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Third Extrusion Project: Project Analysis

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Third Extrusion Project

Project Analysis

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Third Extrusion Project
Project Analysis

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Executive Summary

This paper uses a case study approach to analyze the Third Extrusion Project (TEP) in Cerro Matoso S.A (CMSA). The TEP was chosen to be analyzed because of the importance to the company, the quality of the project management, and the impact in CMSA’s business. The analysis was focused on the managerial and organizational aspects, rather than on technical topics. It was based on the Strategic Project Leadership framework proposed by Dr. Aaron Shedar. [14]

BHP Billiton, the parent organization of CMSA, is one of the world’s premier mining companies. Its project management office aims to ensure that the project management processes of BHP Billiton subsidiaries are “best practice” and a source of competitive advantage. CMSA’s mine has one of the highest percentage nickel deposits in the world. This subsidiary has established itself as a low cost reliable supplier of a preferred high quality and low impurities Ferro-Nickel. The TEP will contribute to increase nickel production about 1%, and improve the overall fines handling in the plant.

This project was evaluated on six aspects: leadership, strategy, spirit, adaptation, integration, and learning. The evaluation showed many positives such as: the strong leadership of the project manager, the strategic fit of the project, the high commitment of the owner’s team, the suitable application of project management procedures, the senior management support, and the active participation of the client along the project life cycle. The project was very successful, but there is room for improvement in some areas: contractor selection, lessons learned communication, and cost estimation.

In conclusion, the strategic management applied on this project was very good and contributed to the project success. The TEP was very aligned with CMSA’s strategy of long term sustainability and low production costs. Furthermore, team alignment was possible due to the clear definition of the scope, objectives, and the excellent communication between the owner’s team and the client. The strong matrix organization and the fast-track approach were very beneficial to the project, facilitating the decision making process.
1. Company Background

Cerro Matoso S.A (CMSA) is a nickel mining company located in the northwest of Colombia. The company is a subsidiary of BHPBilliton, a merger between two highly complementary companies — BHP Limited of Australia and Billiton PLC headquartered in London. In 2001 BHPBilliton acquired 99.9% of CMSA, providing it with the cash flow stability required to take a longer-term view on all aspects of the business. For instance environmental and community issues, as well as the access to a network of expertise and best practices around the world.

CMSA’s vision is to be the world leader in the nickel industry, earning superior returns for its shareholders and contributing to the sustainable development of the region where the company operates. Its strategy is based on low production cost and a strong commitment on HSEC (health, safety, environment, community) issues. CMSA maintains ISO 9002 certification for its quality management system, ISO 14001 certification for the environmental management system, and OHSAS 18001 certification for its occupational health and safety management system.

CMSA’s mine is one of the highest-grade lateritic nickel deposits in the world and has mining concessions containing reserves capable of sustaining the current level of production for at least 20 years. The ore is mined by open pit methods and processed in two production lines located next to the mine. The plant produces around 46,000 tones of high-purity, low-carbon ferronickel granules per year, which are used exclusively in stainless steel production. Some applications of stainless steel are heavy machinery manufacturing, armaments, tools, construction, automotive industry, batteries, and high-temperature equipment including gas turbines and environmental devices. Nickel can be alloyed with metals such as iron, copper, chromium and zinc. These alloys are used in making metal coins, jewelry, valves and heat exchangers. In CMSA, the majority of nickel exports are to Taiwan, Japan, United States, India, and Europe.

2. Data Sources, References and Method of Analysis

The main sources of information for the TEP evaluation were:

**People**

The main source of information for this project was obtaining through interviewing six key team members and one representative of the client.

- Hernán Rincón – Project Sponsor – V.P of Technical Services. 57-4-7723-376. Hernan.E.Rincon@bhpbilliton.com
- Jesus Sanchez – Project Manager – 57-4-7723-227. jsanchez@cmatoso.com
- Marcel Vanín – Lead Mechanical Engineer – Project Engineering Business Unit. 57-4-7723-769. mvanin@cmatoso.com
- Humberto Gonzalez – Lead Electrical Engineer – Project Engineering Business Unit. 57-4-7723-611. hgonzalez@cmatoso.com
- Cristina Barreto – Control and instrumentation engineer - Project Engineering Business
Written Information and Project References
Supporting documentation was provided by the project manager, such as: concept study, feasibility study, investment process manual, project schedule, budget, and project performance reports. Additionally, information was retrieved from BHP Billiton website.

Method of Work
The project analysis was conducted using the technique of case study research. It was based on the Strategic Project Leadership conceptual framework. This framework is composed of six major areas: Leadership, Strategy, Spirit, Adaptation, Integration, and Learning. [13]

The data was collected by interviewing team members, reviewing project documents, and a literature research.

3. Project Description -Background and History

History
The Third Extrusion Project (TEP) started in August 2003 and was completed in September 2004. This project aimed to increase the extrusion capacity and hence the overall nickel recovery in CMSA, ensuring that the second production line would operate at design 175-dtph (dry tons per hour) without loss of fines. By this, the company would increase its production by 1.3 millions of pounds per year and eliminate the release of fines to the settling ponds.

Initially a team of experienced engineers was selected to determine the best economical and technical alternative for solving the existing problem of fines handling. Various options were studied using the Operating Excellence (OE) methodology and presented in a concept study report to the SSM ExCo (Stainless Steel Materials Executive Committee). OE is a philosophy and an improvement methodology that enables BHP Billiton to better respond to an increasingly more complex and competitive business environment. This methodology is based on process improvement tools (six sigma), facilitations skills, and change management tools. [1]

The alternative options studied at concept level were presented in a decision matrix by the OR team, applying a weighed scoring model to rank each alternative against different criteria (See Appendix 1). To ensure the best outcome, laboratory and pilot scale tests were conducted. Among ten options the selected alternative was the installation of a second extruder in the production line 2, which would be the third extruder in the plant.

Due to the nature of the project being an increase in capacity through the duplication of an existing equipment and the low risks associated with this project, the SSM ExCo approved to
advance to the feasibility stage on a fast-track basis [2]. The initial project budget was calculated during the concept study by Hatch, a design and consulting company from Canada. The capital costs presented by this firm added up US$3.46 millions with a contingency of +/- 20%. During the feasibility phase the selected alternative was rigorously evaluated in order to optimize the total life cycle costing and NPV for the investment. However, it was found that the initial budget calculation did not include some important issues. A new calculation was undertaken by the project manager and Bechtel, based on prices obtained directly from the suppliers. The total capital cost for the installation of the duplicate extruder was estimated at US$6.06M +/- 10%. To complete the missing budget, senior management decided to fund the project using the internal investment pool of CMSA. As a consequence, some projects with lower levels of priority had to be frozen.

Jesus Sanchez was assigned as project manager of the TEP in the feasibility phase by Hernan Rincon, the Vice-president of Technical Services. Then the project team was fully integrated, playing an integral part in the design and engineering. The project team, which is called the owner’s team in CMSA, was composed by: four project engineers and one HSE (Health Safety and Environment) leader from the Engineering Business Unit (B.U), one process engineer from the Rotary Kiln and Electric Furnace (RKEF) B.U, and one purchaser from the Purchasing B.U.

By the end of August 2003, the scope of the feasibility study was defined. Then the bid process for the basic engineering design was completed. Bechtel Corporation was the winner bidder that performed the basic and the detailed engineering of the TEP. The former was completed on October 12th 2003 and the latter on February 18th 2004. Before proceeding to the execution phase an Independent Peer Review (IPR) was undertaken. The IPR requested to refine the budget and the mass balance calculation (mass of fines that will be handled by the new extruder). Subsequently, the SSM ExCo approved moving to the execution phase.

