A simulation-based framework for estimating probable open-pit mine closure time and cost

Morteza Paricheh*, Morteza Osanloo*

Department of Mining and Metallurgical Engineering, Amirkabir University of Technology, Tehran, Iran

Article info

Article history:
Received 28 May 2017
Received in revised form 22 July 2017
Accepted 28 August 2017

Keywords:
Sustainable development
Open pit mine
Mine closure time
Mine closure cost

Abstract

Today, the technical challenges for estimating closure time and cost are two significant parts of mine closure management. In this paper, a simulation-based framework is established to determine the probable open-pit mine closure times and mine closure costs. The model incorporates price uncertainty into the probable mine closure time. To estimate the closure cost more accurately, the Hutchison’s technique is modified using the predefined mine closure times. This technique uses Monte Carlo simulation method and decision tree analysis to estimate mine closure cost in a probabilistic manner. The proposed framework is applied in a 2D hypothetical geological block model. The results show that the model works well and it can be used in real cases.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

Nowadays, sustainable development (SD) is one of the main critical and challenging tasks in most industries around the world. SD is the development that meets the needs of the present generations without compromising the future generations to meet their needs (Nathorial and Bardos, 2004; Galvic and Lukman, 2007). The concept of SD gained its interest among the miners from the United Nation’s Earth Summit Conference in Rio de Janeiro, Brazil in 1992. After that, many researchers have been discussing the subject and seeking the methods to incorporate the SD aspects into mining operations. Now, the number of mining publications on this topic is increasing very rapidly (Moran et al., 2014).

The literature reviews show that sustainability principles and indicators are implanted into the mining operations using three strategies that include avoiding, reducing, and final treatment of the negative impacts of mining operations. The best strategy gives special prominence to the initial prevention of any negative social, economic and environmental impacts before it even occurs. In this regard, the preventing strategy should be determined during the mine design and planning phases. It indicates how the earth must be dealt and how the mining operation must be planned without any undesired impact. At the second level, the focuses are more on reducing the unwanted impacts created during the mining operation. Finally, what can be done at least are treating and managing the negative effects and preventing the diffusion and spread of the contamination. Of course, in many cases, separating these categories is not very clear and transparent. The newly published works by Rahmanpour and Osanloo (2017) are classified as the first category where the sustainability principles are considered in the first phase of open pit mine design at the stage that ultimate pit limit is defined. Similarly, Li et al. (2013) formulated and tested mixed-integer programming models to avoid long-term exposure of potential acid forming waste rock, causing acid mine drainage, which would incur ongoing collection and treatment costs. Badiozamani and Askari-Nasab (2014) also proposed a mixed integer linear programming model which includes tailing capacity and reclamation material requirements to make sure that the oil sand mine site is restored to a natural or economically usable landscape. Furthermore, Osanloo et al. (2008) modified Lane’s cutoff grade model in order to not only maximize the net present value of a porphyry copper mining project, but also minimize the adverse environmental impacts of the project.

Environmental impact assessments can be classified as the second group, where examine the anticipated environmental effects of a proposed project and find ways to mitigate or even avoid any negative long-term impacts of the project (Folchi, 2003; Mirmohammadi et al., 2009; Ogbonna et al., 2015). Others such as those are done by Laurence (2011) and Hilson (2000) similarly...
reviewed the major barriers have impeded the implementation of a sustainable mining practice.

The third group which mainly encompasses all forms of action may be taken after the mine closure and try to at least keep stable and then improve the bad created condition includes the work by Phillips (2012). The same, Worrall et al. (2009) showed how to deduce the negative aspects from the millions of legacy mine lands exist around the globe and provided some criteria and indicators when these lands are being reclaimed.

Despite these, some researchers believe that mining is not part of SD because it is a temporary use of land and it has some negative impacts on the environment, social and economic issues. As the response to these criticisms, minerals are clearly a part of SD because they are necessary if the quality of life, job creation, and economic growth are to be improved, but at the same time, protecting the environment while supplying these minerals is essential (Villas-Boas et al., 2005). In other words, mining operation would be sustainable when it is able to create a good balance among its three environmental, social and economic pillars (Botin, 2009). For this purpose, for a mine to contribute positively to SD, a comprehensive reclamation and closure plan, which is capable of considering social and environmental objectives in addition to the economic objectives, is necessary from project inception (Laurence, 2011).

The closure plan (i.e. the reclamation and closure plan) defines a vision of the end results of the mining operation and sets the objectives to realize that vision. This forms an overall framework to channel all of the actions and decisions were taken during the mine life (Laurence, 2006, 2011). Nowadays, in most of the countries, the mines with no closure plan are not permitted to start their operations. An appropriate closure plan which involves all three above-mentioned avoiding, reducing and treating strategies guarantees a successful and on time closure without any negative environmental, social and economic impacts.

