IMPLEMENTING LAST PLANNER IN OPEN PIT MINING PROJECTS: CASE STUDY

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ABSTRACT

Surface mining operations have particular attributes resulting from geological variability. This paper aims to show improvements gained from the implementation of the Last Planner System (LPS) in open pit mining. Lean Construction concepts and principles had never previously been implemented in this kind of heavy civil construction project in Peru. With the Last Planner System of production control implemented, it is anticipated that productivity will improve as well as planning reliability (Ballard and Howell 1997) to match the degree of variability in the project's characteristics. This is likely to help the company currently under analysis, GyM, to increase efficiency and generate value in clients and stakeholders of all surface mining projects. The best practices in planning and operations control have been collected from two case studies, the Shougang and Brocal projects, in which there was successful implementation of Last Planner System (LPS) in big surface mining services carried out for GyM. This paper will analyze results from both, and propose adequate means to a sustainable LPS in all open pit mining projects.

KEY WORDS

Open pit mining, Last Planner System, Implementation, Management System

INTRODUCTION

Mining activity in Latin America and Peru has represented one of the region's main sources of income ever since ancestral times. In 2010, there was investment of more than 4 billion dollars in mining operations, almost 70% more than the previous year (América Economía 2010). Although major economic emphasis is given to the sector, there hasn't been a clear effort to conceive better practices in the production management system, hence the importance here of implementing a Lean approach.

The Last Planner System focuses in improving productivity and reliability in weekly work plans in order to conceive production as a work flow process for generating value for customers (Ballard 2000). GyM Contractors have moved towards implementing a Last Planner System approach in two open pit mining projects: Shougang and Brocal. The main approach to its implementation was to focus on the interrelation between the areas of Production and Support, and so involve the Support Areas in the LPS system.

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GyM has already formalized a project management system, inspired by Lean Construction principles, for all projects. Based on this, work has focused on analyzing results from the initial Shougang and subsequent Brocal projects, in order to find a way of developing a customized management system for open pit mining projects. It has been necessary to adopt a strategy for building a strong interrelationship between Production and Support Areas with a profound link with the LPS system.

It is commonly known that Open Pit projects are heavily influenced by geological changeability potentially compromising planning and control. Current management processes react to this instead of making efforts to anticipate it. Furthermore, it is the case that, these kinds of project are usually located in remote and difficult areas, bringing about numerous challenges to supply management. Almost all work relies on equipment performing correctly, hence the importance of focusing on the Equipment Support Area.

SHOUGANG AND BROCAL: TWO CASE STUDIES

The study was carried out in two different projects of GyM, a large-scale Peruvian construction firm. One project was carried out in the Nazca Desert, at the Shougang iron surface mine between August and December 2009. The other was held at Cerro de Pasco, at 4300 metres in the Andes, at the Brocal copper surface mine between June and August 2010.

A DIFFERENT VIEW OF SUPPORT AREAS

The first implementation process, carried out at Shougang, was developed according to Lean Principles. The first problem identified was a lack of collaboration and a deficiency in information transparency. Production was acting separately from its Support Areas and there was no established, formal means of communication. After collecting information relating to the production management system, there was a need to implement an In-process planning routine (Izquierdo 2011), in accordance with GyM´s project management system, whereby a formal communication of constraints identification and follow-up was established. Figure 1 shows the interrelations between Production and Support Areas.

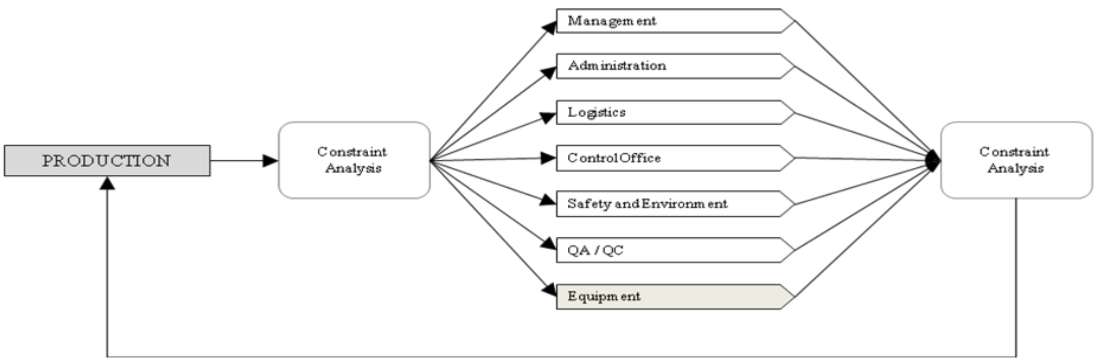

Figure 1: Common relationship between Production and Support Areas

To carry out the Last Planner System in Open Pit Mining, it was important to highlight equipment as the most important resource for global project performance.