During the project life cycle several workshops about risk assessment and team alignment were performed, encouraging the participation of staff from different business-units and management levels. Humberto Gonzalez, an electrical project engineer, stated: “The participation of main actors in different alignment workshops was essential to achieve the project success. Through the workshops we enhanced the integration of different parties, strengthened team dynamics, and reinforced individual commitment. Representatives from the production process, engineering, purchasing, security, HSE and the contractors were continuously involved. They were part of the HAZOPs (hazard and operability analysis) conducted before initiating several activities such as: the basic engineering, detail engineering, construction, critical tie-ins, commissioning, and start-up. The main objective of those HAZOPs was to reach the goal of zero harm and minimize any possible loss.”[3]

Marcel Vanín, a mechanical project engineer, described the delay in the structural steel fabrication as the most challenging event during the execution phase. “Since the structural steel was in the critical path, any delay on this activity could have a huge impact on the project schedule. The structural steel manufacturer estimated overoptimistic times, without considering the required organization in production and engineering to meet the delivery dates. As a result, we hired an independent controller who monitored the structural steel fabrication
and shipment. Furthermore, a CMSA’s representative undertook a weekly visit to the manufacturer plant. To overcome the schedule delay, we agreed to include a second assembly shift during the night and reinforce the first shift. Additionally, we contracted a small fabrication group to manufacture the parts that the main manufacturer would not be able to supply.” [4] Jesus Sanchez, the project manager, pointed out: “the best way to solve the delay in the project schedule was working as a team with the contractors and vendors. Therefore we defined in conjunction with the manufacturer a new delivery strategy based on the assembly sequence of the structural steel.”[5]

Cristina Barreto, an instrumentation and control engineer, summed up three critical events: 1) a delay in the detail engineering, 2) a delay in the structural steel fabrication, and 3) a delay in the installation and test of equipments. “The contractor in charge of the installation and commissioning of the equipments did not have enough manpower to finish on schedule. Two weeks before completing the construction phase, we though it was going to be impossible to meet the start-up due date. Thus we worked hard as a collaborative team with the electricians of RKEF and Engineering to speed up the installation and testing process. A strict daily follow-up of each activity was undertaken, carrying out a concurrent installation and commissioning of all the equipments.”[6]

Juan Castillo, a civil engineer, described the project history from the point he started. “The civil engineering work began on March 5th 2004. One of the main difficulties we faced during the excavation activities was the presence of underground pipes and electric cables. Another challenge was the delay in the concrete placing of the extruder building foundation. As the supplier failed to deliver on time, we were forced to make the concrete mix manually and add a second shift during three days.”[7]

The project start-up was on September 6th 2005, and the project cost was about US$ 5.4 millions. Actually, the TEP is in the operation phase which extends over the full economic life of the asset. A post investment review will be carried out six months following start-up in order to evaluate the economic success of the project. Additionally, a close out report will be completed in order to benefit from the project execution and lessons learned.

**Motivation**

The second production line commissioned in 2001 was operating ten tons lower (165-dtph) than the design throughput capacity and generating fines at a rate that exceeded the capacity of the current extruder. This loss was quantified as a mean of 3.5-dtph, equivalent to 115,800 pounds of Nickel per month and about 5 million dollars in revenue per year. An increase of feed rate to the second line design of 175-dtph would lead to a fines loss of a modeled 4.3-dtph, making even worst the fines handling. [2]

A third extruder was needed to process the excess fines being lost to the environment due to the low capacity of the existing system. CMSA had gained a good understanding of the extrusion process through the operation of the current Line 1 and Line 2 extruders. This experience would be applied to the design and implementation of the new extruder.
Objective and Goals
The objective of the TEP was to increase nickel recovery in CMSA by approximately 1% and ensure the second production line would operate at design throughput capacity of 175 dthp without loss of fines from the system [3].

The goals of this project were:
- Increase production by 1.3 million pounds of nickel per year.
- Increase extrusion capacity of second production line by 40 dtph.
- Deliver a project with zero harm, on budget, and on schedule.
- Eliminate the discharge of fines to the settling ponds.
- Improve overall fines handling.

4. Product and Project Characteristics

Scope
The scope of the TEP project was to construct and install a duplicate extruder alongside the existing extrusion building of Line 2. This would increase the extrusion capacity of the second production line by 40-dtph and provide greater flexibility of operation and maintenance. [8]

The approved budget was US$6.06 M +/- 10% and the time line 12 months, from August 29/2003 to August 26/2004. The main deliverables of this project were: Concept Study, Feasibility Study, Basic and Detail Engineering, Procurement, HAZOPs, Civil Construction, Mechanical Completion, Instrumentation & Electrical Completion, Commissioning and Start-up, Training, and Documentation.

