start. The penalty function for deviating grade illustrates an interesting capability of non-linear programming as compared with linear programming, in which grade limits are constraints. In a non-linear programming model, where the limits to grade are in the objective function increasing costs, we obtain a description, which is much closer to reality. Extreme solutions are avoided and the desired grade is therefore obtained with good uniformity.

2.3 The dispatching procedure

The operational plan's results - shovel rates and truck paths - are now to be executed by the dispatching, which is found by solving a classical assignment problem. A truck which becomes available at the crucher or at the waste dump is dispatched by the path found by the operational planning to an ore or a waste shovel. It is dispatched to this new destination following an

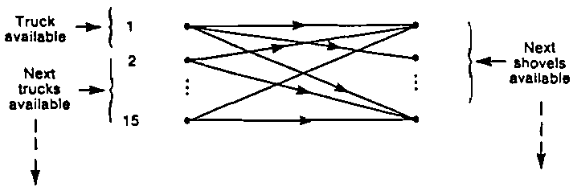

Figure 7. Assignment problem for dispatching

optimization of its destination together with the destinations of the next 10-15 trucks to be dispatched. The following example will show that a near sighted decision only considering one truck at a time can be far from optimal. Let us suppose that we send the first truck to its best shovel, but there is some good second choice. If this shovel would be the best choice also for the next truck and all the other shovels are far from this second truck, then it is better to reserve this first choice for the second truck and send the first truck to its second choice. This system goes a step further in realism than former dispatching systems which dispatch according to the expected departure time of the previous truck and the expected arrival of the dispatched truck in a deterministic way. This dispatching procedure finds the time distribution of arrival of the dispatched truck to the shovel as well as the time distribution of departure of the previous truck from the shovel. These time distributions are Erlang functions of which the parameters - average and standard deviation - are estimated continuously from observed data. This permits the dispatching system to estimate the arriving trucks' waiting time as well the shovels' waiting time and make the

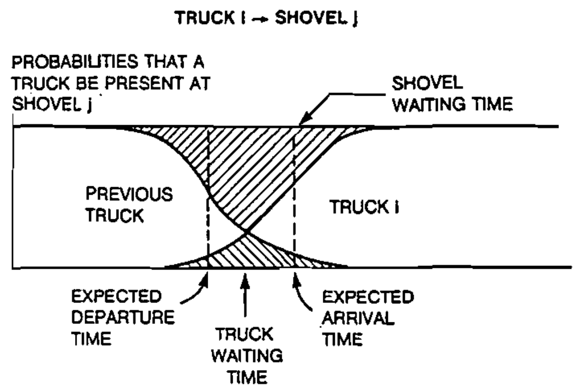

Figure 8. Truck and shovel waiting time

dispatch decision according to their expected waiting times. There is now more information available about the shovels' and trucks' situations and the assignment procedure takes an appropriate amount of this information into consideration. Updated knowledge about the real waiting times will enable the dispatching to identify and realize opportunities for time savings by deviating a little from the operational plan and not sending a truck to a temporarily congested shovel. This opportunity recognization is an important feature in that there are sufficient things not foreseen that can go wrong and cause inevitable time losses. This feature enables the system to maintain its strategic goal, namely to reproduce the operational plan.

In this manner the trucks' arrivals will always be synchronized with the shovels' loading rythm. This inbuilt feature also ensured good synchronization when trucks arrive from two dispatching points.

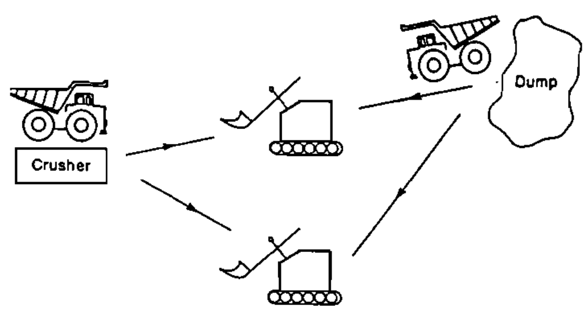

Figure 9. Synchronization of trucks dispatched from two points

The dispatching is not necessarily finalized at the trucks' departure from the crusher. The operation could include two or even more mines. The dispatch would be made initially to one mine,

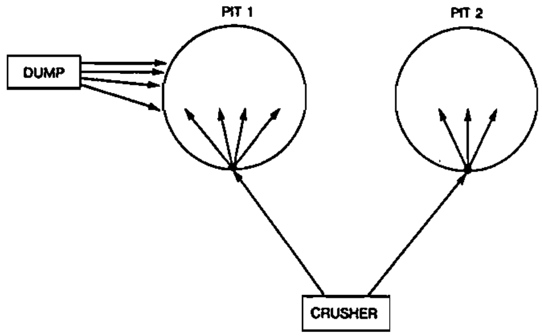

Figure 10. Two level dispatching

and then when the truck arrives at the mine the final dispatch of the truck to a certain shovel would be made.

