# Methods for Equipments Selection in Surface Mining; review

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## Abstract
*One of the principal costs in mine is related to purchase and application of equipment. Proper fleet selection, in a way that it secures the production needs of a mine as well as minimizes costs of production, is one of the real challenges of mine planners. As such, with the selection of suitable fleet of equipment and their application, could minimize the capital and operational costs. Classifying the equipment selection process into three phases i.e. type of fleet, size of equipment and calculation of required numbers, the present article focuses on different application methods in each of these phases, their advantages and shortcomings.*

**Keywords**: *Surface Mining; Equipment Selection; sizing Equipment, Fleet Selection*

## 1. Introduction
The production process in a mine is divided into four parts of drilling, blasting, loading and hauling. The later two aspects i.e. loading and hauling allocate more than half of the total mining cost. The cost related to purchasing loading equipment is more than the vehicles needed for other sections. However, the principal part of the operating costs is related to hauling. Table1 highlights the share of each of components in the operation costs [1]. With respect to these higher costs, selection and application of type, size and number of equipment could significantly reduce the total production costs.
Equipments selection related to each section is accomplished with respect to existing operation limitation and circumstances as well as production needs. The equipment process in the mine is divided into three phases. First, transportation fleet is determined by taking into account physical and operational conditions of the area and the proposed rate of production. Second, size of suitable machine is distinguished by considering planning parameters. Finally, the required number of each of the equipment is determined in order to secure the proposed production.

## 2. Equipment Selection in Surface Mining
### 2.1. Selecting Fleet Type
For ore transportation at a surface mine, different fleets can be used. Shovel- truck and loader-truck are mostly utilized fleets, however; with respect to existing circumstances at the mine, equipments like dragline; bucket wheel excavator; in-pit crusher; and conveyer too could probably be used.
In this selection, multiplicity of parameters and alternatives may possibly lead to a number of complexities hence; selecting accurate equipment needs enough experience as well as taking into account all parameters in connection with each other. By this reason, at this stage, inclination is often toward a procedure where decision is being taken relying on experiences of experts. In this regard, on could point to application of expert system as well as multiple

attribute decision making technique. Fig.1 indicates effective parameters in selection fleet types [2].

**Expert System:** This is one of the first systems planned for selecting equipments in surface mining in 1987. In the proposed project, the main reasons described for using the expert system were the intense need of equipment selection process, past expertise, experiences and some of the effective parameters being qualitative hence; it tried to show the whole process of change of human experiences to an understandable language for computer in the field of mining equipments selection. This system is able to involve the expert knowledge in primary and secondary selection of equipment for surface coal mines [3]. In 1990, another expert system, in order to classify equipment, was planned in the open pit coal mine of Britain with the help of fuzzy logic. This expert system, for primary extraction method, employed drilling and hauling equipments and could receive geological information from software like SUPAC and DATAMINE. Data related to mine equipment is summoned from an external database [4]. The developmental process of expert system continued and in 1992, yet another system was planned for equipment needed for a project with soil conditions that includes 930 rules. This system was able to select equipments necessary for drilling, loading, hauling, placing and compacting earth and the proposed data consisted of bulldozer, scrapper, loader, trucks and compactors. For each type of equipment selected, there are unique qualities that must be considered (such as power, size, application etc.). The developed expert system can be used for earth-moving projects ranging in scope from 10,000 to 4,000,000 bank cu yd [5].Yet another expert system was presented in 2002 that had basic differences with previous ones such as its interference to the uncertainty related to influential factors in the matter selections. This system was much reflective and apart from calculating uncertainty ratio, it permitted user to determine the rate of important elements in selecting equipments [6]. Some other expert systems have also been proposed for equipments selection, in which, scraper selection system [7] and dragline selector [8] are important.

