Process Innovation by Working Miners: A Case of User Innovation in Copper Mining Industry.

By

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ABSTRACT

Employees are known to develop and use key process improvements. In this thesis, I explore innovation by mining employees working in Codelco, a Chilean mining company. The data on these innovations come from a contest sponsored by mine management at the Andina division of Codelco. This contest encourages workers to come forward and reveal the improvements they have made.

The research method used for this case study is based on data and information collected from interviews with managers, workers and members of the contest organizing committee. In addition, a survey was given to more than 50 workers involved in the current version of the contest, to evaluate and analyze their interests and motivation drivers to participate in the contest.

One of the main findings is that more than 10% of total workers do behave as user innovators, and 85% of the survey's participants have created at least two innovations at Andina. For the workers, the main reasons to participate in the contest are making a contribution to the company, to develop a deeper knowledge in a specific topic, and also to be recognized by family, colleagues and managers.

The key lessons of this case study are that user innovations in the copper mining industry do happen, and creating the right incentives for workers to innovate and share their innovations, can increase their motivation, performance evaluation and add value to their company and the industry.

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Industry Background

The copper mining industry is affected by the volatility of copper prices. When the price is high, there is a higher gross profit. In addition, new explorations, new projects, expansions and reopenings are activated, and the main concern is to reach the highest levels of productivity. On the other hand, when the price is low, there is a decrease in gross profit, as well as investments in explorations, postponement of projects, and closing of high-cost operations, with the main focus on keeping the costs under control.

Copper demand estimations are increasing, and the main focus is on raising production levels and productivity, avoiding failures, interruptions or "distractions" in the process. This emphasis reduces the possibilities of encouraging a "trial and error" culture, and of supporting creative ways to solve operational problems by the miners.

The largest producer of copper in the world is the Chilean state-owned corporation, Codelco. It is the largest company in Chile and plays a key role in the country's economy and development. In 2011, they produced 1,735,000 *tmf* equivalent to 10.7% of the world mining production. Codelco has 6 operations: Chuquicamata, Radomiro Tomic, Salvador, Andina, El Teniente, and Gabriela Mistral. Andina Division accounts for 13% of Codelco's production and in 2011 with 234,000 *tmf* and

it was the division with the highest increase in production equivalent to 24% y/y (Codelco Results January-December 2011). With the new expansion of its operation, it is expected to produce more than 650 thousand *tmf* by 2016. Currently they have approximately 5,500 workers, composed of 1,500 of their own workers and 4,000 contractor workers.

Innova Award Contest

A Description of the Contest

Since 2004, the Andina Division of Codelco has been running the Innova Award, an annual contest that aims to generate opportunities for all the people, who work in the Division to improve their processes continually and creatively, with a focus on working quality, safety, care for the environment, cost reduction, increased productivity, and automation of duties. Innova is a way to encourage a culture of innovation within the entire organization.

Innovation starts with the workers and contractor workers, even before they have been invited to participate in the contest. To tackle problems in their daily work, with their own resources, they develop a solution that aims to produce a significant impact on the organization and operation of the mine. During this period, they go through a trial-and-error process until they find an acceptable solution, and then they implement it. In parallel, they share their ideas and improvements with their unit's manager.

The contest started in 2004 with 93 projects submitted for evaluation. In 2011, they reached 185 projects, and by 2012, they expect to have 244 projects presented for evaluation. In the case of each project innovating workers, with the support of a mentor, prepare a presentation about their operating innovation project. This presentation has a defined structure and includes the authors of the innovation's

project, and the area; the required inputs, the unit responsible of the operation, expected results and KPIs; a definition of the problem they are facing, considering the impact on the results of the operation and KPIs; definition of possible solutions, and selection of the final one; and the impact and results after developing and deploying it.

A management jury, composed by the manager of the area (e.g. mine, plant, infrastructure, etc.), management staff and joint committees of the area, select the final participating projects. Then a divisional jury, composed by the general manager of the division, the executive committee, unions' representatives, and joint committees' representatives, evaluate the projects. For every 10 projects presented by each area, the jury selects one that best accomplishes the evaluation criteria.

The evaluation of the jury is based on four criteria: creativity and innovativeness, value added to the business, sustainability, and preparation and presentation. After this evaluation, the best projects from each area go to the second and final stage.

In this stage, the workers gather more information regarding the impact of the project and present their work, showing economic, safety and environmental impacts, and other relevant results to the divisional jury, which selects the four best projects, which are the winners of the contest.

Usually the first stage runs from January to June, and the second stage goes from July to October.

The contest finishes in November with a celebration dinner for all the participants of the contest where the winners are presented. Each of the winners receives a paid one-week vacation in a set place within Chile, for himself and his partner. Although this prize is exceptionally well recognized, workers' main motivations to participate in the contest is to have the opportunity to be recognized for their work, sharing it with key people of the organization, especially with higher management, with whom do not interact frequently.

This contest is an opportunity to facilitate innovation by end users, allowing them to share the problems they have, and the solutions they built, as well as the value they are adding to the company; they also value receiving recognition for their contributions. In addition, it allows them to understand their needs and the problems and restrictions of a feasible solution. Once most of the workers have participated in the contest, they want to apply again, using the contest to communicate their contributions to the business, with recognition and new career development opportunities.

During the 8 years of the Innova contest, 750 projects have participated, involving more than 2,200 workers, and generating an estimated value of $ 100 million for the division.

How the Contest Works

Aligned with Andina Division's perspective, the Innova contest aims to generate opportunities for all the workers, by improving their processes continually and creatively, with a focus on working quality, safety, care for the environment, cost reduction, increase productivity, and automatization of duties.

In this sense, this division has worked to improve workers safety, and in 2011, it achieved the lowest accidents frequency rate of 0.93 accidents over 1 million worked hours in all Codelco's divisions. In addition, Andina is the division with the lowest direct CO_2 emission levels, reaching 82,000 metric tons per year.