Customer
BHP Billiton, the parent organization of CMSA, is in the global natural resources business. To be successful a detail assessment of each new investment is undertaken. The main objective of this assessment is to deliver benefits for all stakeholders, including the clients, the shareholders, the employees, the community, and the government. Therefore, stringent performance measures have been created to form a source of competitive advantage and deliver superior returns on the investments.

The clients of the TEP project were: the shareholders of the SSM CSG, who were represented by SSM ExCo, and the users of the new extrusion process. The new extruder would be operated and maintained by the workforce of the Rotary Kiln and Electric Furnace (RKEF) Business Unit. Thus, people from this department were continually involved during the different stages of the project life cycle. As the TEP was an extension of an existing facility in CMSA, external stakeholders such as the buyers of ferronickel, the community, and the government were not impacted by this project.

The TEP’s sources of funding came from an internal investment pool of CMSA. As the investment expenditure was less than US$20 million, the approval system is sufficiently flexible to allow the specific Customer Sector Groups (CSP) to manage this project. CMSA belongs to the Stainless Steel Materials (SSM) CSP; therefore project reviews are submitted to the ExCo of this group.
Product Type

Every project relates to a product. In this case the final product is nickel recovered from fines through the installation of a duplicate extruder in the second production line. The expected extra production after the implementation of the TEP project is 1.3 millions of pounds per year. The added extrusion process could be classified as derivative. It is derivative because it is an incremental change to an existing process, the extrusion process of the second production line.

Market Uncertainty

The nickel market is based mainly on supply and demand. Prices depend on existing stocks and on the capacity to satisfy demand. In Western economies, nickel is mainly used for stainless steel production (65%). Its market is linked to growth in industrialized countries, as well as in countries, which are becoming industrialized. According to Pareto’s Law, 20% of the market players share 80% of it. This law is especially true for nickel, as this activity needs an important capital immobilization and develops at a slow rate (minimum time frame between a pre feasibility exploration project and implementation is 5 years, and that does not include the profitability time frame). It is considered that the key market players are stable on a 5-year term. The unknown factor about this market is the part of non-capitalist countries like Cuba, China and especially the former USSR, which has a considerable influence on the world market (21%) [9]. Presently, the nickel industry is facing limited increases in mine supply, low inventories, restricted scrap supply, and a very strong increase in consumption of stainless steel. The consensus is that nickel market will continue to grow. Furthermore, the demand of primary nickel will continue to outstrip supply, largely due to the rapidly increasing demand for stainless steel in China. [10]. The primary nickel supply business is characterized by: high financial and technical barriers to entry, moderate to high industry rivalry, high bargaining power of suppliers and buyers, and a low threat of substitution. (See Appendix 2)

Cerro Matoso has established itself as a low cost reliable supplier of a preferred high quality and low impurities Ferro-Nickel. It is well established that demand for CMSA FeNi exceeds available supply, which is further illustrated by the fact CMSA is able to sell secondary scrap products at premium prices. With future diminishing ore grades, new projects have been implemented to ensure Fe-Ni production levels remain as high as practically economic. The Third Extrusion Project will bring additional agglomeration capacity, ensuring the continued success of upgrading while permitting higher throughput and improved recovery of Ni. [8]

