Mine Planning Information from Photogrammetry Sources in El Teniente Mine

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ABSTRACT

This paper contains discussions about photogrammetry and its application for development design and actual reconciliation and secondly, discussion about El Teniente Mine Scheduling which will discuss the background of the changes from CAD to M24D, critical parameters to be captured, coding development, user interface, field tracking, and its current state and future development.

An integrated mine system must be capable of displaying and reporting valuable information that can be used to easily understand, manage and take action on the key parameters being reported.

One of the key aspects of integration is the standardization of the mine information up to a level capable of adapting the main characteristics of past projects of the mine, and also enforcing the same or higher standards for newer projects being developed.

In El Teniente, Photogrammetry is used to map the progress of horizontal developments at the mine, the constructed three-dimensional (3-D) representation of each gallery captured by this technique is then used by the geologists to obtain structural information of the areas being photographed.

The sooner the operation area realized that there was valuable mining information that could also be used from the Photogrammetry being applied, and three possible areas of development were envisioned. The first area was creating a link between the developments being planned on a yearly and monthly basis and matching them with plan sections of the 3-D developments of the system, in order to account for deviations taking place in an online manner. The second area of development was using vertical sections of the 3-D developer and estimating the over-break of the excavations on different areas of the mine. The third area of development was thought as a more detailed analysis of the sections so they could provide information on the thickness of the shotcrete being applied.

The paper presents the different alternatives being used and how the project is currently being developed and managed at the mine, with the challenges associated to implementing this reporting platform, and the results being obtained.

INTRODUCTION

The first step to guarantee the appropriate start-up of a mining project is to ensure the constructibility. Under this point of view, one of the most complex activities that underground mining has to face has relation with monitoring and control of mining developments, allowing a quick management of possible deviations with respect to development plans or other objectives.

For all above, the implementation of an integrated analysis and reporting system of constructability allows control in a daily way of multiple Key Performance Indicators (KPIs) and its latest analysis from any computer. In other hand, the graphical reporting of constructability plans and day progresses in 3D, including photogrammetry technology, allows El Teniente mine to make decisions on what is due developed.

METHODOLOGY

The working process for a mining project can be assumed as a compliment of 4 fundamental blocks: (1) Inputs; (2) Standards and procedures; (3) Tools and (4) Outputs. The next figure shows the interaction between these stages all them marked up in a management process that last for approximately 100 days.