What the Innova contest has done is to position this focus and challenge every worker at Codelco Andina.

It has helped to involve and include everyone in the organization to think of their problems, and then take the lead to find ways to solve them. Considering that Andina Division has approximately 5,500 workers, in the last two years more than 10% of the workers have participated in the contest, and 2,200 workers have been part of the history of the contest. There is no evidence in the mining sector in Chile of a similar or higher participation rate with deployed projects.

The information about projects and participants of the Innova contest, in its 8 years of operation, shows a high number of projects the first two years. In the next

four years the number of participants decreased considerably, but in the last two years, they quadrupled the number of projects. The detailed evolution in the number of projects and participants of the contest is shown in the following table.

Table 1: Innova Contest

Year	N° of Projects	N° of Workers Involved
2004	93	280
2005	80	240
2006	51	153
2007	57	171
2008	45	135
2009	41	123
2010	197	585
2011	185	555
Total	**749**	**2,242**

The average number of participants for each project is three workers. In most of the cases, they are from different units within an area, for instance, operations, maintenance and safety.

At the beginning of each contest, the general manager sets the number of projects for the following version of the contest. In order to align this number with the deal flow of projects, the managers of the areas are responsible to provide a minimum distributed number of projects based on the defined total number of

innovations. In 2011, the number of projects was 185, and for 2012, the expected number of projects is 244.

Components of the Contest

In every project, there must be a leader position who is responsible to define, articulate and execute the projects steps. The Innova contest is no exception. This person is one of the key components for its success. Therefore, the leader of the contest has to be well known and has a well connected network within the company. He knows the organization's structure and the stakeholders recognize his position in the contest.

He is responsible for reaching the target number of innovation projects, articulating the different participants of the contest to play their role at the right time. He is in charge of promoting the contest, coordinating the activities and setting the time to present and evaluate the projects, together with the final awards ceremony. Lastly, he defines and arranges the prizes for the winners of the contest. He is permanently engaging workers to participate in the contest.

The leader who has been responsible for the Innova contest since 2004 is Juan Giuliano. He has worked for Codelco in Andina division for 31 years. For the contest,

he reports directly to the general manager and the manager of the Health and Safety Area.

Another key component of the contest is the general manager and managers of the areas (represented by mine, plant, projects, services, and sustainability). Considering the hierarchical structure of the organization, if the general manager is committed and involved in the contest together with the rest of the managers, then the rest of the organization is more open and interested in being part of it. Analyzing the history of the contest, the participation and follow up performed by the managers of the areas is directly related to the number of projects presented by their units. The same situation occurs when the general manager shares the importance of the contest and requests updates from the managers about participation in their areas.

Unions and joint committees play a decisive role by supporting the contest and promoting it in their activities with the workers. In addition, their representatives are part of the evaluation committee. Their support is a key factor for the success of the contest.

Supervisors and contest area leaders are in charge of finding and collecting the potential participant projects, and encouraging the workers to take the lead. They have direct communication with the contest leader to inform him about the participants, and the questions from the workers, and to suggest actions to increase

participation in each area. In addition, they participate as tutors of projects by helping the workers build and prepare their presentation for the contest.

Workers are the central component of the contest. Although they voluntary apply to the contest, they commit with themselves to find and build a solution for their problem, and then commit with the company to prepare and share their experience and its contribution. By word of mouth, they promote the contest with other workers and their feedback allows improvements for the contest and its process.

During the process of the contest, there are elements that help give it a positive outcome. The first of these elements is the evaluation process and selection of projects. It has to be explicitly explained to all the participants and be clearly understood by them. Any doubts or weaknesses of the process can damage the credibility and reputation gained.

A second element is to define and deploy a permanent strategy of promotion of the contest, targeting the workers as the main audience. This promotion keeps alive the interest in the contest and helps to trigger the problem-solving approach with the workers.

The last element is to collect the comments and experiences of the workers. Generally, the final result of this task is the creation of a book with all finalist

projects and authors, including messages from the different stakeholders, and a promotional video that is shared within the organization in different social activities.

Innovation Examples

The following examples represent a selection of innovations that have been part of this contest.

Fat Containers

One of the crushers of Codelco Andina needs permanent lubrication, and for that purpose, they used a 180 kilogram barrel of fat, which needs to be moved more than 300 meters and elevated more than 15 meters to the top of the crusher. The workers performed this task 3 times a day (for each shift), for more than 30 years (Figure 1).

Some workers began to think about how to change the way they feed the crusher's lubrication system with fat. The change they designed involved replacing the barrels with containers. They installed one container in the top of the crusher with an oil pump engine (Figure 2). In addition, they contacted the fat provider and asked them to change the way they supplied the fat to the mine from barrels to containers. The fat providers changed to bringing a container to the entrance of the

crusher's chamber, and operators in the mine then connect the container full of fat with the one in the top of the crusher.

With this improvement, mine operators could saved more than 80,000 kilograms of fat the first year. One of the main causes of this result is that barrels always kept some residual fat (up to 1/4 of a barrel), a loss that disappeared with the containers and pumps. In addition, the two workers in charge of moving the barrels increased their productivity and could do other activities.

Figure 1: Old Barrel of Lubrication

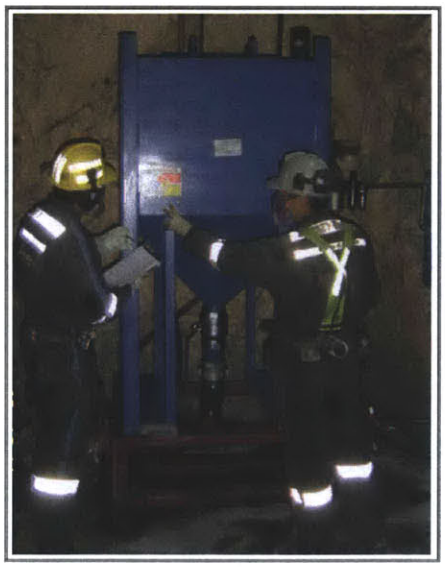

Figure 2: New Container for Lubrication

Portable Metal Detector

In most of the mining operations, the machinery that picks the large rocks has buckets with teeth that grip the rocks (Figure 3). The problem is that these teeth can break during operation, and then they fall with the rocks into the crushing process. As the teeth are much harder than rocks, they can then stop the crushing machines from working properly and so produce losses for the operation.