Product and Process complexity

The third extrusion facility is located adjacent to the second extrusion plant. The green fines (dryer dust) and calcine fines (kiln dust) are drawn from the existing bins (BN-157 and BN-158) to the pug mill ZM-487. In the pug mill, the materials are pre-mixed with thickener underflow slurry and some water, obtaining a paste of approximately 20% moisture. Then the discharge material is conveyed to the pug sealer ZM-488, through conveyor CV-245 which is equipped with a weigh meter, a moisture analyzer, and a tramp belt magnet. Feed into the pug sealer is augered through the pug chamber. The chamber operates under vacuum, with the vacuum being applied via a vacuum pump (pump PP-287 or PP-288).
The material passes through the pug sealer and into the extruder ER-03. The pug sealer and extruder combination provides high shear mixing and deaeration. The extruder discharge produces product in a pellet form, which is typically cylindrical at 50x200 mm in size. The extruded pellets are fed to the kiln through the conveyor 0325-CV-235, and combined with the new kiln feed. [8] This is the last step of the nickel recovery process via the third extruder. After that all the combined material is processed in the electric furnace and the refinery. Finally, the resulting granulated product is packed in containers or bags, and shipped to the Cartagena seaport.

**Project Type**

**Technical Uncertainty**
This project would be classified as low-tech because no new technology has been introduced. The third extruder is a duplication of the existing two extrusion plants at CMSA. Most of the construction techniques and methods have been used before on similar projects.

**Pace**
The pace for this project can be determined as fast/competitive. The feedback from the key team members was that this project had to be completed as soon as possible. The SSM ExCo approved to apply a fast-track methodology in order to speed up the project. It allows starting a subsequent phase prior to approval of the previous phase deliverables when the risks involved are deemed acceptable.

**Project Size and Duration**
The approved budget for this project was for US$6.06 million dollars with a contingency of +/-10%. By September 2004 the estimated project cost was US$5.4 million dollars. The project’s official life cycle was almost one year from conceptual study till start-up. It started in August 2003 and was completed on September 6th 2004. The number of people involved at the peak of the construction phase was 91, with an average of around 60. Most of the people on the project came from 10 main organizations: Corpacero (Structural Steel), Bustillo Ingenieria (Civil Works), Schader Camargo (Installation), Daniel J.Fernandez (Roofing & Siding), Socimet (Grounding), Trane (Air Conditioning), DFS (Sump pump, tie-ins), MDOE (Manuals), Maquirrenta (Haul truck renting), and PID (Drawings).

5. Business Perspective and Project Success Measures

**Business perspective**
At the corporate level, BHP Billiton’s business model is designed to support the achievement of superior shareholder returns through the:
- Maximization of returns and the management of risk at the portfolio level.
- Effective deployment of capital to new growth projects and merger and acquisition opportunities.
- Efficient extraction of value from existing assets.
- Facilitation of knowledge sharing and best practices procedures throughout the Group
- Achievement of value through a customer centric marketing. [11]
At the business level, CMSA strategy is based on:
- Operating Excellence. It means, maximize cost efficiency reducing operating costs by 2% per year and achieve a return on capital greater than 15% by 2006.
- Zero harm through the enhancement of HSEC performance.
- Brownfield optimization through the implementation of projects.
- Long term sustainability through the exploration for additional reserves, continuous improvement, nickel recovery, and upgrading of lower grade ores.

The business perspective of the TEP was to increase nickel recovery and the occupancy factor of the second line kiln. By this, CMSA would obtain an operating improvement and as a consequence, a per pound reduction of nickel production cost. Additionally, it would help to achieve the nickel production established in the production plan.

**Business plan**

CMSA has implemented three management systems (MS): the environmental management system (EMS), the safety and occupational health management system (SOHMS), and the quality management system (QMS). One of the most important processes of the QMS is the strategic planning process, which is composed by four stages: plan, do, check, and act. Through the different activities of this process the company defines the long term strategic objectives, the mid term goals, and the short term tasks. A five-year business plan is developed, based on an external analysis of the environment and an internal analysis of each business unit. Therefore, it includes the goals and key issues of each B.U. The tasks, responsibilities, and resources allocation for the first year of the business plan are defined in the operational plan. The TEP project came from the long term sustainability strategy and the nickel recovery objective. It was a specific task to be completed within the operational plan of 2004.

**Project Success Measures**

The success of the TEP was assessed within three dimensions: safety, cost, and schedule. For each dimension various Key Performance Indicators (KPIs) were defined.