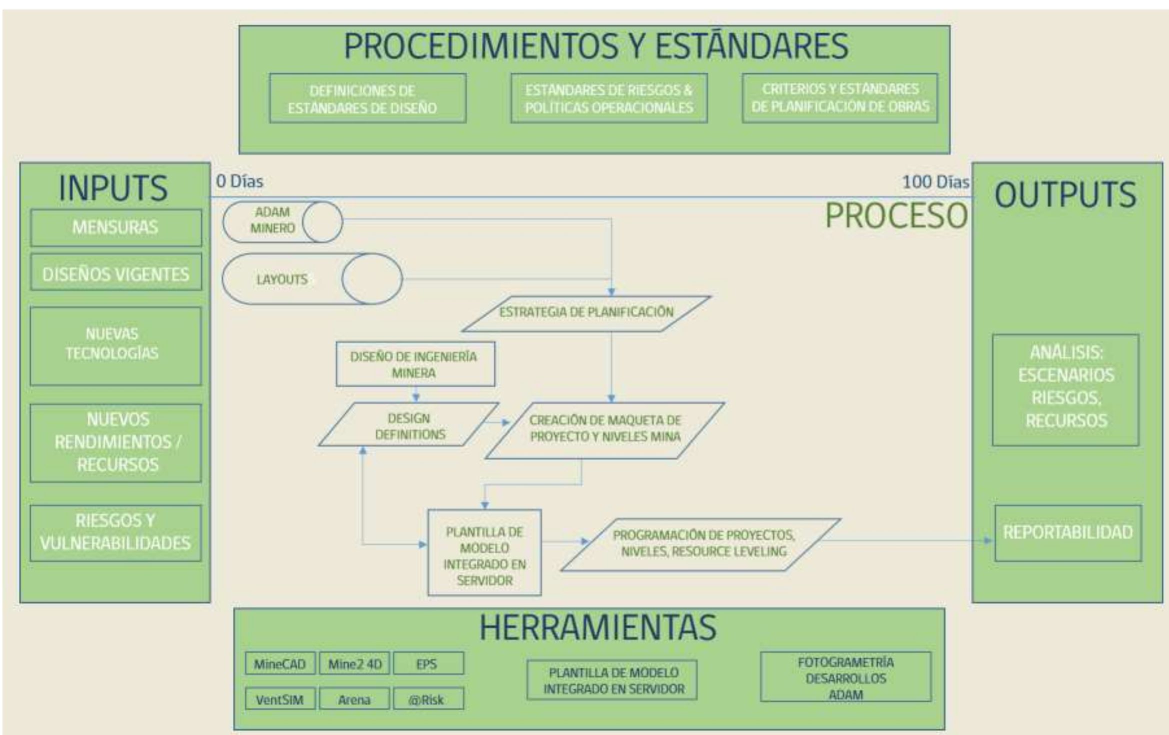


Figure 1 Work scheme for the development of a mining project. Source: Personal compilation.

In this context, it is interesting to analyse some dimensions with respect to the requisites to implement and integrated system with Photogrammetry technology:

Standardization of Designs

The development of a mining project starts with de definition the standards of designs and codifying. This standardization generates the base for the later activities, making it necessary for all the stakeholders involved in the process and agree to and consolidate the criteria that will lead.

Once the criteria are established it is necessary to generate design definitions that characterize each gallery or development in order to make all the later analysis, as well as an appropriate codification to every gallery, defining attributes depending on the case.

Design Definitions

The design definition concept summarizes all the characteristics and parameters of design that define a gallery or development activity. The generic case considers the following characteristics:

- **Colour:** It is assigned a colour or hue to each design depending on their functionality. In Figure 2, a case is exemplified:

Figure 2 Colour definition according to design functionality. Source: Personal compilation.

- **Description:** The name of the designs it is structured in the following way: SECTOR_LEVEL_GALLERY. For example, if there is a design which description is FP_IL_CHIM this means that the design is associated to the gallery that is found in the Footprint sector (FP), in the Injection Level (IL) and they correspond to a Chimney (CHIM).
- **Section:** For every design it is necessary to assign the type of section that will turn the CAD lines in to 3D excavations. There is an example of this in figure 3:

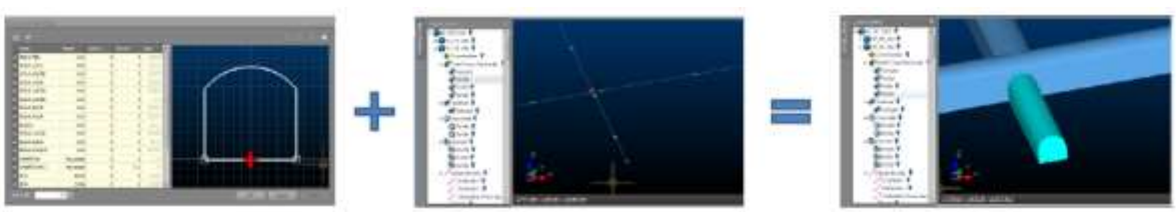


Figure 3 Application of a design definition to a base line. Source: Personal compilation.