Seeking a comprehensive closure plan, the closure time and cost are the most challenging issues which need accurate estimations. Valuation of mining investment opportunities typically focuses on revenues, initial capital and recurring operating expenditures. Less emphasis is generally placed on the costs that are harder to quantify, such as decommissioning, closure and reclamation (Espinoza and Morris, 2017). Mine closure costs have the potential to affect the ultimate pit limit, production schedule, mine life and ultimately the profitability and net present value of an operation (Nehring and Cheng, 2016). Therefore, incorporating true closure costs into financial feasibility studies is an essential aspect of modern mining operation before the mine is even put into production. Obviously, the lack of available financial resources will be the strongest impeding factor toward the implementation of any efficient waste minimization technologies or closure and reclamation activities in the mining industry (Hilson, 2000; Franklin and Fernandes, 2013).

Estimating closure cost is not an easy task because of the finite number of mines which are closed safely according to the available standards. However, the topic of closure or reclamation cost estimation, especially for a particular mining method has scarcely been investigated and has received relatively little attention in the academic literature. Also, current reports and guidelines do not include the way to estimate these costs (Worrall et al., 2009). Soltanmohammadi et al. (2010) believed that closure goals and post-mining land use prescribe the methods, the measures and the costs of mine closure. Then, in order to estimate the closure costs, the after-use option of the land must be determined first.

Jones (2012) authenticated the work of Soltanmohammadi et al. (2010) and said cost estimates will vary depending on the purpose for which they are prepared and the organizations undertake the estimate. He considered different approaches by different organizations including operating companies, government authorities, and financial organizations and uses a hypothetical example based on practical experience to illustrate some of these differences in estimation methods. Gronhard and Scott (1979) divided the reclamation process into separate activities that must be performed, including preparation and planning, re-contouring, topsoiling and re-vegetation. The cost of reclamation was then estimated for a given set of mine conditions. An interdisciplinary approach employing hydrology, geographic information systems, and a recreation visitation function model is used by Mishra et al. (2012) to estimate the damages from up-stream coal mining to lakes in Ohio. The estimated recreational damages to five of the coal-mining-impacted lakes, using dissolved sulfate as a coal-mining-impact indicator, amounted to $21 million per year.

Leinart and Schumacher (2010) evaluated the role of cost estimating in mine planning and equipment selection and introduced Sherpa as a cost estimator software. A combination of Decision Tree Analysis (DTA) and Monte Carlo Technique (MCT) was used to establish a cost probability curve that in turn provides closure costs at different levels of confidence by Hutchison and Detto, 2011 (we call it Hutchison’s technique). The main Hutchison’s hypotheses are the pre-defined optimistic, pessimistic and most likely dimensions of mine waste management and their probabilities and costs, which in turn are a function of future waste characteristics, the final configuration of the pit, waste dump, tailings and water pile, future climate condition and future regulatory standards.

Pavloudakis et al. (2012) proposed a methodology for predicting the maximum budget that is required for financing environmental protection and land reclamation works throughout the entire life of the mine. The method is based on MCT and DTA as same as Hutchison’s technique. The method is able to calculate the maximum reclamation cost taking into account a minimum acceptable profitability index of the project by incorporating the uncertainty of the parameters. Nehring and Cheng (2016) evaluated the effects of post-mining land use costs in optimal mine design and planning. It is mentioned that many countries have adopted a performance bond, which is included in the permitting procedure and is sufficient to cover the reclamation cost of the mining site in the event the mine owner does not complete all the required land reclamation activities. Furthermore, according to Adibee et al. (2013), physical properties (slope, erosion, the existing trees and plants and their characteristics) and chemical properties (acidity and alkalinity, heavy metal contamination, lack of nutrients, electrical conductivity and hardness) of rock and water in the site must be considered in order to identify the most suitable post-mining land use and its associated costs and benefits. The adverse effects of the waste dump on the environment must be described because the characteristics of the wastes can be used to predict their environmental impacts and reclamation costs across the site.

It is also obvious that reclamation and closure costs are closely related to mine design for a specific mining project. For instance, in the case of an open-pit operation, the costs vary with the size of the ultimate pit, its average strip ratio, the mine life and also the greatness of the surrounding mine’s facilities (Rahmanpour and Osanloo, 2017). Therefore, the reclamation cost estimator must take into account the pit, waste dump, tailing dam and other mine
دریافت فوری
متن کامل مقاله

امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات

<table>
<thead>
<tr>
<th>ISI Articles</th>
<th>مرجع مقالات تخصصی ایران</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات