A SIMULATION MODEL FOR STRIP MINING

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Abstract. The purpose of this paper is to present concepts and approaches for implementing a strip mining production planning system. Submodels within this system use FORTRAN IV, GPSS/360, MPS/360, and MARVEL languages.

The primary problems considered within this model are production forecasting, equipment evaluations, and operational strategies with respect to strip mining. A "typical" strip mine could be as shown in Figure 1. There will always be one or more excavating machines of several types to remove the overburden and ore from the deposit. This equipment includes bulldozers, draglines, shovels, and wheels with capacities up to 200-cubic yard bucket. The material to be handled by this equipment may have to be loosened by the use of explosives. The ore generally must be transported from the immediate mining area via trucks or slurry pumping to some type of preparation plant. The preparation plant products must have storage available prior to removal by rail or truck. There are usually several different points in such a system which require surge storages with limited capacities. Sequencing problems can be further complicated when two or more separate ore strata are in a deposit.

This particular model allows the use of live data describing the ore deposits to be used as transaction streams. A Fortran IV program produces these transaction streams from a mathematical model of the ore deposits and mining plans. Each mining plan will produce different transaction streams which are input to a GPSS/360 queueing model. These live data transaction streams are processed by the GPSS/360 queueing model using .1 hour time units. Typical simulation runs may consider time periods of several years. Typical transactions can represent .01 to .1 acres (more or less) of a strata. Surge storage capacities within the queueing model generally are the upper limit on transaction size. Various decision rules pertaining to minimum quality processed as a function of unused surge storage capacity and working shifts for various crews and equipment are easily incorporated in the GPSS/360 model. Output from the GPSS/360 model serves as input into a Fortran IV reporting program. These reports generally require considerable floating point computation to obtain summaries containing weighted averages, standard deviations, true utilizations, ratios, and other economic and engineering indicators.

Strip mining and basic ore processing can be a combination of discrete and continuous processes with finite queueing. Some examples of discrete processes are the bucket loading and swinging for draglines and shovels, the loading and dumping of trucks and trains, and working shift logic. Examples of continuous processes include the use of a wheel for overburden removal and replacement, the use of variable rate slurry pumping, and the sizing and further processing of various size ore in the preparation plant to produce the desired products. Finite queueing is accomplished by limited surge storage at various points in the system or by physical restrictions such as the need to place overburden on top of ore. In the worst case, the machines removing overburden and ore will be idled to let the remainder of the system work off excesses. Continuous serial and parallel processes are approximated by discrete processes in the GPSS/360 queueing model. Parallel processes are easily handled by the use of independent discrete streams. Serial processes can be handled as shown in Figure 2. A simple example consisting of two serial processes would be accomplished by producing a transaction copy sent down a separate stream, the processing time calculated for both streams, the simulator clock advanced by the maximum of the two times, the streams merged and the copy destroyed. This is easily accomplished with the SPLIT, ADVANCE, MATCH blocks in GPSS/360. Similar logic would be used for more than two serial processes, although different GPSS/360 blocks could be used. Various combinations of multiple serial and parallel processes are logically separated by surge storages within this model. When designing new systems or evaluating present equipment, queues or large surge storages may be placed between groups of processes to give additional pertinent information.

Production forecasts, sales forecasts, and current inventories can be input to a linear programming model and used for long-range planning as shown in Figure 3. With such an approach, engineering-type decisions can be reflected as iterations within the model with respect to altering shift logic, mining plans, equipment evaluations, ore quality minimums, etc. Typical management-type decisions requiring iterations would be capital investment in equipment, raising or lowering minimum inventory levels, assignment of positive or negative values to impurities, or in general, altering the guidelines for investment analysis or operating procedures. Many of these decisions can appear to be subjective in nature to the analyst, but in reality are control exercised by informed management. The linkage between the simulation and "optimization" models can be relatively manual or automated, depending on the application. The concept of an iterative loop involving simulations and optimizations is not new or unique; it is merely an attempt to obtain usable information from a dynamic system in which objectives are changing in a nearly unpredictable manner with respect to time.

The various languages and modeling tools within the system outlined in Figure 3 allow rapid problem implementation. Such an approach is simple, workable, and quite effective.