The figure below presents some definitions of design created for a real case:

N°	COLOR	DESCRIPCIÓN	ANCHO	ALTO	DIAMETRO / RADIO
81	Chocolate	FH_DLLOHZ	4.2	3.9	2
82	LightSteelBlue	FH_POZOSFH			40
83	Yellow	FH_POZOSPERF			5
16	Red	FP_NE_CABECERAS	7.2	7.1	2.6
17	Red	FP_NE_CHIM			1.5
14	Red	FP_NE_CRUZADOS	5.9	5.8	2.6
13	Red	FP_NE_FRONTON_EXT	3.8	3.7	2.6
1	Pink	FP_NH_ACCESOS	5.2	5.1	2.6
2	SandyBrown	FP_NH_CALLES	4.1	4.0	2.6
8	LightGray	FP_NH_CHIM_SLOT			1.5
4	PowderBlue	FP_NH_CRUZADOS	5.2	5.1	2.6
5	DarkTurquoise	FP_NH_FRONTON	4.1	4.0	2.6
7	Red	FP_NH_FRONTON_EXT	3.8	3.7	1.9
6	Blue	FP_NH_FRONTON_INY	3.8	3.7	1.9

N°	COLOR	DESCRIPCIÓN	ANCHO	ALTO	DIAMETRO / RADIO
40	Fuchsia	FP_NT_LOOP	6.2	6.1	3.34
36	Yellow	FP_NT_PILOTO_PIQUE			1.5
70	Pink	IN_NX_ACCESO	8.9	6.7	4.44
66	LightGray	IN_NX_CARPETA	5.2	0.2	
75	LigthBlue	IN_NX_BARRIO_CIVICO	5.2	5.1	2.6
62	CadetBlue	IN_NX_BARRIO_CIVICO_ANDEN_BUSES	8.2	5.9	2.6
58	DarkTurquoise	IN_NX_FRONTON	4.2	4.1	2.1
71	Red	IN_NX_FRONTON_EXT	4.2	4.2	2.1
79	Blue	IN_NX_FRONTON_INY	4.2	4.1	2.1
78	Red	IN_NE_CABECERA	7.2	7.1	3.8
54	Red	IN_NE_CRUZADO	5.9	5.8	2.95
69	Red	IN_NE_GALERIAS	5.2	5.1	2.6
72	AntiqueWhite	IN_NH_GALERIAS	5.9	5.8	2.95
53	Blue	IN_NI_CABECERA	7.2	7.1	3.8

Figure 4 Example of design definitions, El Teniente mine. Source: Personal compilation.

Naming Convention

The assignation of key characteristics to each design line or gallery is another useful tool that helps the standardization of mining developments because it allows selecting, filtering, identifying and reporting, in a simple way, all the activities created in the platform.

Once the number of attributes is designed by all the stakeholders, the next step is to concatenate those attributes to generate the naming convention for each gallery or construction. For the example developed along this document, 10 attributes where defined and all together they define a specific gallery.

Finally the concatenate structure of these attributes generates the name and it is defined as follows:

MINE_SECTOR_PRODU_LEVEL_TYPE1ID1_TYPE2ID2_TYPE3_IDD

For example, the name of a collection point in calle 5, zanja 7, in the Production Level, East Side, and belonging to module 3 of a project at the footprint of a mine sector named NM would be:

NM_FOS_M3_PL_CLL5_ZJA7_CP_HW

Standardization and planning definitions

Once the standard of design is defined, a model of the project is built considering all the headings and constructions. These elements are then sequenced following development plans and directions of construction. This sequence is made by guiding the segments accordingly and connecting them following the logic sequence pre-established by the user (Figure 5). This initial sequencing gives us the definitions for the next step which corresponds to scheduling tasks in which the performance of teams and the allocation of resources are considered, allowing performing critical path analysis and generation of guidelines for the project.

Figure 5 Sequencing activity, with detail on the gallery connection according to the planned sequence. Source: Personal compilation.

Equivalent distance definition

The concept of equivalent distance allows direct comparison between different sections to obtain an approximation of the time the amount of inputs required for development of a gallery with a particular section. The equivalent distance considered as base section the one where the mine has more experience in constructing. Thus, if you have an "A" section the equivalent distance will be calculated as follows:

$$M_{eq_p} = \frac{A\ section\ perimeter}{Base\ section\ perimeter} \quad (1)$$

This indicator allows the estimation of perimeter associated resources such as fortification. Moreover, this same analysis performed with the area:

$$M_{eq_p} = \frac{A\ section\ area}{Base\ section\ area} \quad (2)$$

In this case, the indicator gives an estimation associated to sectional area such as the marine movement of this section A with respect to the base section have the experience.

