Short Communication

Simulation of Truck-Shovel Operations Using Simio

Ibrahim Amin[1]*, Muhammad Adil[1], Safi Ur Rehman[2], Ishaq Ahmad[1]

[1]Department of Mining Engineering, University of Engineering & Technology, Peshawar, Pakistan
[2]Department of Mining Engineering, Karakoram International University, Pakistan

*Email: ibrahimdpw@gmail.com

Abstract: This research work was mainly directed towards the selection of optimal fleet for a cement quarry using 3D simulation models with Simio, which is the most convincing and understandable tool for quarry managers and staff. Quarry, haul roads and their specifications were taken from Google Earth while fleet capacities, and cycle time of operations was assumed matching with realistic data of a cement quarry. The objective of this study was to provide feed for two crushers of 300 tph capacities with minimum number of trucks and shovels. Student (academic) version of Simio software was used. Scenarios of quarry were created by exporting quarry data of Cherat Cement Ltd., from Google Earth in Simio. Total seven scenarios were checked by changing number and capacities of trucks and shovels. The model yields different results for various situations. The best results were selected. The model presented can also be used for deciding best location of shovels on different faces depending upon the chemical composition of materials available at faces for making ideal feed for kilns. The management could rightly decide by using the simulation models for complex processes at mining/quarry operations and could easily generate report and visual presentations.

Keywords: Optimization, simulation, cement quarry, Simio.

Introduction

The most desirable goal of any mining project is achieving maximum profit by extracting ore at the lowest possible cost over the mine life (Askari-Nasab et al., 2007). Cement industry lacks in utilizing modern techniques and technologies. Most of managerial decisions are made on trial and error basis which often inherits errors and inefficiency. Materials extracted from quarry are often handled with conventional system of truck and shovel. Truck and shovel operations constitute 50 to 60 percent of an open-pit mine's overall operating costs (Ercelebi and Bascetin, 2009). Hence optimal utilizations of resources will save money. An efficient truck-shovel system reduces hauling, operating, and maintenance costs, while meeting production targets and providing a steady and reliable feed of material (Torkamani, 2013).

This can be done by various techniques of operations research (OR). The OR techniques involve complex mathematics, and hence not presentable to quarry management. The simulation provides very versatile platform which can be understood both by researchers and quarry management and is used in the current research work.

Simulation is the imitation of the operation of a real-world process or system over time. Whether done by hand or on a computer, simulation involves the generation of an artificial history of a system and the observation of that artificial history to draw inferences concerning the operating characteristics of the real system (Banks et al., 2005). Simulation is an analysis tool for predicting the effect of changes to the existing system and a design tool for predicting the performance of new systems. Hence the simulation translates the real scenario to a model. That model then can be used to observe the loopholes in a system. Applications of simulation to mining industry specially to quarry operations in literature are found to be very scant and the published work is very limited.

In the current study, the fleet selection and allocation which is almost impossible in real scenario is made possible with the help of this simulation using Simio. Truck-Shovel simulation is a discrete event simulation, which is the process of generating the behavior of a complex system as sequential well-defined events. Each event occurs at a particular instant in time and marks a change of state in the system. The outcomes of simulation are then compared with static results like spread sheets and tables which make it more and more realistic by comparing with ground realities.

Simio is a discrete simulation modeling framework which is based on Intelligent Objects, a product of SIMIO LLC., academic version of which was used for simulating truck/shovel operations in this study. The application of Simio to scheduling has been presented (Thiesing and Pegden, 2015). Simio is easy to use simulation environment in which there is no need to write programming code to create new objects due to built-in architecture of various objects. More details about the Simio have been presented by Pegden and Sturrock, (2013) and Kelton et al., (2013).

Materials and Methods

Simio has an object based library, which is used to develop the model. Following are the steps taken. A typical flow chart shows the tools used in developing the model of this study.

- Import of the 3D quarry in Simio

- All four faces of the quarry were modeled as sources.

- Loading of Dump Trucks is done by Shovels modeled as servers, and the output of shovels is set to "input@crusher" so that the ore will go to the crusher through the dump trucks.

- In Transport Logic option Ride on transporter is set to true and then in Transporter Name select "DumpTruck" so that the ore would be picked and dropped by that DumpTruck.

- The Network Turnaround Method for the DumpTruck vehicle has been set to 'Reverse' to allow for the train to reverse while on the path – as opposed to exiting and re-entering the path in a forward direction.

- In Routing Logic option of the DumpTruck, Initial Node is set to "Input@Crusher" so that the truck will pick up the ore and dump at the crusher.

- Curves option is used to have smooth and sharp roads and curves in it.

- Loading of dump Trucks is done by Shovels models as servers, and the output of shovels are set to "input@crusher" so that the ore will go to the crusher through the dump trucks.

Input data background was exported from Google Earth as shown in Fig. 1 Cherat Cement Quarry, and Trucks, Shovels, Crushers and Paths were created on actual roads using standard library of Simio.

Fig. 1 Cherat Cement Quarry through Google Earth.

Numbers of trucks, shovels and crushers with capacities assumed have been given in Table 1.

Table 1 Assumption of equipment capacity.

