Economic advantages of dynamic analysis in the early stages of mining projects

Abstract

The use of dynamic simulation is technically advantageous for the project as shown by various authors. However, is it economically advantageous in the early stages of the project (FEL1 and FEL2)? The methodology to economically evaluate the use of dynamic simulation considers the time and development cost compared with the time and cost spent to change the project in the next phase, considering changes that could be avoided with the use of dynamic simulation. Five process plant projects were evaluated, each one with an estimated CAPEX of US$ 300 million. The saved average is US$ 44,200.00 and US$ 182,400.00 for FEL 1 and FEL 2 respectively. The percentage cost savings for FEL2 (2.0%) and FEL3 (3.1%) are significant. The estimated delay avoided for FEL2 (3 weeks) and FEL3 (8 weeks) is directly related to the implementation delay, whose cost is expressively greater than the savings shown. The study concludes that the use of dynamic simulation is economically advantageous for the project.

keywords: mining, dynamic simulation, high-level simulation model.

1. Introduction

In the last decades we have seen a great growth in the use of simulation for risk analysis (Wu and Olson, 2013). In mining projects, the simulation is used in production and profitability optimization, modeling of operations, modeling for mining scheduling and decision-making aid for multi-criterion conditions (Chinbat and Takakuwa, 2009, Parreira et al. 2012, Pop-Andonov, 2012, Botín et al., 2015, Lagnika, 2017). However, the simulation is underutilized in plant engineering, where it is generally applied to evaluate the variation of costs as a function of delivery date (Gutfeld, et al., 2014, Jessen et al., 2015).

Most of mining projects go through some form of front-end (FEL) studies, in line with IPA definitions before reaching the implementation stage (Stange and Cooper, 2008). Many of the projects start with a scoping study (FEL1), followed by a pre-feasibility study (FEL2) and a feasibility study (FEL3) before it is approved for implementation (ALBASHRI, 2016; MOTT A et al., 2014).

The estimation accuracy of the preliminary project (FEL 1) is -15% to +30%, improving to -2% to +10% in FEL 3 (Hayati and Ganji, 2016). Project detailing costs time and money. The smaller the amount of errors in the preliminary design, the less the effort will be in the later phases of the project.

The use of dynamic simulation is technically advantageous for the project as shown by various authors (Cardoso and Teles, 1997; Altiok, 2010; Juliá, 2010; Bergquisst, 2012; Asbjörnsson et al., 2013; Cremonese et al., 2017). It is usual to apply dynamic simulation in FEL3 phase. Time to develop a study and lack of information are the main reason why the simulation is not used in the FEL1 and FEL2.

As the innovative work shown by Cremonese et al (2017), the time to develop a study can be decreased to hours (not weeks as usual) and the information obtained to make the model and the outputs of the simulation will decrease the information lack. The dynamic simulation will decrease the number of project changes and uncertainties.

This research asks three questions: (1) Can we use simulation in the FEL 1 and FEL 2 phases? (2) What is needed to apply simulation in the preliminary phases of the project? (3) Is it economically advantageous?
2. Materials and methods

For evaluation of the economic potential of the use of dynamic simulation in FEL1 and FEL2, five case studies were used. The case studies were iron ore process plants with CAPEX of around US$ 300 million. Each process plant has around 50 pieces of process equipment (Crushers, Screens, Spiral Classifiers, Thickeners, Mills, Cyclones, etc.) and 50 of material handling equipment (Belt Conveyors, Bins, Piles, Stackers-Reclaimers, etc).

In all cases, it was necessary to make project changes in the later phase due to the size of the bins. The influence of the bin size in the process plant capacity is not the purpose of this work and can be seen in Cremonese et al. (2017). These changes could have been avoided if the simulation had been carried out in the previous phase.

To calculate the potential economic benefit of the use of simulation, the following methodology was used:

1. Estimation of the “man hours” necessary to make the changes in each project (Considering Mechanics and Civil disciplines)
2. Estimation of Project Management and Control cost, due to the changes per Project Phase (FEL2 and 3);
3. Estimation of the delay in the project, due to the changes and consequently the delay in the beginning of the enterprise’s implementation;
4. Estimation of the “man hours” necessary to develop a dynamic simulation study considering high-level dynamic analysis developed by Cremonese et al. (2017);
5. Calculation of the change cost in each project;
6. Calculation of the dynamic simulation cost per Project Phase (FEL1 and 2);
7. Calculation of the difference between the cost of dynamic simulation and changes in the project.

3. Theory / calculation

3.1 Assumptions

Mechanical and Civil disciplines are the most significant disciplines considering man effort. Due to this, they were the only ones considered in the study. It is known that other disciplines are affected by the alterations, but they were not considered. Project Management/Control and Schedule delay are considered as described below.

The man efforts to make the project alterations for Mechanical and Civil disciplines in FEL2 and FEL3 are shown in Table 1 and Table 2. These data were obtained for the efforts of an average man utilized in the five case studies.

<table>
<thead>
<tr>
<th>Equipment Calculations</th>
<th>Data Sheets</th>
<th>Drawings</th>
<th>Total for Belt Conveyor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junior Engineer</td>
<td>Senior Engineer</td>
<td>Junior Engineer</td>
<td>Senior Engineer</td>
</tr>
<tr>
<td>FEL2</td>
<td>6</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>FEL3</td>
<td>12</td>
<td>4</td>
<td>12</td>
</tr>
</tbody>
</table>

Table 1
Mechanical documents – Man efforts.