Programming activities platform

At this stage, parameters such as performance, equipment associated with the construction, shift system, etc are incorporated. While the tool searches the optimal allocation of resources and therefore the plan, you can assign preferences to certain construction work so that when assigning, these tasks prioritize over others. Once the construction plan and the allocation of resources are established, the program provides a 3D view of the developments following the optimal route calculated. Figure 6 shows the complete platform (Gantt Chart and 3D modelling).

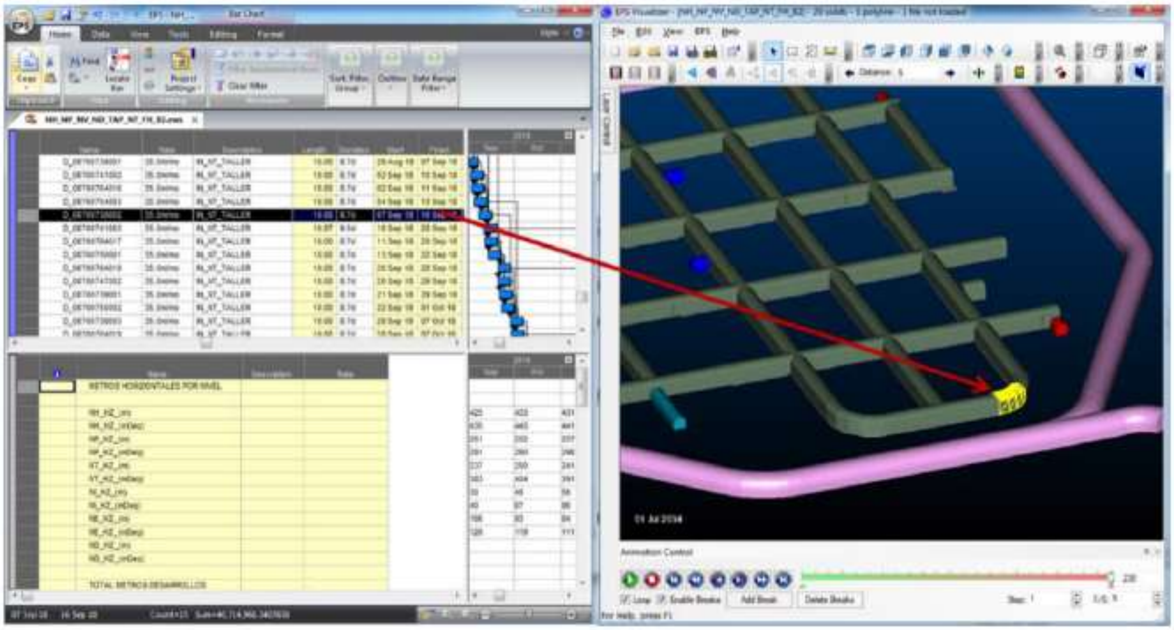


Figure 6. Programming activities platform and 3D visualization. Source: Personal compilation.

This step represents the last stage in which software is used, once the allocation of resources and the plan works, all information is brought to an on -line platform that allows viewing predefined reports, from any computer.

Online working and multi-project

All the developments project work with a multi-user and multi-project platform. This system provides the opportunity to work on several projects at a time and then simultaneously to generate an integrated project.

One advantage of working online with a database or server is to maintain traceability of the information under a work plan to identify design changes, planning, resources, etc. and keep a check on these changes.

Finally, staff requirements to successfully implement a project with all its productive levels and associated infrastructure considers: A chief engineer who is in charge of the project, dedicated staff of engineers, depending on the size of the project, it may include more than 1 level per person or for more complex projects should have one engineer for each project level. In the end, it may be necessary for the subsequent risk analysis, analyst risks that can integrate the results obtained with models of probability.