Equipment	Capacity
Shovel	4-7 tons/bucket
Truck	50-60 tons
Crusher	300 x 2 tph

Crushers and shovels were fixed, whilst the number and/or capacities of trucks were changed in each scenario to reach optimality. After the model completed it was run as 3D simulation. Figures 2-4 show the model having 3D objects running on quarry roads, shovel loading truck and truck in standby position with crusher respectively. The results are based on 8 hours (one shift) performance; different scenarios have been discussed in the results section 3.
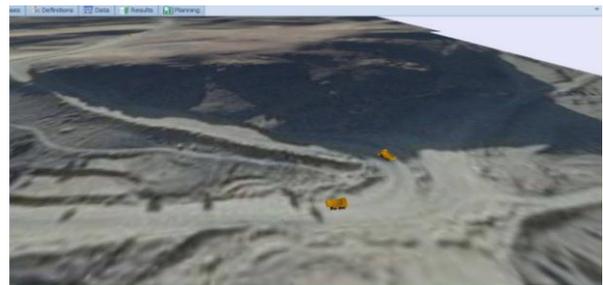

Fig. 2 Trucks running on haul roads.

Fig. 3 Shovel loading truck.

Fig. 4 Truck in standby position with crusher.

Results and Discussion

The simulation model presented is based on performance of crushers which depends on trucks and shovels utilization. Trucks and shovels are said to be optimally utilized only if they provide the required feed to crusher. Therefore, total of seven scenarios were checked with changing number of trucks until

optimality is reached in crushers results. Two crushers having throughput 300 tph each for eight hours shift crush a total tonnage of 4800 t. The actual materials transported could be more than the required from the stockpiles. Therefore, a provision has been kept in the model. The results show an increase in material transportation from 3917 to 5961 tons which is more than the requirements.

Details of various scenarios, the input data and simulations results have been given from Table 2-8

Table 2 Scenario-1.

Input (Number, Capacity)	
Trucks	9x50, 4x60tons
Shovels	3x4tons
Results (Utilization)	
Trucks	95.38 %
Shovels	99.88 %
Crushers	71.62 %
Materials Transported	3917.93 tons

Table 3 Scenario-2.

Input (Number, Capacity)	
Trucks	8x50tons
Shovels	3x6tons
Results (Utilization)	
Trucks	98.33 %
Shovels	84.83 %
Crushers	73.01 %
Materials Transported	3933.57 ons

Table 4 Scenario-3.

Input (Number, Capacity)	
Trucks	7x50, 3x60tons
Shovels	3x5tons
Results (Utilization)	
Trucks	97.22 %
Shovels	98.64 %
Crushers	73.28 %
Materials Transported	3958.46 tons

Table 5 Scenario-4.

Input (Number, Capacity)	
Trucks	9x50 tons
Shovels	3x6tons
Results (Utilization)	
Trucks	96.81 %
Shovels	99.90 %
Crushers	86.32 %
Materials Transported	5949.26 tons

Table 6 Scenario-5.

Input (Number, Capacity)	
Trucks	7x50, 3x60tons
Shovels	3x5tons
Results (Utilization)	
Trucks	98.10 %
Shovels	97.91 %
Crushers	86.49 %
Materials Transported	5961.61 tons

Table 7. Scenario-6.

Input (Number, Capacity)	
Trucks	9x50, 4x60tons
Shovels	3x4tons
Results (Utilization)	
Trucks	98.53 %
Shovels	73.45 %
Crushers	86.69 %
Materials Transported	5934.93 tons

Table 8 Scenario-7.

Input (Number, Capacity)	
Trucks	8x50, 2x60 tons
Shovels	3x7tons
Results (Utilization)	
Trucks	98.71 %
Shovels	85.87 %
Crushers	87.39 %
Materials Transported	5938.94 tons

The results clearly show that simulation can be used for checking "what if" questions, as have been observed in scenario1 in which 13 trucks were deployed with 3 shovels of 4 t/bucket capacity. Increasing and decreasing the number of trucks and capacity showed clearly the effect on results of material transported. At the last scenario only 10 trucks were deployed with the same number of shovels 7 tons/bucket capacity, which yielded an optimal result of transporting 5938.9 t of material while the ideal target for crushers is 4800 t. Hence scenario 7 was chosen an optimal result the simulation model presented.

Conclusion

All materials on quarry faces were considered ideal, matching with kiln requirement while practically chemistry of natural deposits changes from point to

point. Hence, integration of simulation model with chemical composition of the material at quarry which is also the plant requirement is recommended for future research.

References

Askari-Nasab, H., Frimpong, S., Szymanski, J. (2007) Modelling open pit dynamics using discrete simulation. *Int. j. Min. Reclam. and Environ.,* **21** (1), 35-49.

Banks, J., Carson, J., Nelson, B. L., Nicol, D. (2005). *Discrete Event System Simulation*. 4th ed., Pearson Hall, US. 3-17.

Ercelebi, S. G., Bascetin, A. (2009). Optimization of shovel-truck system for surface mining. *SIAMM – J. of The South African Inst. of Min. Met.* **109** (7), 433-439.

Kelton, W. D., Smith, J. S., Sturrock, D. T. (2013). *Simio and Simulation: Modeling, Analysis, Applications.* 3rd ed. Pittsburgh: Simio LLC.

Pegden, C. D., Sturrock, D.T. (2013). *Rapid Modeling Solutions: Introduction to Simulation and Simio.* Pittsburgh: Simio LLC.

Thiesing, R. M., Pegden, C. D. (2015). Simio Application in Scheduling. In: *Proceedings 2015 Winter Simulation Conference.* L. Yilmaz, W. K. V. Chan, I. Moon, T. M. K. Roeder, C. Macal, and M. D. Rossetti, (eds). 4150-4159.

Torkhamani, E. (2013). Linkage of Truck-and-shovel Operations to Short-term Mine Plans Using Discrete Event Simulation. M.Sc. thesis, University of Alberta, Canada, 150 pages.