The main constraint of Production is to operate with the correct amount of equipment, on time and without breakdowns. So, as a solution, an In-process planning routine was settled upon with equipment viewed as another Production Area (Operations). Thus, Production and Equipment worked together in operation planning (Figure 2), developing Lookahead, Constraint Analysis, Weekly Work Plan and PPC. The relationship shown in Figure 2 came about as a solution to ensure work flow in the production management system, expanding the LPS into Support Areas.

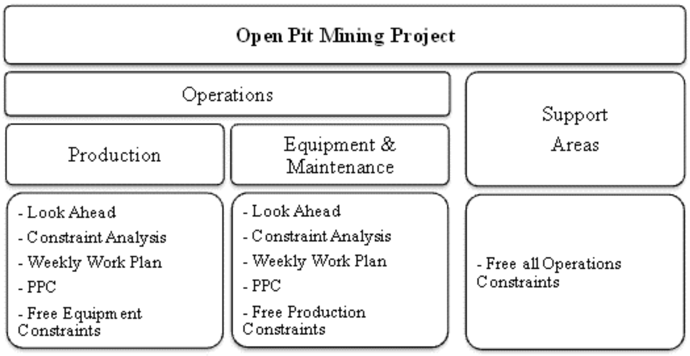

Figure 2: Open Pit planning structure and responsibilities based on LPS

The first step was to develop production planning. The key element in this exercise is to identify equipment as the main focus of success for scheduling completion. Production needs Equipment in the field as scheduled and Equipment needs to be able to anticipate Production. Taking Shougang and Brocal, the main constraints in Equipment where found in:

- Spare parts supply
- Subcontractor repair services
- Labour Force

In addition, it is important to define from the beginning a clear supply chain plan. The Logistics Area in the project is the most important Support Area for Equipment workflow.

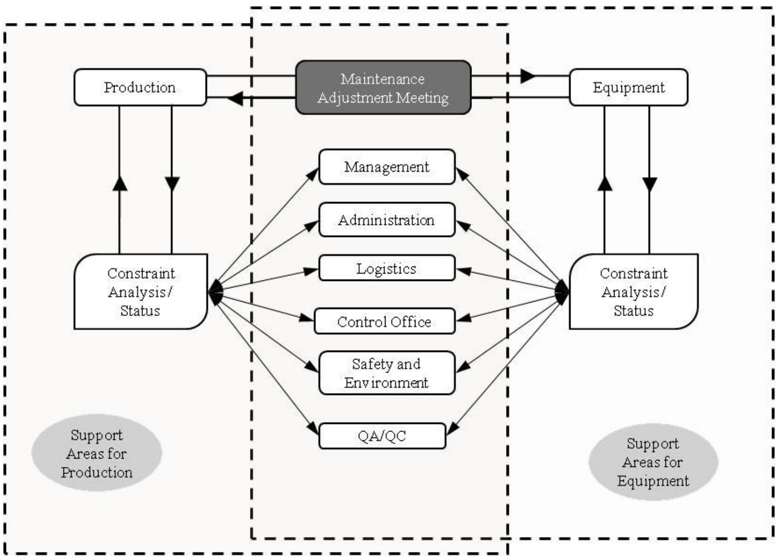

Figure 3: Open Pit area interrelations

Nevertheless, for all areas to work properly, the relationship between Production and Equipment had to be intense and dynamic. We found in Shougang that there was weak communication between these, since they were working separately and there wasn´t a clear vision of the problem. The solution was a clear view of the interrelations between areas. Figure 3 shows clearly how Equipment is treated as an Operation Area and how constraint analysis is established. A vital observation is that Production and Equipment should have a Maintenance Adjustment Meeting. This is a prior meeting to communicate and discuss Equipment Lookahead in order to adjust it to the Production Lookahead and identify all needed to achieve reliable planning.