To prevent damage to the crushing machines, the mine had installed large metal detectors that would automatically stop the belt when they identified metal in the rock stream moving past them. The problem that remained was that these stationary detectors did not indicate precisely where the metal was so that it could be found by workers and taken off the belt. So the belt operator had to search for the metal and find it to make the belt work. This situation resulted in a loss of 3 hours per day of operation of the belt.

To solve this problem, operators looked for current solutions to detect ferrous elements and locate them within mining operations. They were able to find a metal detector for mining belts for almost $2,000. The restriction of the machine was that it required maintenance every two months. Then, they realized that a portable metal detector like the ones used in airports, could solve the problem remarkably quick, since it did not require maintenance and or specialized training, and economically, since its cost was 95% lower than to the total cost of the mining detector.

They tried the device, and it performed well. They reduced the time of belt stops to 1.5 hours per day, which is equivalent to $4 million in savings over five years.

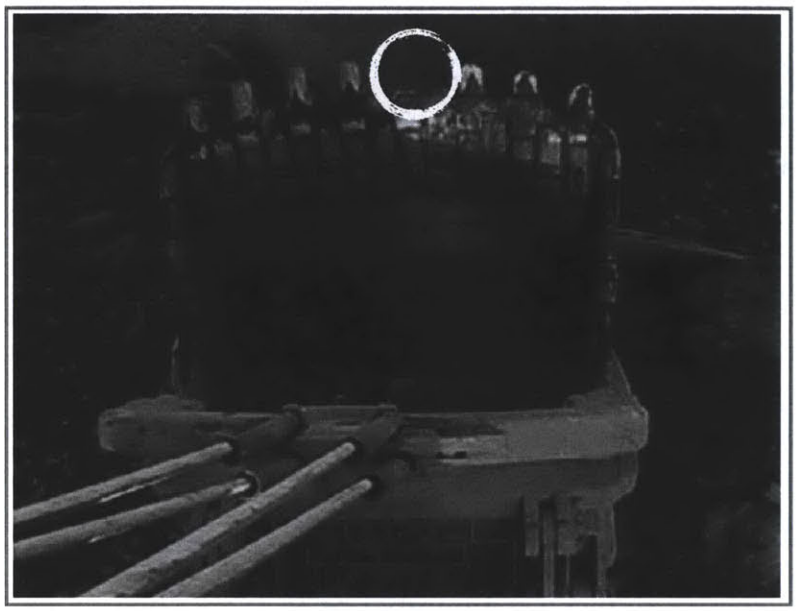

Figure 3: Missing tooth in Shovel's bucket.

Design change of Belt in Plant Operation

The heap leaching of copper normally requires a comminution process. This is performed to optimize copper recovery through achieving the proper size of rocks, which depending on the ore is between 6 and 20 mm.

If the trucks cannot get directly to the primary crusher, then belt conveyors move the ore rocks. This belt connects to other belts to get the rocks into the primary crusher. When one of the belt conveyor stops, due to a metal detection in the belt, the inertia produced by the rocks makes the belt keep moving for almost 15

seconds, which means almost 35 meters of displacement. This situation causes the second belt to get congested with a pile-up of rocks, in some cases enough to drop mineral to the floor. This problem forces the belt's operator to go to the place of congestion, and clean the area. It was one of the causes for not achieving production program goals, and thus generating collection losses of up to 5,000 tons of mineral per day.

Operators found a way to avoid this congestion by building a dynamic brake that synchronized the stopping of the belts. Building and integrating a PLC they could test and try the right timing to control the stops of both belts and avoid congestion. This change reduced the number of accidents due to non-planned maintenance in belt damages, kept production places clean, decreased production losses, and decreased cleaning and maintenance costs. The estimated net present value of this innovation was $ 5.4 million for 5 years using a discount rate of 8%.

Unobtrusive Measurement of Incrustations in Ducts

Water is a fundamental source throughout all the copper production process. Water is used in flotation beneficiation, smelting, and electro-refining. In addition, it is used to wet roads and suppress dust. Lastly it is used for domestic and human purposes like drinking, and bathing. Water is transported through pipes. Due to the alkaline nature of water, including chemicals such as calcium, it produces

incrustations in these ducts. This situation has a direct impact on a decrease of water flow, difficulties or malfunctions to measure elements in pipes, and it forces to use fresh water since the treated water does not go through properly because of the incrustation. Measuring incrustation in pipes became one of the main challenges for the maintenance team in Andina. So they researched alternatives, finding three: a mechanical, thermographic, and using ultrasonic. The mechanical process consists of opening the pipes to measure the incrustations, stopping the operation of the area. The thermographic process avoids opening the pipes, but tests showed that this process detects only shallow defects. The best solution was an ultrasonic device that had never before been used in mining operations. It can measure the thickness from outside of the pipes, noticing the different elements with 0.3 mm of precision. It can work without stopping the operation of the plant, and it is not necessary to wash the outside of the pipe.

Using this technology they identified incrustations in the main water-piping network, within a few weeks and without stopping the operation. They could repair the most critical points avoiding losses of pressure for the concentrator plant. They reduced the execution time for measured point in pipes from 8+ hours to 2.25 hours equivalent to 70% reduction. Lastly, they decreased the cost of measurement to 44%, not considering that the previous solution had additional costs related to operational stops.