**Mathematical Modeling:** In 1988, a mathematical model was presented for selecting equipment and analyzing their costs. This particular model is for fleets that principal equipments are excavator and truck. The proposed system consists of two optimum models. The first model is to select equipments for fleet with the aim of minimizing costs of excavating unit. In the second model, equipments with the aim to optimize rate of production are being assessed in the form of a fleet. Constraints to the proposed model include the rate of annual production, diggability, loader haul distances (limited to 150m), and number of passes that lead to fill trucks (limited to 3 to 6 bucket). The uses of the models can be summarized as the -selection of the optimum equipment fleet for a given stripping job, -the determination of the minimum stripping cost, -the evaluation of the contractors fleet from the view point of sufficiency, and -the estimation of the cost of performing the stripping with the contractors fleet [9].

**Genetic Algorithm:** In 1999, a system called XSOME was established on the basis of knowledgebase and using genetic algorithm. This system was designed to solve problems related to equipment selection of opencast mining. In this system, advanced genetic algorithms search techniques to find the input variables that can achieve the optimal cost, and linear programming was used to develop a compound system on the basis of knowledge base and genetic algorithm [10].

**Queuing Theory:** Using queuing theory, in 2003, a computerized model FLSelector was designed for mining and construction operations. This model was able to select the best fleet combination of loaders and haulers that can complete an earthmoving operation with optimum output (least cost, maximum production, or minimum project duration). These calculations are made on the basis of possible fleet. This system was not designed for selecting the type of fleet and information related to project qualities led it to determine the number of required loaders. In reality, this model was applied for stages after selecting loaders and determining capacity of its bucket [11].

**Multiple Attribute Decision Making Techniques:** These techniques, in order to select mine equipments, were used for the first time in 2002. In this project, existence of qualitative and quantitative attributes along each other was the principal reason for utilize Analytic Hierarchy Process. The proposed attributes in this research includes mine parameters, technical and production features, performance of equipments, financial consideration, reliability, maintainability, mine life, operating condition, and safety and environment. The selection of fleet type has been accomplished from among five choices [12]. In 2003, a correction about the manner of classification of effective parameters in selecting fleet was presented and the process of equipments selection was carried out in a coal mine in Turkey. In this research, effective attributes are studied in two groups of operational and technical parameters and costs, each of which also includes a bunch of secondary attributes. This selection was accomplished from among four systems of shovel-truck, loader-truck, shovel-truck along with in-pit crusher and conveyor and, shovel and in-pit and conveyor. In this study, AHP method has been used to select suitable fleet [13]. Due to existing weak points in each of MADM methods, other methods including a compound multiple attribute decision technique has been widely used. Process of using compound methods aimed to develop MADM techniques. For instance, a software EQS was developed in 2006 where fuzzy AHP was used to select equipments. This process, to some extent, removed problems of uncertainty hence; some of the required information in this software is determined through expert systems [14]. In recent years, compound methods have been used widely and several other researches have been conducted in this field. For instance, in a research a new weighting method of decision matrix based on Hessian matrix has developed [15]. In another research Combination of Analytical Hierarchy process (AHP) and entropy method applied to calculate global weights of the attributes. The weights then passed to the Technique for order by similarity to ideal solution (TOPSIS) method that the most efficient mining equipment alternative(s) could be appointed through distance measurement so that the best alternative has the nearest (distance) to the ideal solution and farthest from the negative-ideal solution in fuzzy environment [2].

### 2.2. Selecting Size of Vehicles

After selecting types of equipments for the mine fleet, selection of their size is carried out. As such, first, regarding to hole diameter, loading height are determined and then drill equipment and loader are determined with due attention to their attributes. Thereafter, hauling equipment with respect to loader is selected in a way that their height must have in proportion to each other. The size of equipments is selected with respect to distinguished parameters of each of the machines. The principal factor for drilling equipments is borehole diameter and for hauling and loading machines is their capacity and operation height.

Sensitive parameters that are taken into consideration while selecting size of machines include equipment costs, tires, complexity, matching factor-system approach of machines, loss of production, maintenance, infrastructure and haul roads, dilution and selectivity, flexibility and versatility, possibility of selected extraction, reflectivity and applicability, environmental problems and milling costs.