RESULTS AND DISCUSSION

The reporting results obtained, as well as the potential of analysis obtained from the use of this integrated system are presented below:

3D and 2D Reporting

The 2D display allows the junction between information of the daily advances and budgeted according to construction plans.

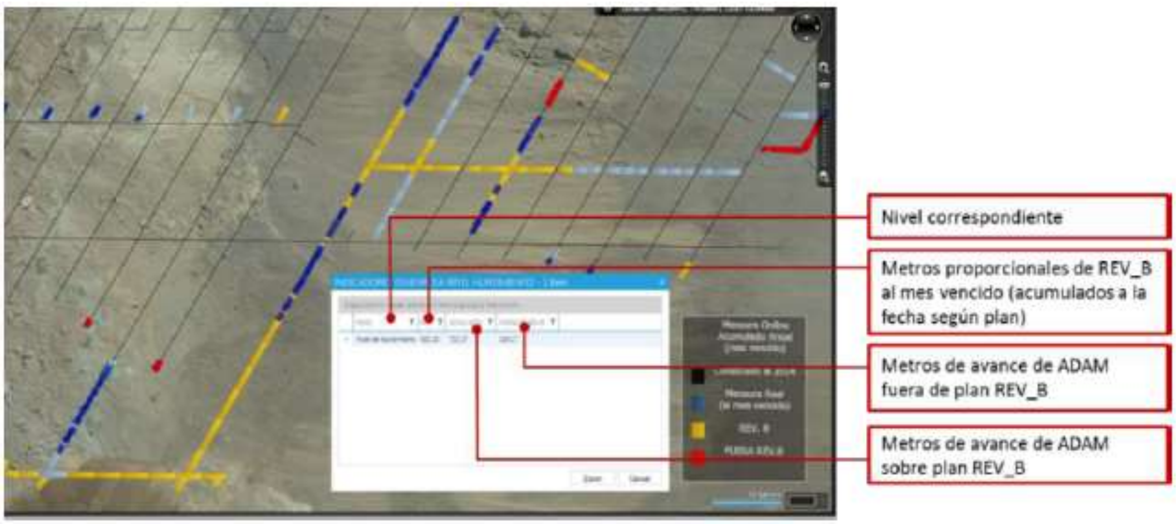


Figure 7 2D Reporting. Source: Personal compilation.

Moreover, the 3D reportability has benefits from a visual point of view incorporating information from existing databases in the division. Some applications are:

- Visualization of real headings versus planned headings for the analysis of under / over-excavation.

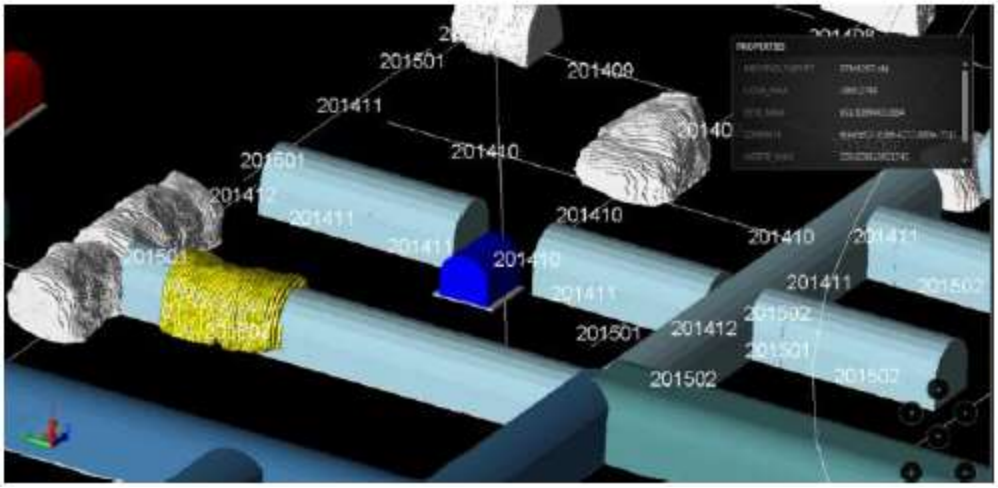


Figure 8 Visualization of Photogrametry and planned design for a gallery. Source: Personal compilation.