Figure 4: Opened Water Pipe

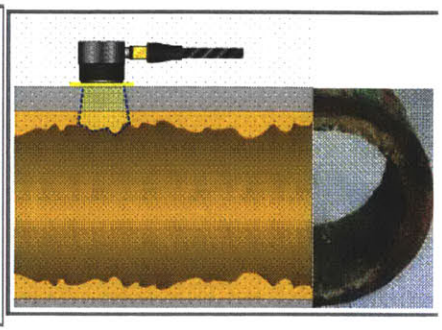

Figure 5: Scanning Scheme of Ultrasound

Larynx Microphone in Crusher Plant

Workers are frequently exposed to harsh environmental conditions, particularly dust, when they are within mining operations. This exposure in the long run can increase the probability of suffering silicosis. In order to avoid this risk, it is necessary to use a respirator mask.

In addition, the operation requires that workers stay in communication constantly, but the use of the respirator does not allow them to use the radio communication, forcing them to take off the mask to talk.

There is a tradeoff between staying protected from dust and communicating with other workers. The operation team at the primary crusher of the plant decided to find a way to keep the respirator on and talk at the same time. They searched in the market, but they did not find a respirator that had a communication system

integrated. So they decided to build one, and the solution they found was to use a larynx microphone connected to the radio.

The main benefits are improving health and safety conditions for operators. They can avoid breathing dust, can be more focus on the tasks they are performing, and increase the use of the respirator in polluted places.

Figure 6: Worker wearing the respirator

Figure 7: Worker talking without the mask

Figure 8: Worker with the larynx microphone

Figure 9: Worker talking with the respirator mask

Replace time reduction of gyratory crusher concaves

The crushing process is divided in three stages: primary, secondary and tertiary crusher. The first stage crushers take the mineral ore rocks and reduce them to a size small enough to be taken by the next (secondary) crusher in the process.

Usually the primary crusher is a gyratory one, and it is composed of a vertical spindle, the foot of which is mounted in an eccentric bearing within a conical shell (Figures 10 & 11).

Figure 10: Gyratory Crusher

(Picture:ThyssenKrupp AG)

Figure 11: Gyratory Crusher in operation

(Picture: Metso)

With a normal operation of this crusher, the walls (concave) need to be replaced avery eight months to be effective in crushing the mineral. For each crusher, there are 72 concave units with a total weight of 22 metric tons. Based on research with experts and manufacturers' representatives there was not evidence of practices

that allowed a reduction in the replacement time, and the total time to do it was 32 hours, not satisfactory for an autonomous operation.

By reducing the number of concave units, they could minimize the replacement time. Previously the gyratory crusher had 4 rows with 72 concave units (Figure 12), and after different trials, they could use 48 concave units in 3 rows (Figure 13).

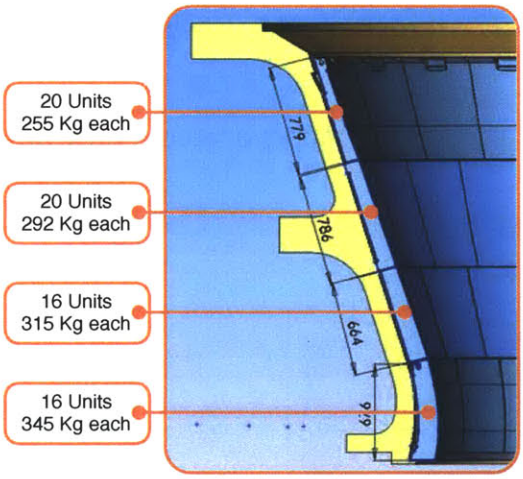

Figure 12: Previous Gyratory Crusher

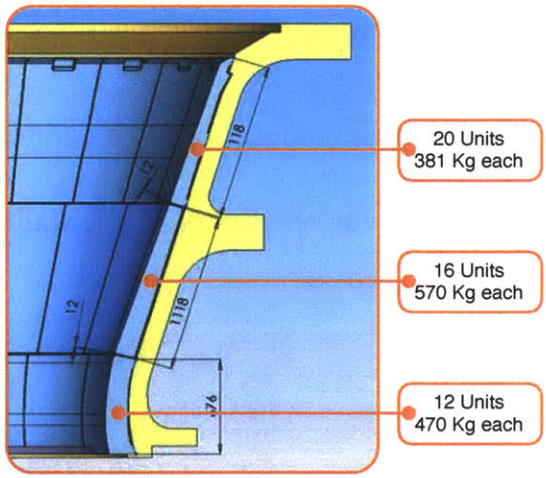

Figure 13: Current Gyratory Crusher

This reduction in the number of concave units accelerated the replacement process but in addition required an improvement in the concave mounting system (Figure 14). In addition, to improve the alignment system and reduce the assembly time, they added centering guide "pins" (Figure 15).

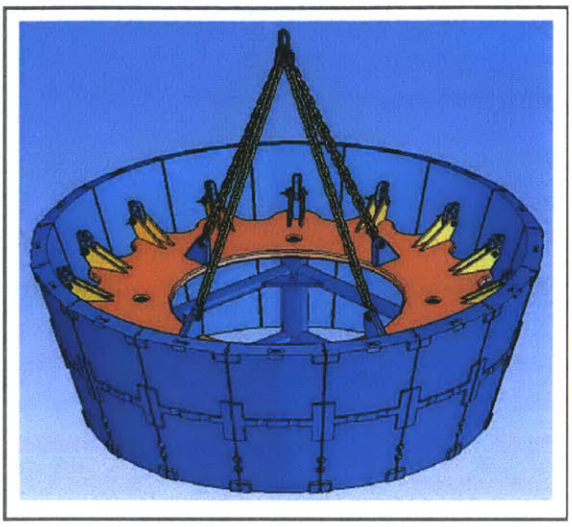

Figure 15: Improved concave mounting system

Figure 16: Improved alignment system

To extend the durability of the concave units, they incorporated a new design profile increasing the thickness of the wall (Figure 17).