PLANNING & CONTROL IN OPEN PITS

PRODUCTION PLANNING

Production was responsible for planning completion. The heavier issue in this exercise is to deal with rock variability. Therefore, a general schedule was too difficult to perform in addition to client's continuous changes in planning. However, a general schedule was performed indicating mine durations in each sector, material quantity and corresponding dump. In Shougang, every 3 months, the client delivered a new plan and the general schedule was updated.

In this way, Production Lookahead horizon couldn´t be too long because of planning changes that could occur along the way. Variability and lead times for repair parts were the key element to consider when defining the number of weeks of Production Lookahead. The method followed for the Lookahead process was detailing the general schedule. The assignments in the Production Lookahead had to be detailed with each type of material and quantities. Figure 4 shows an example of Production Lookahead were each assignment corresponds to a specific level, dump, sector and certain equipment involved.

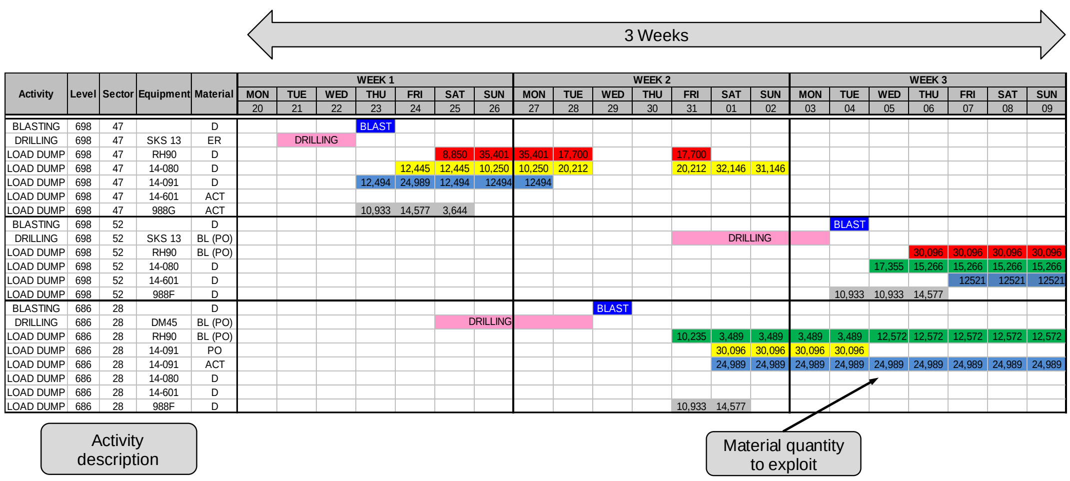

Figure 4: Production Lookahead

In order to complete assignments as planned, it was necessary to assure resources such as material, equipment and personnel. Most of the personnel in Open Pits are equipment operators and some are mechanics. The most important feature to control is equipment. Therefore, PPC's most important elements to control are Logistics and

Equipment. Each cause of incompletion was specified. For every cause there was a specific corrective action proposed.

EQUIPMENT PLANNING

As stated before, equipment is the most important resource for Open Pit projects. This is why it was essential to have a reliable Equipment Plan. The Equipment Area also developed a detailed Lookahead, taking into account the following:

- Type of maintenance and frequency
- Lead time for repair parts for each type of maintenance
- Maintenance shouldn't interrupt production work flow

There were three types of maintenance:

- Preventive Maintenance (PM): This was developed when equipment reached a certain number of working hours (e.g. 125, 250, 500 machine hours). The idea was to prevent any failures.
- Predictive Maintenance (PdM): This was developed when failure was predicted through oil analysis, field observation and wastage.
- Corrective Maintenance (CM): This was developed to deal with equipment failure.

The same horizon of weeks in the Production Lookahead was considered in the Equipment Lookahead, with all preventive and predictive maintenance and, where possible, corrective maintenance taken into account. Figure 5 shows an example where description, equipment code, date and type of maintenance were included.

Item	Machine		WEEK 1							WEEK 2							WEEK 3						
	Code	Description	MON 20	TUE 21	WED 22	THU 23	FRI 24	SAT 25	SUN 26	MON 27	TUE 28	WED 29	THU 30	FRI 31	SAT 01	SUN 02	MON 03	TUE 04	WED 05	THU 06	FRI 07	SAT 08	SUN 09
1	54-006	DRILL SKS					PM2000						PM125										
2	54-902	DRILL DM45		PM125						PM250						PM125							
3	14-079	EXCAVATOR CAT 365C	PM250						PM125						PM1000								
4	14-080	EXCAVATOR CAT 365C		PM125						PM250						PM125							
5	14-601	EXCAVATOR CAT 365C		PM125						PM250						PM125							
6	16-046	WHEEL LOADER CAT 988F	PM125						PM250						PM125								
7	11-135	MINING TRUCK 773D	PM1000							PM125							PM250						
8	11-137	MINING TRUCK 773D			PM125							PM1000							PM125				
9	11-138	MINING TRUCK 773D					PM250							PM125							PM500		
10	11-139	MINING TRUCK 773D	PM125							PM500							PM125						
11	11-140	MINING TRUCK 773D				PM1000							PM125							PM250			
12	11-141	MINING TRUCK 773D	PM500							PM125							PM250						
13	11-258	MINING TRUCK 773D		PM125							PM250							PM125					
14	11-259	MINING TRUCK 773D							PM500							PM125							
15	11-264	MINING TRUCK 773D					PM125							PM250							PM125		
16	11-265	MINING TRUCK 773D							PM500							PM125							PM250
17	11-266	MINING TRUCK 773D		PM125							PM250							PM125					
18	13-131	TRACTOR CAT D8T						PM500								PM125							
19	13-600	TRACTOR WD500				PM125							PM500							PM125			

Figure 5: Equipment Lookahead

After the Lookahead process, it was necessary to define all repair parts needed for preventive maintenance. From this Lookahead, it was possible to identify automatically which parts were needed in the following weeks. This identification wasn't carried out in the Shougang or Brocal Projects. During the implementation process, repair parts were established for each type of preventive maintenance and equipment. This was consolidated in a Lookahead for repair parts called Material Lookahead.

For predictive and corrective maintenance, it was necessary to identify required dates and types of repair parts needed to repair the equipment. A repair part mechanism called the RQ (Requirements) format was developed.

During each week it was possible to determine which type of maintenance was going to be performed, depending on which repair parts were available. At the end of the week, reliability of the plan was measured studying which maintenance was performed or not performed in accordance with the Equipment Lookahead, through a PPC analysis, shown in the Operations Meeting according to the In-process planning routine.

IN-PROCESS PLANNING ROUTINE

The best way to involve all areas was through formal means of communication via meetings between Operation and Support Areas. In Open Pits, it was better to have a primary meeting for maintenance plan adjustment, in which the Equipment Area presented their Lookahead indicating required dates for equipment repair and time for respective maintenance. This meeting was held between Production and Equipment Areas only. The purpose was to coordinate maintenance, anticipate and make changes by bringing forward or delaying maintenance. The main idea was to never interrupt work flow process. After this adjustment, Production was able to develop their Lookahead.

After both the Equipment and Production Lookahead, an Operations Meeting was held during which all constraints were consolidated, with Support Areas notified afterwards. Finally there was a Project Meeting in which constraints status was analyzed and Support Areas were responsible for freeing-up operational constraints.

EQUIPMENT PERFORMANCE CONTROL

It was necessary to carry out an equipment inventory through key performance index or KPI. These indicators allowed:

- Equipment status analysis
- Productivity, cost and maintenance status
- The taking of corrective action

For accurate KPI it was necessary to acknowledge equipment hours and distribution as shown in Figure 6.