**Safety Indicators**

In CMSA there are two categories of safety indicators: pre-contact and post-contact. The pre-contact indicators are preventive measures such as safety meetings, planned inspections, safety observations, and incident reports. Their main goal is to minimize the occurrence of an accident and increase the awareness about safety issues. Conversely, the post-contact indicators register corrective measures after an accident has occurred. For instance:
- Medical Treatment Case (MTC). A MTC is an occurrence that results in treatment by medical practitioner and is beyond the scope of the first aid.
- Restricted Work Case (RWC). A RWC is an occurrence that results in a person being able to work but unable to perform the full duties of his/her regular work. [12]
- Lost Day Case (LDC). A LDC is any workplace injury that has resulted in the person not returning to their unrestricted normal duties after the day on which the injury was received.
- First Aid (FA). One-time treatment of minor scratches, cuts, burns, etc., with possible follow-up visits for observation, but not treatment.
Cost indicators
CMSA is using the traditional cost-control approach based on a plan versus actual cost comparison. The cost variance (CV) shows if the project is over or under budget. It is calculated as follows: \( CV = \text{Planned Cost} - \text{Total forecast} \)

The total forecast is the actual cost (total commitment) plus the remaining work (uncommitted work).

Schedule indicators
The schedule is controlled using Gantt charts that compare the planned progress for each activity against the actual progress. Additionally, an S-curve is built to compare the actual vs. planned cumulative percentage of work done. (See Appendix 3)

Once the project is in the operation phase the accomplishment of each goal defined during the feasibility phase is evaluated. Furthermore, in the post investment review a financial assessment is undertaken.

Assessment
During the execution phase the progress of the investment was monitored against the Key Performance Indicators (KPIs) and milestones identified in the Investment Approval Request. The TEP project was completed on time and under budget. The safety performance was good although the target of zero harm was not accomplished. One LDC (lost day case) and one FA (first aid) occurred during the installation of the structural steel. The accident was investigated and divulged using the PAMS methodology. PAMS stands from the acronym in Spanish of Process for the Analysis and Improvement of Situations.

Refer to appendixes 3, 4 and 5 to see some KPIs used during the execution phase of the TEP project.

6. Project Strategy and Value

Value to the Company
The TEP contributes to CMSA’s long-term strategic objectives and fits BHP Billiton strategic framework. The overall economics and recovery of Ni at CMSA will be improved by proceeding with the installation of a third extruder. This project is completely aligned with CMSA strategy to reduce nickel losses and improve recoveries. Improvement in recovery of the process is a specific goal within the 5-year CMSA Strategic Business Plan. Additionally, it will contribute to low operating cost and deliver operational excellence. [8]

The TEP will provide approximately 1.3 million lbs of nickel to be recovered from current fines production losses. This project will eliminate the current loss of fines from the extruder circuit and hence improve recovery of the process by approximately 1%. The fines currently leaving the circuit have a processing cost associated with them to that point and hence the per lb production costs are expected to benefit from the improved recovery and higher throughput.

The project allows for increased flexibility of the extrusion system operation, the two extruders
in Line 2 will ensure that some form of extrusion capacity is always available. This, combined with the current buffer in the silos will ensure that fines are not transferred to holding ponds. Since the second extruder of Line 2 is a duplicate of the current extruder, it reduces the quantity of spares required in stock and aids with maintenance procedures. [8]

Project Definition Process
CMSA does not have a formal selection process for their portfolio of projects. They use an informal committee to discuss the progress and funding of projects in their portfolio, based on the goals and tasks defined in the business plan. The business units present proposals to obtain the technical approval of their projects. If a project is technically feasible an AFE (Authorization for expenses) is submitted to the ExCo.

As Gustavo Cano states, “The TEP project was triggered in 2003. A bottle neck to operate the second production at its 175 dtph throughput capacity was identified. Although we were able to reach the production capacity of the kilns, we had to send a lot of material with high content of nickel to the settling ponds, and then reprocess this material. The design capacity of the existing extrusion system was 24 dtph, while the rate of fines generated was 45 dtph. We needed to achieve the production plan, maximizing nickel recovery and improving the overall fines handling” [13]

Defining Strategy and Competitive Advantage
The project strategy is the link between the business strategy and the project plan. It is defined as the approach, position and guidelines of what to do and how to do it, to achieve the highest competitive advantage and the best value from the project. [14] BHP Billiton main strategy is to sell more products at higher margins by meeting the needs of their customers while reducing risk. The TEP will contribute to reach CMSA’s business strategy of obtaining long term sustainability and operational excellence, throughout nickel recovery and a decrease in the operational costs. At present, CMSA is the lowest cost major nickel producer with a premium product. The competitive advantage of the company is based on the: high content of nickel, low production costs, and high quality operation.