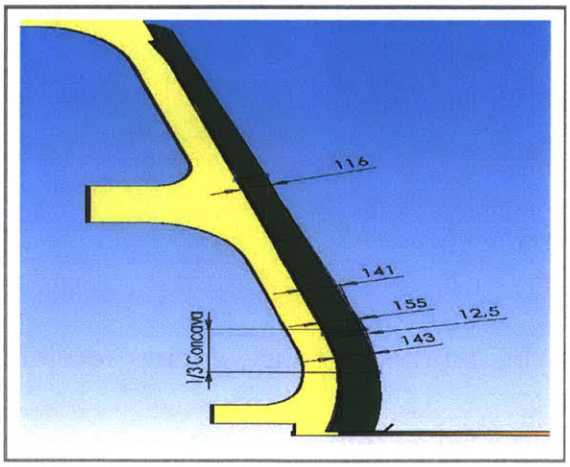

Figure 17: Thicker concave wall design profile

All these improvements helped to reduce the replacement time in 30%, from 32 hours to 24 hours. The new concave mounting system reduced the associated risk to the replacement. The process was autonomous between crusher's detentions and

SAG mill stops. They improved use of steel in 95% and generated annual savings of $ 618,000.

Impacts of the Innova Award Contest

The Innova Award contest allows users to be recognized as people who are not only thinking about problems but creating, building and executing solutions that benefit the company. It encourages users to go through a trial and error process, and understand the value of learning by doing. The elapsed time to develop their innovation was within one year for 89% of the workers. These projects focus on a problem and provide a solution in a short time.

In addition to workers, contractor companies, whose employees work directly in the operations of the mine, can also participate in the contest, and have been among the winners. Most of the interviewees mentioned that many innovations are built together by the mine's own workers and contractor workers.

Because of the close involvement of contractor companies and contractor workers in the mine's operations, we consider their employees to be the equivalent of employees of the mining company itself. They are also users who can identify problems and needs, and with the right tools from their own company or the mine, they are able to innovate.

Analysis of User Innovation in Innova Contest

It has long been known that even workers who are not technically trained can create important improvements on the processes they work with. Thus, Adam Smith (1776, 17) indicated "a great part of the machines made use of in those manufactures in which labor is most subdivided, were originally the invention of common workmen, who, being each of them employed in some very simple operation, naturally turned their thoughts towards finding out easier and readier methods of performing it." This is known to be true today, via quantitative research conducted by innovation scholars (summarized in von Hippel 2005). As that work explains, users innovate when they have a need or problem, and they use their own resources to find a creative solution, with the purpose of using it, and freely share their experience and work.

Incentives for Entering the Contest

In order to determine the main drivers for the miners to develop these innovations, we collected direct information from a sample of 50 employees of Andina who have done this work in their operation.

The most significant reasons they chose to apply to the Innova contest are: to have the opportunity to make a contribution to the company; to develop experience

and deeper knowledge in a topic; to be recognized by their family, their co-workers, and the company; and to win the contest.

The results of this survey are shown in the following tables and figures and analyzed further on.

When workers were asked about the time they took to build their innovation project more than 89% indicated 12 months or less. The results are the following (Table 2)

Table 2: Time to build the innovation

Time range	Response Percent
Up to 6 months	51.1%
6 to 12 months	38.3%
1 to 2 years	8.5%
More than 2 years	2.1%

As Table 3 shows, the people they shared their project with while they were building it were mainly colleagues and their supervisor.

Table 3: With whom they shared their work

	Response Percent
Family member	25.0%
Colleague(s)	75.0%
Supervisor	66.7%
Area Manager	10.4%
None	2.1%

As shown in Table 4 and Figure 18, when asked how many times they had applied to the Innova contest, 70.8% applied up to 3 times:

Table 4: Times applied to contest

	Response Percent
Never before	6.3%
1	8.3%
2	35.4%
3	20.8%
4	10.4%
5	8.3%
6	2.1%
7	8.3%

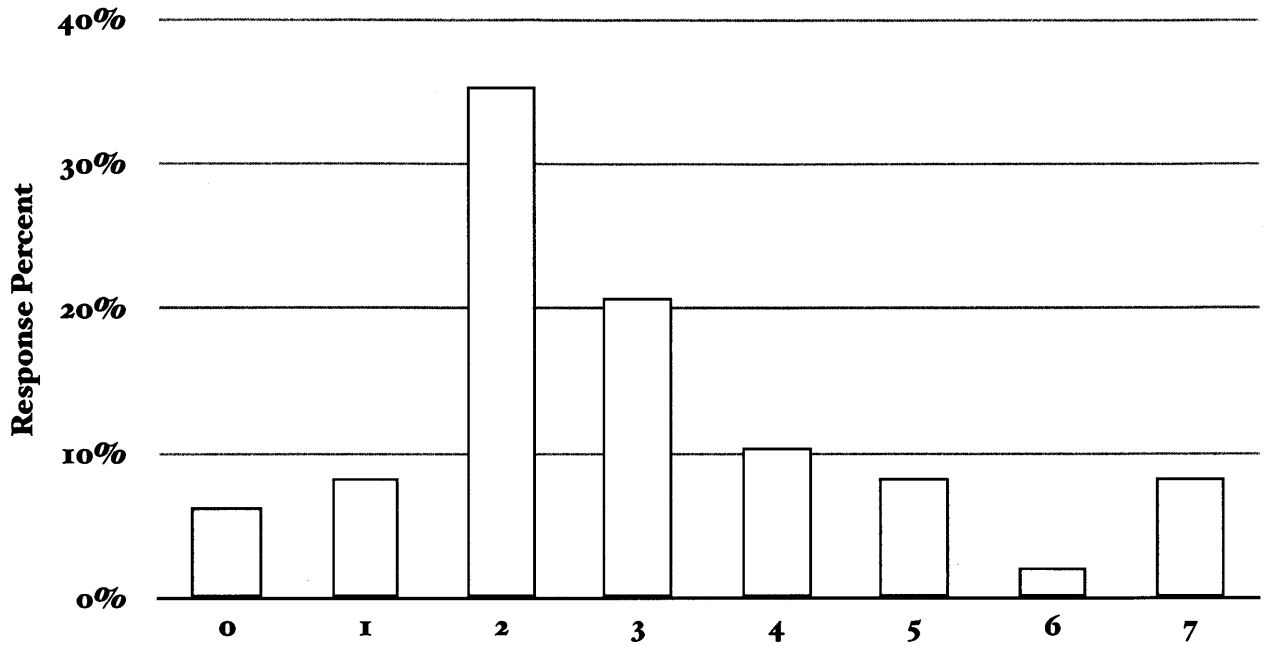

Figure 18: Times applied to contest.