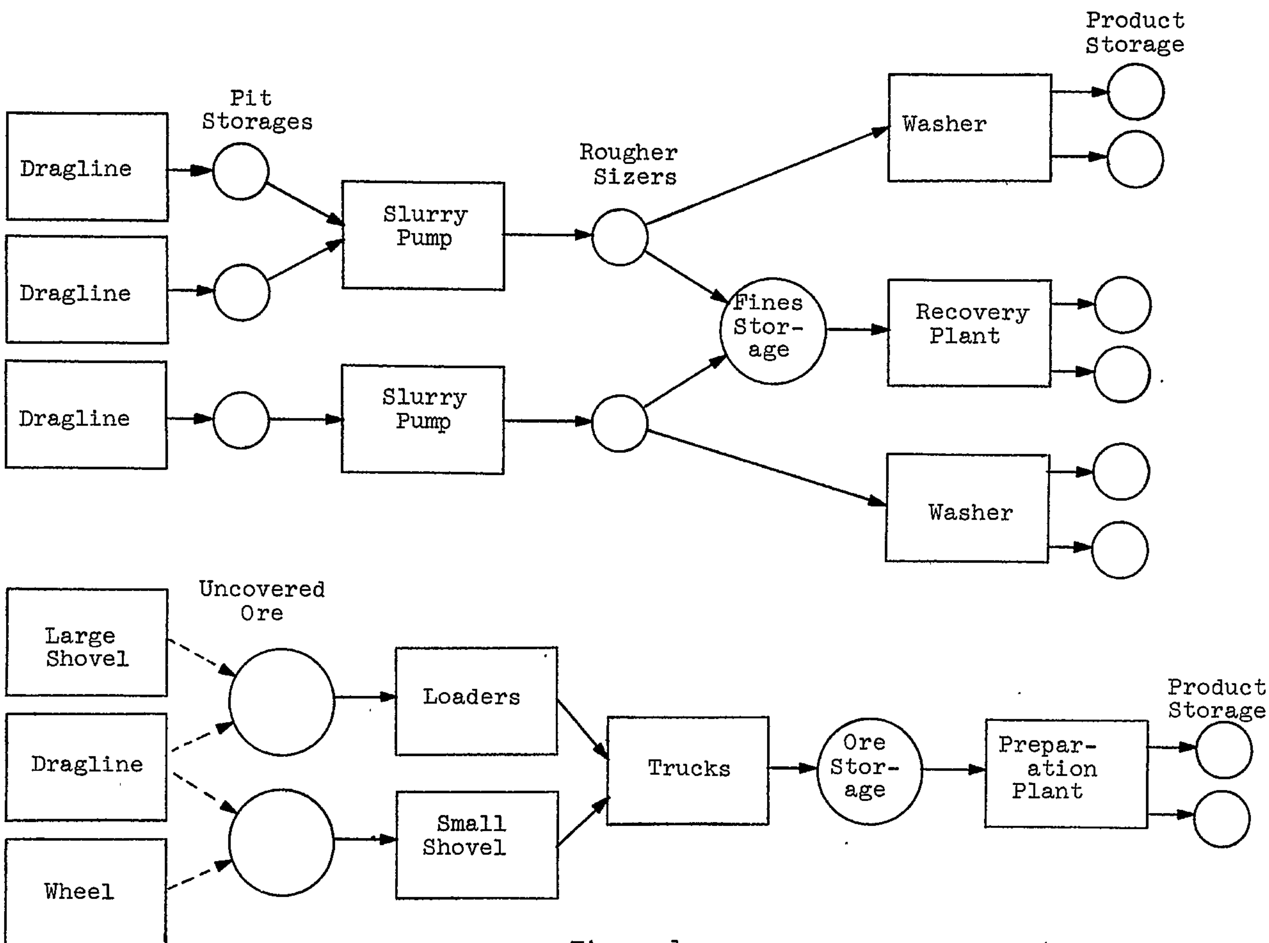

Figure 1.

TYPICAL FLOW

Fig. 2

APPROXIMATION METHOD

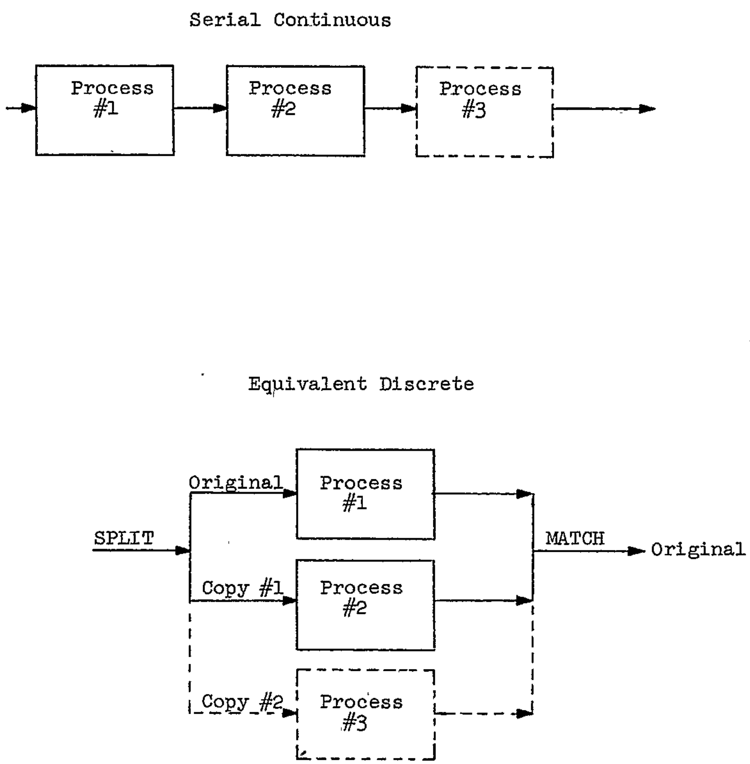

Figure 3.

PLANNING SYSTEM