- Viewing scheduled mine developments. This option enables quick validation of the construction program, enabling the analysis of specific periods of time as required.

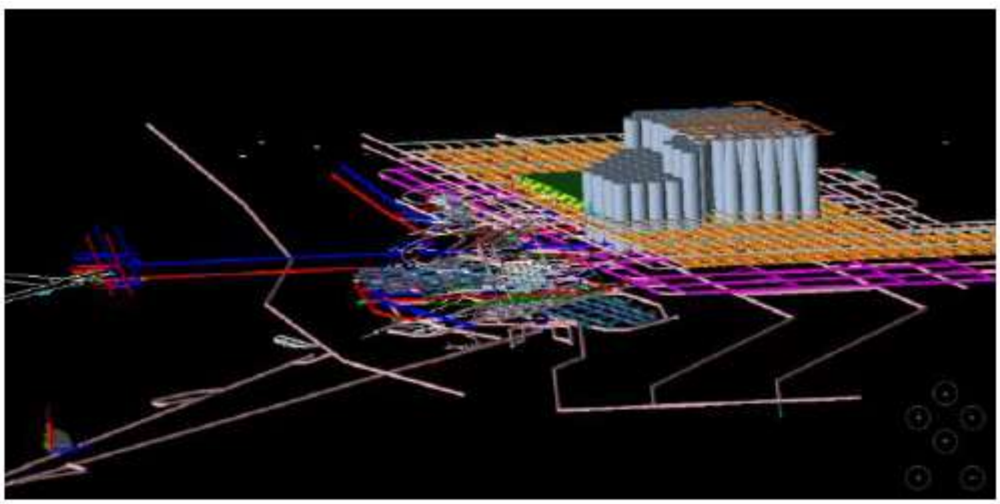


Figure 9 Project 3D Visualization. Source: Personal compilation.

- Dynamic reporting. The platform delivers the ability to generate dynamic reports according to the requirements and attributes of each project, previously defined and loaded into the online system.

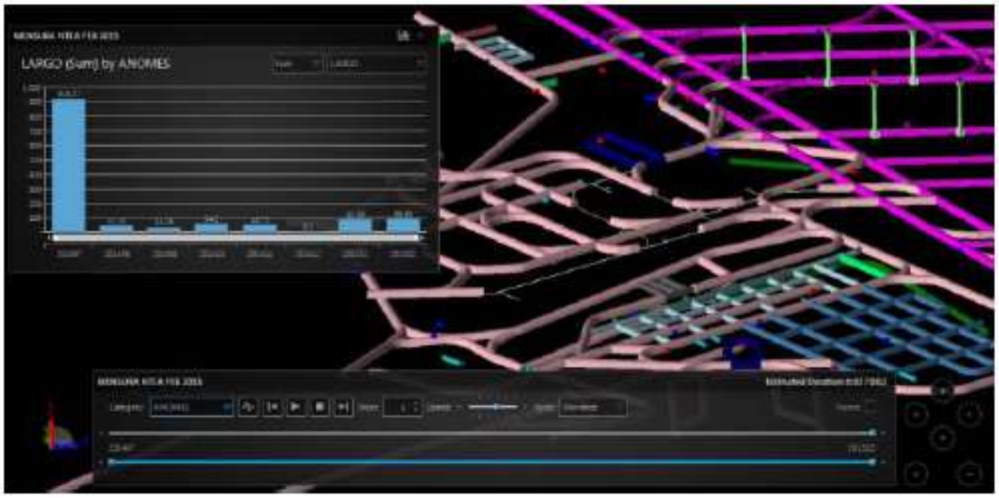
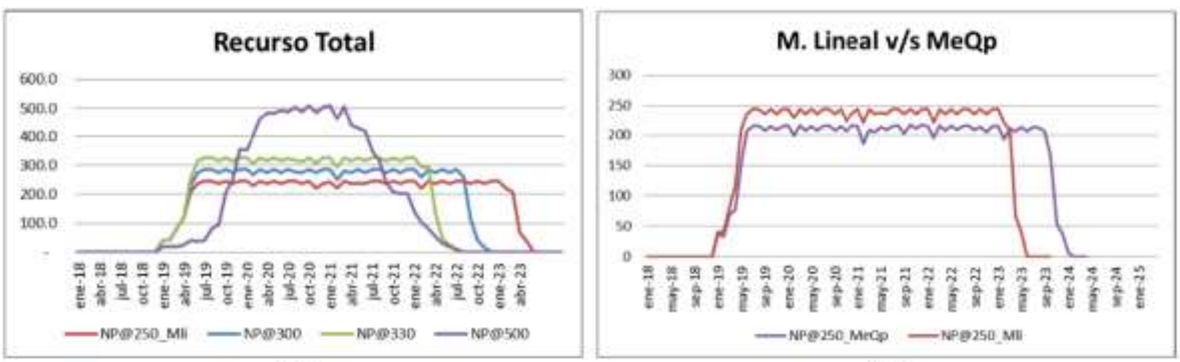