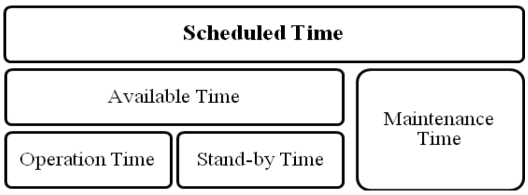

Figure 6: Equipment - hour distribution in Open Pit mining

The KPI´s were as follows:

- Operability (Op): Percentage of time during which equipment has worked, considering total work and maintenance hours
- Availability (A): Percentage of time during which equipment is in condition to work
- Utilization (U): Percentage of time during which equipment is available and working
- Mean Time between Shutdowns (MTBS): Average operating time between machine stoppages
- Mean Time to Repair (MTTR): Average downtime for machine stoppages

KPI were analyzed week by week in the Operation Meeting. If any of these were out of range, immediate corrective action was taken in order to optimize equipment use. In order to assure work flow, it was necessary to analyze the project's equipment supply chain.

EQUIPMENT SUPPLY

Before LPS implementation, production work was delayed because of breakdowns in equipment without adequate maintenance. Repair parts weren't arriving on time and there was insufficient stock.

The projects established three methodologies for requesting repair parts: Min/max Stock, Material Lookahead (ML) and Requirements (RQ). The last two depended on which type of maintenance was performed.

Material Lookahead stands for the repair parts needed for preventive maintenance, while Requirements (RQ) stands for the repair parts needed for predictive or corrective maintenance. Materials with a high rate of rotation, such as grease, oil, lubricant etc, were then identified. The main objective was to have a permanent stock of high rotation elements which wouldn't appear on the ML or RQ. Logistics checked stock frequently and assured this process with automatic purchase orders when reaching a minimum stock.

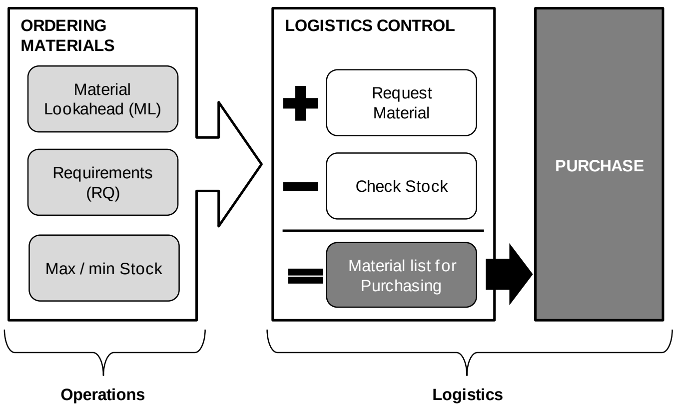

Figure 7: Equipment Supply Methodology

Logistics was responsible for consolidating and verifying stocks, as shown in Figure 7. Logistics presented a weekly status, including date required on project, description, etc. This status was necessary in order to update Equipment Lookahead.

RESULTS

RELIABLE EQUIPMENT SUPPLY

Before LPS implementation, ware house stock (Figure 8) was budding since repair parts were ordered individually, without considering the entire maintenance package. Ware house was troubled with stock traffic, having lots of repair parts unused waiting for other parts necessary to complete maintenance packages. Also, duplicity in orders and lack of control were identified as a result.

Maintenance Items	Jun-09	Jul-09	Aug-09	Sep-09	Oct-09	Nov-09	Dec-09	Jan-10	Feb-10
Wear Parts	339817.01	298990.08	339648.08	463635.75	452001.82	490806.78	433025.11	416458.92	303690.44
Equipment - Filter	187840.46	289166.62	261474.92	249354.44	257858.01	236852.52	225000.23	227036.81	270682.67
Equipment - Lubricants	74544.91	204196.58	300781.14	303141.62	303500.58	295950.79	296661.23	281734.93	204699.70
Equipment - Tire	291902.30	472100.34	143913.43	273579.11	184277.75	59714.85	290613.23	271773.83	357367.10
Equipment - Spare Parts	1219890.29	1151696.22	1749977.25	2354258.65	2315673.11	2483864.83	2780249.58	2694521.66	2390995.40
Equipment - Undercarriage	79411.73	14962.27	193337.83	190851.53	37064.31	26559.30	25534.80	24885.65	22245.37
Total	**2193406.70**	**2431112.11**	**2989132.65**	**3834821.10**	**3550375.58**	**3593749.07**	**4051084.18**	**3916411.80**	**3549680.68**
Mean Lead Time (days)			**2.14**	**3.13**	**3.07**	**4.30**	**4.30**	**5.46**	**5.55**

Figure 8: Shougang's Maintenance Stock Value

Analyzing the period between June and September (Figure 9) stock value had an increasing tendency. During LPS implementation, an RQ order was established and quickly was able to stabilize stock's (Figure 10) and later reducing it. There was a positive effect in the economic impact of the project, assuring all scheduled maintenance being held on time having all correct repair parts packaged. As shown below on Figure 10, the bold purple line shows Lead Time rises with this effect allowing more anticipation time in Look Ahead planning.