They were equally distributed between sharing and not sharing the project with colleagues from outside of the company (Table 5)

Table 5: Shared the project outside the company

	Response Percent
Shared	50%
Not shared	50%

Yet 95.7% would like to share the results of their project with colleagues from outside of the company (Table 6)

Table 6: Main reasons to apply

	Response Percent
Like to share	95.7%
Not sharing	4.3%

As shown in Table 7, and as will be analyzed in this chapter, the main reasons to apply to the Innova contest by priority (1 highest priority and 7 least priority) are:

Table 7: Would like to share project outside the company

	Response Percent						
	1	2	3	4	5	6	7
Recognition from Codelco	30%	6%	13%	19%	11%	9%	13%
Recognition from Colleagues	27%	16%	9%	13%	9%	18%	9%
Recognition from Supervisors	27%	9%	9%	13%	11%	22%	9%
Family recognition	32%	14%	11%	7%	5%	20%	11%
Opportunity of making a contribution to the company	35%	21%	0%	0%	4%	13%	27%
To develop deeper knowledge in a specific topic	28%	13%	13%	2%	2%	21%	21%
To win the contest	13%	26%	13%	13%	13%	7%	15%

Table 8 shows that most of the participants have 5 or more years of work in the company, either at Codelco or at Codelco Andina.

Table 8: Years of work in Codelco and Andina

	Response Percent	
	Codelco	Codelco Andina
Up to 1 year	0.0%	0.0%
2 to 4 years	12.5%	20.4%
5 to 10 years	18.8%	24.5%
More than 10 years	68.8%	55.1%

Furthermore, having the opportunity to show their work represents 92.7% of the preferences when they chose what they like the most about the Innova contest (Table 9)

Table 9: Like the most of the contest

	Response Percent
Prize	24.4%
To present to Managers	7.3%
Award Winning Dinner	9.8%
Have the opportunity to show my work	92.7%

Making a Contribution to the Company

Operations in mining gather many people from different backgrounds and with different profiles. Engineers from different disciplines (mining, mechanical, civil, and industrial), technical and maintenance specialists, risk and safety professionals, operators, human resource and administrative staff, all work to achieve their goals and key metrics regarding safety, production and uptime. They need to make the operation run as smoothly as possible. They face challenges and problems that require evaluation and prioritization, which must be solved in order to keep or improve their results. Frequently, those problems can be understood only by working in the operation everyday and night. Thus, thinking of ways to solve the problems requires a deep understanding of the need and restrictions of the solution.

Therefore, the workers find ways to solve the problems and contribute to improving the results and quality of their work, their unit, and the company.

Based on the interviews performed with the workers, belonging and working for a public company makes them think that if they can perform better, then it will have a positive impact on the results of the company, and thus on the country and its people. The information published by Codelco regarding its contribution in 2011 to the Chilean government budget accounts for $ 4.9 billion. Codelco's tax obligation along with the first category income tax equivalent to 20% for 2011, has an additional

commitment following the presidential decree D.L. 2398 (1978), to annual payments of 40% as complementary income tax.

Considering that 88% of the studied group have been working in the company for more than 5 years and 68% for more than 10 years, the innovators also view their contribution to the company as delivering a legacy for the workers to come.

Personal Learning

In the case of the interviewed miners, 94% of them indicate an interest in developing a deeper knowledge of an area. The purpose of this learning process is to give them an opportunity to think about their problems, identify and gather the necessary tools to evaluate and build a feasible solution, and most importantly, use this solution in their work.

Through their innovations, workers also want to learn about others' experiences and topics. Innovators frequently received feedback and information from other workers about innovations developed by workers from different units, who operated within a common area. They are challenging themselves to build working teams and learn to understand others' work as well as their own.

Workers who innovate in mining have incentives similar to those identified among software developers working on open source projects by Hertel et al. (2003),

and Lakani and Wolf (2005). These volunteer code contributors were strongly motivated by the pleasure and learning they found in working on their innovation projects.

Recognition

The sense of being recognized by family, colleagues and the company, is perceived by the worker as a necessary component to encourage them to develop innovations.

As Bassett-Jones and Lloyd (2005) conclude, a positive reinforcement and recognition of work could outweigh economic incentives for workers. It is a way to validate the importance of their work and the impact it has on the unit and company results. At the same time, it gives the opportunity to those people close to them to express a sense of admiration for their work. Sharing their work with other colleagues and people inside and outside the organization fuels this recognition expectation.

During the development of their innovation, they show it to co-workers and supervisors. Once they complete their work, they share their project and results inside and outside the company. When they were asked about their willingness to share their work with other colleagues outside the company, 96% of them expressed their interest.

What they like the most about the Innova contest is the opportunity to show their work to colleagues. As Raymond (1999) and Lerner and Tirole (2002) elaborated, free revealing of innovation-related information can lead to benefits such as an increase in the worker's value on the job market, or even an increase in a firm's profits if the revealed innovation is to some degree specific to assets owned by the innovator (Hirschleifer 1971).