In this phase, the selection possibility is enough due to diversity of existing equipment. One of the principal policies in selecting size of equipments is with respect to "Economic of Scale" theory. According to this theory, the selection of big equipment would minimize unit cost (per ton). However, this theory to a particular extent continues, which is indicated in Fig.2. As observed in this figure, increase of the size of machines, to the limit of distinguished capacity, has caused to decrease unit cost. By this reason, one of the important points in selecting size of equipment is the knowledge of proposed sizes [16].

Apart from taking into account economic of scale theory, use of optimization tools like mathematical optimization tool, simulation and artificial intelligence techniques would also be proved suitable in this field.

### 2.3. Selecting Required Number and Assignment of Apparatus

At the final stage, with respect to daily production rate and capacity of each of the equipments, the required number of each of machines is calculated. At the first, considering production rate, number of loader is determined and similarly, hauler number are determined with respect to the loader, production rate, hauling distance and transportation condition. Applying queuing theory, assignment and optimization tools, not only waiting period of machines is minimized rather it could, to a larger extent, reduce transportation costs.

## 3. Conclusion

The open pit equipment selection problem is a strategic issue and has significant impacts to the open-pit design and production planning. The cost related to purchasing loading equipment is more than the vehicles needed for other sections. However, the principal part of the operating costs is related to hauling. As a result of new technology, economy of scale will continue to be an extremely important factor in the competitiveness of the mining industry. This implies that both mine size (physical dimensions) and mining equipment will continue to grow.

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**Table 1- Cost Distribution of Unit Operations (Copper Mines) [1]**

| Unit Operation | Percentage of Total Cost % |
|---:|---:|
| Drilling | 8 |
| Blasting | 8 |
| Loading | 18 |
| Hauling | 47 |
| General | 19 |

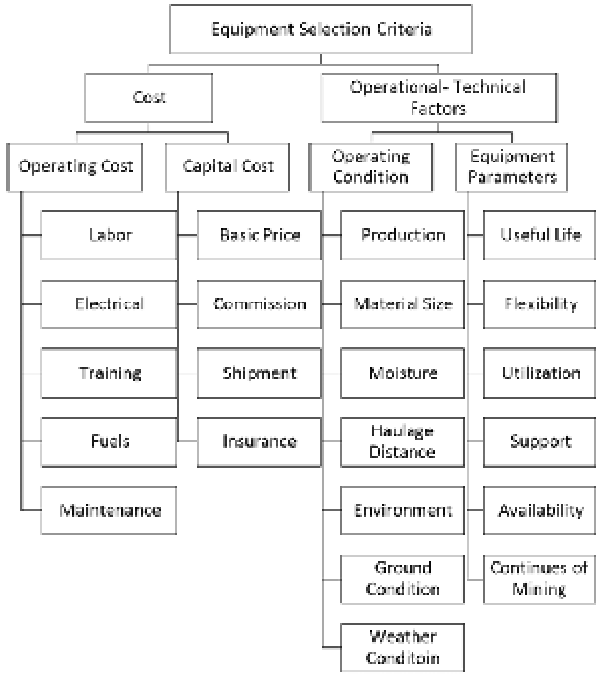


**Figure.1 effective parameters in selection fleet types [2]**

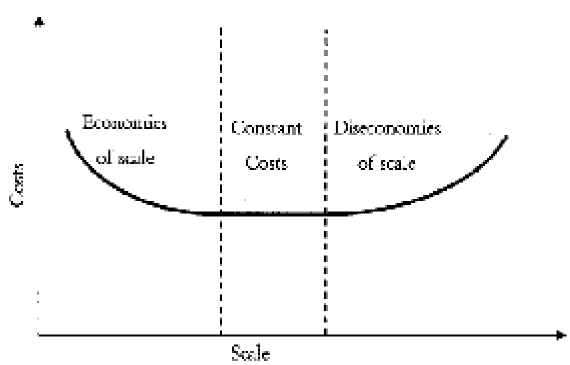


**Figure.2 Economic of Scale in Mining [16]**