Figure 10 Dynamic reporting (performance, overbreak). Source: Personal compilation.

Analysis capability

This integrated system can generate analysis that allows decisions making on multiple scenarios that may arise during construction of a project. To show analytical skills assessment, scenarios were considered using a current project of Division El Teniente.



(a) (b)

Figure 11 (a) Resource levelling considering different performances. (b) Analysis of performances considering equivalent meter for the equipment. Source: Personal compilation.

- Analysis on the amount of resources allocated to the development using the sensitivity tool for assigned resources (equipment, performances, working teams) to identify which one distributes optimally the available equipment.

The figure 11 (a) shows how the projected completion date of a project varies depending on the amount of resources allocated. The base case (in red) has an overall yield of 250 meters per month per equipment. As this performance is increased (by the incorporation more resources) the termination date decreases, however, there is a point (purple curve) when the date is stops decreasing even when there are more resources assigned. This analysis points out the optimal number of resources considering as a restriction the number of fronts available for work.

- Resource allocation, considering equivalent distance performances

In Figure 11 (b) the base case consider a performance of 250 meters per month, this 250 m are independent of the type of gallery and gives us an end date by May. When performing the same exercise, but with 250 equivalent meters performance per month, that is, considering an advance of 250 meters according to the gallery has more experience, the construction plan increases by six months its deadline.

CONCLUSION

Photogrammetry of underground development is a key technology successfully being used in Teniente mine as an key enabler of mining applications oriented to improve the integrated mine planning.

However, the implementation of an integrated system requires the definition of processes and general standardization of working methodologies at different stages. This methodology is based on achieving information about the mine that helps manage in a different scenarios and set traceability of changes (design, resources and performance measurable).

The standardization of engineering process related to integrated management mining preparation, is the basis for having simple and scalable information that will generate a methodology understood by the team in charge. Additionally, this allows the creation of a common database for multiple projects, so that the information about these can be crossed and analysed effectively, quickly and in a comparable way by multiple users and stakeholders.

Furthermore, the definition of standards must identify key parameters such as those responsible for each area and information such as the allocation of resources and critical performance activities. Finally, inputs, outputs and timelines should be considered for each stage of the process, understanding that is essential to achieve an agreement among all engineering teams associated with the development of the project.

NEXT STEPS

The corporation has upcoming challenges such as achieving a major capturing of online information and technological effects on equipment and performance to empower decision against multiple scenarios or uncertainty.

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