The results of collected answers show that recognition accounts as one of the top four reasons to apply to the contest, by 63% of the workers.

Winning the Contest

According to workers, when they have been recognized in the contest they feel this opportunity is a way to prove to themselves that they have solved a problem, thinking about and implementing it in a new way that no one else in the company has done before.

After applying once to the contest, they are willing to apply again to it. This was confirmed by analyzing the participation results of previous years, and validating them with the information gathered from the survey, showing that 85% (n=50) have developed two or more innovations.

When they are participating in the contest, they consider it is an opportunity to share their problems, and what they have done with their own resources or limited resources from their units to solve them, to show their work and how they have contributed to the company, and lastly to prove they are valuable assets for the organization. In addition, each area wants to show that they want to improve operational results, and how they are doing it with these innovations.

Lastly the winners of the contest feel recognition from everyone in the organization, which keeps them motivated to continue creating innovations.

Evolution of Motivations to Participate in the Contest

All the motivational factors described above have changed throughout the history of the contest.

Before the first running of the Innova contest, there was no culture in th Division for mine workers to think of problems they had been facing, nor to think of solutions for them. In order to align incentives to promote this way of thinking, the organizing committee got involved managers for each of the areas of the operation, and made the unions take an active role in the promotion and presentation of the contest. From the beginning of the first contest, the organizers highlighted the prize, and the opportunity for workers to share their work with other peers and been recognized throughout the entire organization.

With the passing of years, the prize has become less relevant, and the focus was on keeping everyone involved in thinking about what they were going to do to present the next year. Therefore, one of the challenges of the organization team was to keep workers, unions, supervisors, managers and even the general manager motivated. The number of projects and innovations decreased within the same year when there was a cut in this chain of control.

In addition, another variable that has a direct impact on the numbers of projects is steady operation. One of the main concerns of the miners is scarcity of time to focus and work on developing their innovations. Any changes in a normal operation require additional focus and time of the workers, and undermine the development of the project. Some examples of abnormalities in the operation are accidents, workers or contractors strikes, climate conditions, and unscheduled detention of processing machinery, among others.

Hierarchical culture and organizational structure are relevant component to consider for the performance of the contest. According to Hoefstede (1980) with an updated confirmation by Rotondo, Carlson, Stepina, and Nicholson (1997), Chile is located within the quadrants of an individualist culture and an unevenly distributed power in organizations and society. On average, Chilean workers in the study industry tend to perform and be recognized at an individual level, with a highly hierarchical organizational structure. In particular, this chain of command is a

relevant factor to increase or decrease the number projects. The role of the general manager of the division becomes fundamental to get the rest of the top management and subsequently the entire organization involved in supporting innovation.

In the same way, poor supervisory relationships can play a key role as a disincentive for employees' willingness to contribute with innovations

The Innova contest follows the pattern of new innovation methods that are based on encouraging solutions developed by users themselves rather than just finding a need and solving it with a third party that does the research and development and builds the solution. This new approach might decrease the cost of production as it was found by Hollander (1965) that about 80% of unit cost reductions in Rayon manufacture were the cumulative result of minor technical improvements.

Importance of Innova Contest for Codelco Andina.

Top management of the company considers the Innova contest an important vehicle for company development, and very useful to promote a culture of innovation, teamwork and continuous improvement. Beyond the immediate economic value that workers and their innovations add to the business, the contest promotes a culture of permanent questioning of how to do things better at all levels

of the organization. Workers are motivated to think about the problems they face at work, and to find solutions.

This division has the challenge to increase the production capacity from 230,000 tons in 2011 to 600,000 tons of fine copper per year by 2019.

Based on the information provided by the general manager of Andina, he expressed that, through these innovations, they found a way to create value for the company and expand their industry leadership to every position in the division.

The Andina Division expects to become a worldwide mining leader and think that this vision can be achieved by gathering workers' ideas, designing and planning rigorously, and defining simple ways to operate and solve their problems.

The contest belongs to everyone in the division and is part of everyone's work. It is an inclusive program that considers the impact these innovations can have in the organization and on workers' quality of life, and improve the safety conditions. In addition, it is a way to renew people's commitment to the corporate values of innovation, teamwork and the pursuit of excellence.

All these projects are a reality because of the persistence and effort of different working teams, after long hours of dedication, to make one concrete solution to a daily group or personal need.

Learnings

There is a change in the way the organization operates when initiatives like the Innova contest encourage participation and recognize the miners and their work. When the company empowers the workers, they feel committed to their organization.

There is a correlation of 80% between outstanding performance evaluation and participation in the contest. Those who have participated in the contest tend to have the highest scores in the performance evaluation ran by the company.

Challenges Remaining

Workers need more training, tools and specialized support to design, build and test their innovations, and to prepare their presentations of their project, including qualitative and quantitative impact, and an economic evaluation.

There are examples of developed innovations that could solve crucial problems within the company and its different divisions. However, some of these were not shared or distributed to others who might with to replicate them. This must change. A possible solution is to have a common information space that allows project authors to connect more easily with other workers that are interested in their project, and share more information to understand the solution, and help them

interact to evaluate, replicate or even improve the innovation. In addition, this system can help manufacturers to learn about and develop the workers innovations further, and diffuse them widely in the mining industry.

According to the organizing committee, there are opportunities to increase the number of projects by making area managers more involved in following up on the projects, and by having more encouraging the participation of all the areas and, in particular, the contracting workers. Involving more contractor workers in the contest can increase the number of projects. Achieving this will require a new design in registration, selection and evaluation process in order to keep all the participants motivated.

Discussion and Conclusions

Chile is the main producer of copper in the world accounting for 34% of the world mine production (United States Geological Survey Mineral Commodity Summaries, January 2012). It is estimated that, in the next 20 years, the world will consume more copper than the accumulated consumption over the entire human history (World Metal Statistics, March 2010 and Yearbook 2008 – World Production. Comisión Chilena del Cobre – Chile Production. Mineria Chilena, Anuario 2010). In order to fulfill this pace of demand, it will be necessary to rethink the conventional way to produce copper, and propose innovative solutions.