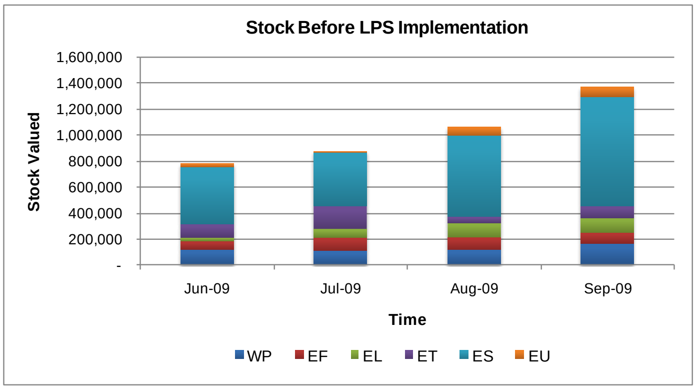

Figure 9: Stock Valued before LPS implementation in Shougang

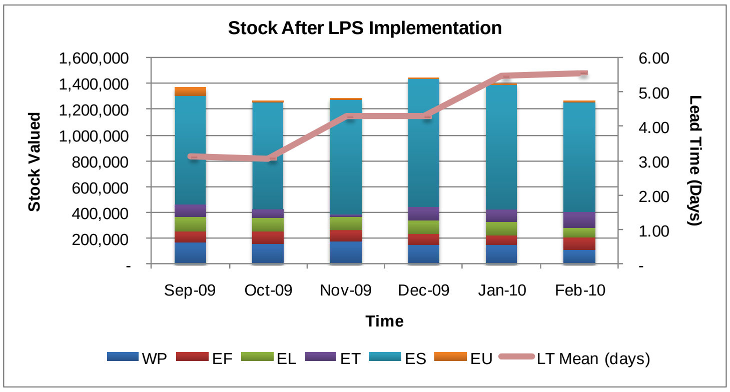

Figure 10: Stock Valued after LPS implementation in Shougang

As mentioned, these results are tangible in logistic improvement in Shougang. However, the LPS implementation is best seen in the efficiency improvement.

EFFICIENCY IMPROVED

An efficiency ratio was defined as resources used over project progress. As surface operations are based on equipment efficiency, a common indicator is cost per bench cubic meters advanced. A ratio cannot be calculated as MH / BCM (Machine Hours / Bench Cubic Meters) because efficiency differs between different types of equipment. A common ratio is to calculate how many dollars are invested per cubic meter advanced (US$ / BCM).