3. RESULTS

It is not an easy task to compare the new truck dispatch system with the older and give exact figures for the gain in productivity. The two systems can not be run in parallel. We have chosen two methods for the comparaison: simulation and long term operation.

The two dispatch procedures have been used on identical conditions with a simulator reproducing a typical day in the mine.

A long term comparaison was possible over two six months periods, which were rather similar in conditions, covering the same months of two consecutive years.

Before presenting the results, let us briefly describe the old system, CHARLEMAGNE, because the gain in productivity of the new system depends on the generation of dispatching of the old system. CHARLEMAGNE is a "real time computer communication system" according to the classification of fig 11. It receives information in real time about the positions of the trucks and about the shovels' conditions. It computes the times of their movements and calculates the waiting time of the truck to be dispatched for each shovel to be considered. It then assigns the truck to the shovel with the lowest calculated waiting time. The truck dispatching is done one by one. In such a system the first level of waiting time reduction has been realized by the pooling of the shovels to become partially collaborating in the queuing theory's sense. This is instead of isolating the trucks in groups going to the same shovels in fixed circuits. It has also realized the gain of tne second level, compared with the human dispatcher, by the more precise information about the trucks' positions and the shovels' conditions and by the capability of computing the trucks' waiting times at shovels. Thus the new system can only add the productivity gains of the third level. That is by further reduction of waiting times due to the full integration of truck circuits and to selection between trucks for dispatch to a particular shovel, not only one by one. Further to the productivity gain important quality gains can be obtained by the new system.

The first comparaison by simulation, presented at fig. 12, is between the new system's results with the old system's, when there is no quality control, as is the case of CHARLEMAGNE. There is a gain of production of 3.2% (from 727 to 750 trucks loads per day and a reduction of the trucks' waiting time from 5.5% to 3.5% of the total operational time. This corresponds to a waiting time reduction of 35%. These gains of the third level are not at all

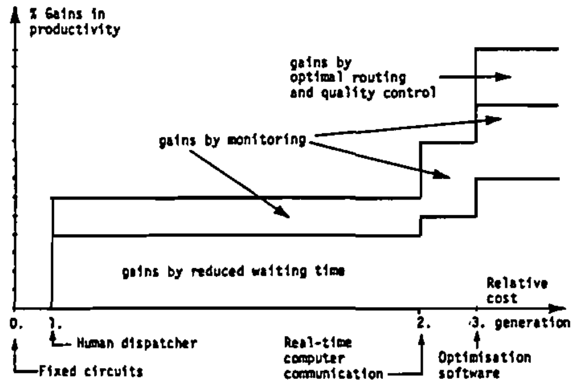

figure 11. Gain in productivity for three generations of truck dispatching according to their relative costs

	Production (truck loads per day)	Truck' waiting time	
		minutes	%
CHARLEMAGNE	727	703	5.5 %
NEW DISPATCH	750	514	3.5 %

Figure 12. Result from simulation

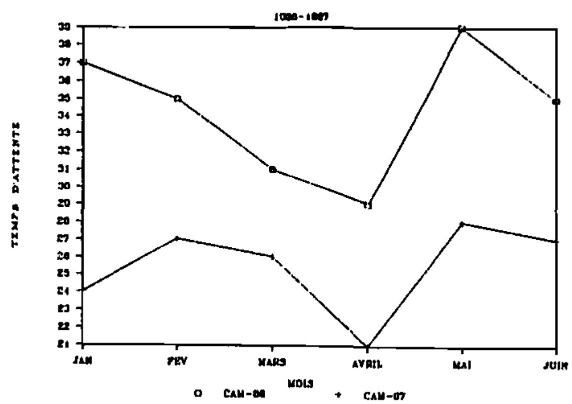

Figure 13. Average truck waiting hours per day, month by month, before (□) and after (+) implementation (from J. Baron 87).

as important as those, which are possible in a mine where the trucks run in closed circuits. One cannot gain 10-15% in productivity by waiting time reduction, when the waiting time only amounts to 5.5% of the total time.

A second simulation with the new dispatch system, now including the quality constraints, still shows a gain of 2% in productivity compared with CHARLEMAGNE without quality constraints. This productivity gain reduction from 3.2% to 2% is the price one has to pay for the better control of the blending.

The second comparaison is made by the production statistics of Quebec-Cartier Mining [J. Baron, 87] about the first 6 months of the operation of the new system. The new system's results are compared with those obtained by CHARLEMAGNE during the corresponding 6 months of the preceeding year. Fig. 13 shows the average number of trucks' waiting hours per day for the fleet of 21 trucks, month by month, for the two periods. It shows an average reduction of the waiting time by 7.3 hours from 24 hours, which is a gain of 26%, and a total productivity gain of 1.5%. This gain corresponds to a monetary gain of 400 000 $/year. It approaches the gain found by the simulation, which it should be possible to obtain, when the operators have acquired more experience of using the system under the various circumstances of operation.

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