The origin of products and services' innovations in this industry may come from external and internal sources. Among external sources are equipment manufacturers, third-party companies that are involved in mining operations processes, and research and development initiatives. In contrast, the main internal sources are research and development centers and specialists.

Although miners have direct participation in all these innovations, they are not necessarily considered as a source of innovation, even though they are the ones who define the problems, propose different solutions, suggest modifications to the developed solutions, and finally approve or reject the innovation they are testing.

Chile is at a stage of development in innovation policy to move from public support to innovation governance (OECD Reviews of Innovation Policy, 2007). In

2005, the Chilean Innovation Council was created to offer a coherent overall governance of the innovation system. It was a better coordination of the public initiatives to support innovations focused on research and development and technology transfer for mining and other sectors.

International mining companies that have operations in Chile have their research and development centers located in other countries. BHP Billiton has its R&D in Australia, Anglo-American in South Africa, Freeport-McMoran in the United States, Rio Tinto in Australia, Canada, the United Kingdom and recently in India. In addition, one of the biggest producers of Copper in Chile and worldwide, Corporación Nacional del Cobre (National Copper Corporation) - Codelco, a Chilean government-owned corporation that has the only R&D Center (Instituto de Innovacion en Minería y Metalurgia · IM2) in the country.

In addition to these efforts, it can become an attractive opportunity for these companies that being close to their main operations, have a better understanding of their problems and work toward the best solutions that meet their real needs with right people.

Users (miners) are key participants and developers of innovations. It can be beneficial for the industry's stakeholders to understand what these users have done up to date, and how they can be included, encouraged and supported into the innovation strategy, to become key producers of innovations.

Mining users have a clear and specific problem, and with their own resources, they find a a way to solve it. Within Codelco Andina, more than 85% of their workers are open and willing to share with others what they have done. They tend to develop functionality novel innovations, and a key component of this development process is the possibility to try and fail as many times as necessary to succeed. Within one year, 89% of the participants build innovations going through a learning-by-doing process, to use and validate the efficiency, applicability, and impact of their solution.

In 2004, Codelco Andina division created the Innova contest to generate opportunities for all workers to improve their processes continually and creatively, with a focus on working quality, safety, care for the environment, cost reduction, productivity improvement, and automation of duties. After 8 years, almost 750 projects have been developed and presented, and more than 2,000 participants have been part of the contest, with an estimated contribution to the company of $ 100 million.

The main drivers for these workers to apply to the contest are: having the opportunity to make a contribution to the company; developing experience and deeper knowledge in a topic; being recognized by their family, their co-workers, and the company; and winning the contest. The Innova contest has helped to involve and include everyone in the organization to think of their problems, and then take the lead to find ways to solve them.

Exogenous factors such us seasonal climate and copper price can impact the normal mine operation and, therefore, influence workers to innovate. In addition, endogenous factors such us organization culture, labor motivation, and accident rate, to name few, also influence the willingness of workers to think about their problems and build solutions.

By analyzing the elements that the Innova contest has defined and used to encourage a culture of innovation with its workers, we show that users are innovating in this industry, and those innovations create a positive ecosystem for the workers and the company.

According to the Chilean Geology and Mining National Service - Sernageomin (2011), in Chile, the total number of workers in mining is 197,000. Although large mining operations account for 89,000 workers, if initiatives like the Innova contest were implemented in other large mining operations in Chile, it might trigger a significant number of innovations from the workers of this sector.

Defining an innovation strategy and creating the incentives to encourage a culture of innovation from workers to manufacturers, providers and academia, can become the key component to increase total factor productivity and face the future challenges of this industry.

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Appendices

Appendix A: Innova Contest Survey - Codelco Andina Division

Please answer this short questionnaire. We want to know your experience and feedback about the Innova Contest.

1. How long did you take to build your innovation project?

☐ Up to 6 months

☐ 6 to 12 months

☐ 1 to 2 years

☐ More than 2 years

Other (specify)

2. To whom did you tell of your project while you were working on it? (You can select more than one)

☐ Family member

☐ Colleague

☐ Supervisor

☐ Area Manager

☐ None

Other (specify)

3. How many times have you applied to the Innova contest?

☐ Never applied before ☐ 4

☐ 1 ☐ 5

☐ 2 ☐ 6

☐ 3 ☐ 7

4. Have you shared the results of your project with colleagues outside the company?

☐ Yes ☐ No

5. Would you like to share the results of your project with colleagues outside the company?

☐ Yes ☐ No

6. What are the main reasons for applying to the Innova contest? Please select the priority for each item (1 to 7, 1 is the most important, and 7 the least important)

	1	2	3	4	5	6	7
Recognition from Codelco	☐	☐	☐	☐	☐	☐	☐
Recognition from Colleagues	☐	☐	☐	☐	☐	☐	☐
Recognition from Supervisors	☐	☐	☐	☐	☐	☐	☐
Family recognition	☐	☐	☐	☐	☐	☐	☐
Opportunity of making a contribution to the company	☐	☐	☐	☐	☐	☐	☐
To develop a deeper knowledge in a specific topic	☐	☐	☐	☐	☐	☐	☐
To win the contest	☐	☐	☐	☐	☐	☐	☐

Other (specify)

7. How long have you been working for Codelco?

☐ Up to 1 year
☐ 5 to 10 years
☐ 2 to 4 years
☐ More than 10 years

8. How long have you been working for Codelco Andina?

☐ Up to 1 year
☐ 5 to 10 years
☐ 2 to 4 years
☐ More than 10 years

9. What do you like the most about the Innova contest?

☐ Prize
☐ Award Winning Dinner
☐ To present to Managers
☐ Have the opportunity to show my work

Other (specify)

10. What are your comments and feedback to improve the Innova contest?