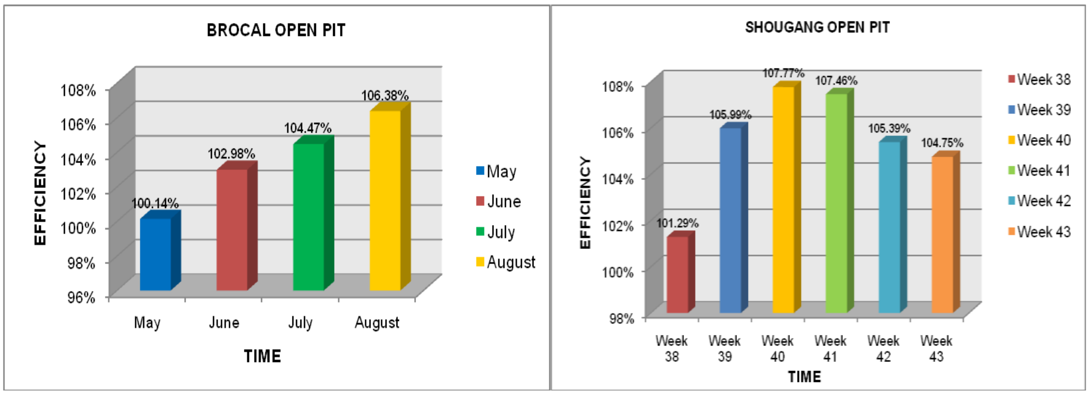

Figure 11: Efficiency evolution in both Shougang and Brocal projects

Thus, if efficiency increases, it means operations are improving. In both Brocal and Shougang, implementation of LPS with an Equipment view (elevating Equipment as another Operation front), improvement in planning with Equipment and Maintenance LA and RQ implementation gave room for efficiency improvement. This was achieved with higher levels of operability and fewer equipment failures, as shown in Figure 11.

RELIABLE PLAN

At first, developing a Lookahead was very complicated. Engineers stated that because of rock variability it wasn't possible to develop a reliable Lookahead. After analyzing PPC and Causes of Incompletion it was discovered that the main source of incompletion involved planning mistakes to a greater extent than geological variability.

After LPS implementation it was possible to achieve a more reliable plan and therefore efficiency also improved as shown in Figure 12 below.

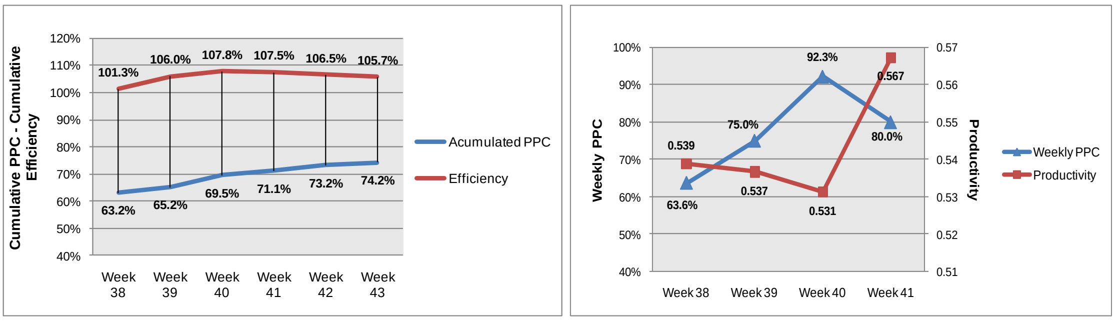

Figure 12: PPC, Efficiency and Productivity in Shougang

The direct relationship between reliability, efficiency and productivity in Shougang shows that a customized management system can bring continuous improvement in the way that surface mining operations are managed.

CONCLUSIONS

The common goal of mining firms in Peru is to maximize utilities exploiting mineral in big quantities and to optimal degrees. In a general contractor firm, the goal has to be shared; the main purpose is to add value to the client while being efficient in the operation. Efficiency will reduce costs without necessarily adding value to clients. For this to happen, an integral workflow vision achieved with LPS is essential, avoiding equipment shutdowns, excessive stand-by hours and reduced operability. In this matter, the application of the LPS shown in this paper is valid to all firms providing open pit mining services.

Implementing LPS in mining services could bring about competitive market rates. This is necessary for contractor firms; otherwise, the same mining firm could carry out the service by itself.

It is important to highlight the importance of the application of Lean Principles in a different kind of project. This allowed improving workflow production process and identification of key elements in this kind of operation where equipment is fundamental to operation success. There was a streamlined communication in which Production, Equipment and Support Areas integrated efforts in a formal communication process with the In-process planning routine (Izquierdo 2011).

Efficiency ratios rose through LPS implementation and resulted in project cost savings. It could have a positive impact in the future of the mining industry, and in future, clients could request a standardized management system as part of a bid policy.

The limited number of case studies made it difficult to draw certain conclusions. Nevertheless, it was possible to develop a customized management system for Open Pits through LPS implementation on these projects and based on the present paper.

Variability on this kind of project has a negative impact on planning and can frustrate the production team. It should not be a reason not to implement a Last Planner System. Lean helps to improve process efficiency and reliable planning even though it was never previously applied to surface mining projects in Peru.

ACKNOWLEDGMENTS

We thank Carlos A. Lepesqueur for his original ideas and leadership efforts when implementing Lean in Open Pit mining operation projects.

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