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

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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: tmining, 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 (ALBISHRI, 2016; MOTTA *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 Classifier, Thickeners, Mills, Cyclones, etc,) and 50 of material handling equipment (Belt Conveyors, Bins, Piles, Stacker-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.

Mechanical documents (man hours for each Belt Conveyor alteration)

	Equipment Calculations		Data Sheets		Drawings		Total for Belt Conveyor	
	Junior Engineer	Senior Engineer	Junior Engineer	Senior Engineer	Junior Engineer	Senior Engineer	Junior Engineer	Senior Engineer
FEL2	6	2	6	2	12	4	24	8
FEL3	12	4	12	4	24	8	96	32

Table 1
Mechanical documents – Man efforts.

Civil documents (man hours for each Building alteration)

	Calculations		Drawings		Total for Building	
	Junior Engineer	Senior Engineer	Junior Engineer	Senior Engineer	Junior Engineer	Senior Engineer
FEL2	12	4	12	4	24	8
FEL3	24	8	24	8	96	32

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).

The cost for one-man hour considered for Simulation Specialist, Junior and Senior Engineer is shown in Table 3. Other categories were not considered in this study.

Cost for one-man hour (US$/hours)

Junior Engineer	Senior Engineer	Simulation Specialist
150.00	300.00	500.00

Table 3
Cost for one-man hour.

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 4
Projects information.

Nº	Country	Simulation did with information of	Alteration in	Number of altered bins	Number of altered belt conveyors	Number of altered buildings
1	India	FEL2	FEL3	2	4	2
2	Mauritania	FEL2	FEL3	3	6	2
3	Brazil	FEL2	FEL3	2	4	2
4	Mauritania	FEL1	FEL2	2	4	1
5	Brazil	FEL1	FEL2	4	8	2

The time spent on alteration is shown in Table 5.

Table 5
Time spent on alterations.

	Time spent on alterations (hours)					
	Mechanical discipline		Civil discipline		Total	
Nº	Junior Engineer	Senior Engineer	Junior Engineer	Senior Engineer	Junior Engineer	Senior Engineer
1	384	128	192	64	576	192
2	576	192	192	64	768	256
3	384	128	192	64	576	192
4	96	32	24	8	120	40
5	192	64	48	16	240	80

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 6
Summary cost before Project Management/Control Costs.

	Alterations cost (US$)			Time spent on Simulation (hours)	Simulation cost (US$)	Variance (US$)		
Nº	Junior Engineer	Senior Engineer	Total	Simulation Specialist	Total	Total		
1	86,400.00	57,600.00	144,000.00	32	16,000.00	128,000.00	144,000.00	Average in FEL2
2	115,200.00	76,800.00	192,000.00	32	16,000.00	176,000.00		
3	86,400.00	57,600.00	144,000.00	32	16,000.00	128,000.00		
4	18,000.00	12,000.00	30,000.00	16	8,000.00	22,000.00	37,000.00	Average in FEL1
5	36,000.00	24,000.00	60,000.00	16	8,000.00	52,000.00		

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

Table 7
Summary cost with Project Management/Control Costs.

Use the simulation in	Saves (US$) considering Manag./Control Cost	% of saves, considering the project cost in next FEL	Avoid delay in the start of the implementation of the project in
FEL2	182,400.00	3.1%	8 weeks
FEL1	44,200.00	2.0%	3 weeks

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 FEL2 (2.0%) and FEL3 (3.1%) are significant. The estimated delay avoidance for FEL2 (3 weeks) and FEL3 (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.

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