<table>
<thead>
<tr>
<th>Calculations</th>
<th>Drawings</th>
<th>Total for Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junior Engineer</td>
<td>Senior Engineer</td>
<td>Junior Engineer</td>
</tr>
<tr>
<td>FEL2</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>FEL3</td>
<td>24</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 2
Civil documents – Man efforts.

The delays occurring because of the changes were estimated in 3 weeks for FEL2 and 8 weeks in FEL3. These data were obtained as an average of delay in the five case studies. Consequentially the delay for the operation of the enterprise was considered the same. Project Management/Control were estimated for one Junior Engineer (16 h/week) and one Senior Engineer (8 h/week).

Process Plant Implementation Cost of the five project analyzed can be estimated in US$ 300 million. The estimated cost of the projects are US$ 900,000.00 (FEL1), US$ 2,250,000.00 (FEL2) and 5,850,000.00 (FEL3). These values considered that in this type of enterprise, the FEL1, 2 and 3 are around 3% of the implantation cost and divided into 10%/25%/65%.
4. Results and discussion

Five projects were used as test cases, three from FEL3 and two from FEL2. The project information is shown in Table 4.

The plant mean production capacity was achieved, increasing the bin capacities. This bin capacity change in the FEL 1 and FEL 2 stages to achieve the plant capacity is minor as compared to the changes that need to be carried out in FEL 2, FEL 3 and project implementation or worse, in plant operation.

The bin capacity change results for alterations in the building and belt conveyor projects.

<table>
<thead>
<tr>
<th>Nº</th>
<th>Country</th>
<th>Simulation did with information of Alteration in</th>
<th>Number of altered bins</th>
<th>Number of altered belt conveyors</th>
<th>Number of altered buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>India</td>
<td>FEL2 FEL3</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Mauritania</td>
<td>FEL2 FEL3</td>
<td>3</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Brazil</td>
<td>FEL2 FEL3</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Mauritania</td>
<td>FEL1 FEL2</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Brazil</td>
<td>FEL1 FEL2</td>
<td>4</td>
<td>8</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 4
Projects information.

The time spent on alteration is shown in Table 5.

Using the “High-level Dynamic Analysis Approach” the time spent to model and simulate the entire process plant was two and three days (16 and 32 working hours) for FEL1 and FEL2, respectively. Considering the time spent on alteration, and the cost of a high level dynamic simulation in the early study of the project, the summary results are present in Table 6.

<table>
<thead>
<tr>
<th>Nº</th>
<th>Simulation did with information of Alteration in</th>
<th>Number of altered bins</th>
<th>Number of altered belt conveyors</th>
<th>Number of altered buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FEL2 FEL3</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>FEL2 FEL3</td>
<td>3</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>FEL2 FEL3</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>FEL1 FEL2</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>FEL1 FEL2</td>
<td>4</td>
<td>8</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 5
Time spent on alterations.

The results shown that the average earned by a dynamic simulation study in FEL1 and FEL2 are 37 and 144 thousand dollars respectively.

<table>
<thead>
<tr>
<th>Nº</th>
<th>Time spent on Simulation (hours)</th>
<th>Simulation cost (US$)</th>
<th>Variance (US$)</th>
<th>Saves (US$) considering the project cost in next FEL</th>
<th>% of saves, considering the project cost in next FEL</th>
<th>Avoid delay in the start of the implementation of the project in</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>32</td>
<td>16,000.00</td>
<td>128,000.00</td>
<td>182,400.00</td>
<td>3.1%</td>
<td>8 weeks</td>
</tr>
<tr>
<td>2</td>
<td>32</td>
<td>16,000.00</td>
<td>176,000.00</td>
<td>192,000.00</td>
<td>2.0%</td>
<td>3 weeks</td>
</tr>
<tr>
<td>3</td>
<td>32</td>
<td>16,000.00</td>
<td>128,000.00</td>
<td>52,000.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>8,000.00</td>
<td>22,000.00</td>
<td>30,000.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>8,000.00</td>
<td>52,000.00</td>
<td>60,000.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6
Summary cost before Project Management/Control Costs.

The time spent on alteration is shown in Table 5.
5. Conclusion

As shown in the test cases, utilization of the “High-level Dynamic Analysis Approach” in FEL 1 and FEL 2 would lead to defining the project parameters (as bin capacities) in the early stages. This would avoid the need of revised discipline engineering, such as Mechanical and Civil, since the belt conveyor length had to be changed and the load of the structure increased. The cost evaluation shows in the five case studies that it is advantageous to use it. The saved average are US$ 44,200.00 and US$ 182,400.00 for FEL 1 and FEL 2 respectively.

The percentage cost saves for FEL 2 (2.0%) and FEL 3 (3.1%) are significant. The estimated delay avoidance for FEL 2 (3 weeks) and FEL 3 (8 weeks) is directly related to the implementation delay, whose cost is expressive, greater than the savings shown, but was not estimated in this study due to its complexity.

The use of dynamic simulation is technically (Cremonese et al., 2017) and economically advantageous for the project as previously shown. However, it is only possible using the innovative “High-level Dynamic Analysis Approach” developed by Cremonese et al (2017), since the development of a simulation model from scratch is more time-consuming and expensive.

Acknowledgements

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References


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