Project Strategic Focus
A special team trained in problem solving and knowledgeable of the OE Methodology conducted a detailed analysis of various alternatives to improve fines handling during the concept phase. They selected the installation of a third extruder as the most suitable alternative, and conducted a SWOT analysis of the project to determine the key strategic factors driving the TEP. (See Appendix 6) Then the project manager was selected to lead the feasibility and execution phase. He was in charge of communicating the project objectives and its strategic fit to the owner’s team members. Humberto Gonzalez stated, “The project strategic objectives and team rules were clear since the beginning, strengthening team alignment and focus.”

7. Project Spirit and Leadership

Project Vision
The desired outcome of the TEP project was widely understood and shared, not only within the team members but also with external parties such as designers and contractors. There were no
changes in the project vision. The TEP was very well defined since the beginning. [4] Jesus Sanchez pointed out, “The project vision and objectives were compelling and vivid enough to create action. We had clear milestones and KPIs to monitor performance, keeping always in mind the targets we wanted to reach.” [5]

**Project Culture**

Project culture is defined as the behavioral norms and expectations shared by members of a project. Projects are no islands. They must be integrated into the corporate environment and help to meet the corporate management's strategic targets. [15] The TEP did not create a new cultural organization. It was driven by CMSA’s values, policies, and standards. As the company is committed to sustainable development, HSEC (health, safety, environment, and community) responsibilities are a priority. Therefore, they maintain management systems to ensure continuous improvement on these issues. CMSA is a very formalized and structured place to work. There are clear procedures and formal rules to be followed. Success is defined in terms of low cost, stability, and smooth operations. The TEP project was safety, cost, and schedule driven. Project culture supported: cooperation, teamwork, trust, and effective communication.

**Project Spirit**

Project spirit deals with excitement, passion, and enthusiasm, as a driving force, which energizes teams, unleashes talent, and enhances project performance. [16] Effective leaders are capable of creating spirit. They know how to articulate an inspiring vision, and work hard to create the culture, which mobilizes people's motivation. [14] Cristina Barreto talked about the project spirit. “We had an extraordinary team, which was tuned to achieve project goals. Everybody wanted to be successful and supported each other, generating a motivating and enjoyable work ambience. It was exiting to work on a project with a great leader, who knows how to delegate, empower, and maintain team dynamics.” [6]

**Leadership**

One of the major changes in organizational life at the turn of the 21st century is the “leadership transformation,” or the changing role of managers into leaders. Organizations are moving from an autocratic world, in which managers, control, plan, and reward employees, into an environment in which leaders create vision, motivation, and excitement, and inspire people to extraordinary performance. [15] Gustavo Cano stated, “Top management supported the project all the way through and played an important role in ensuring commitment among the involved business units.” On the other hand, Humberto Gonzalez made a point to explain, “The PM encouraged team members to pursue project goals enthusiastically. He was a facilitator for the decision making process and promoted participation at all levels. His style is very proactive, minimizing the effect of forthcoming problems. Additionally, he is very respectful of the decisions made by the project engineers of each specialty. He cares about the performance of each individual and the team as a whole.” Marcel Vanin pointed out, “Jesus Sanchez is a strong leader. He has an excellent combination of managerial and technical skills. I would define his style as open door and practical. He is very good at making decisions and delegating responsibilities.”
Team empowerment

Stating actionable objectives helped to gain team commitment and identify sources of resistance. Jesus Sanchez stated, “There were not hidden agendas, each project engineer was empowered and encouraged to pursue project goals enthusiastically. We discussed everything and assumed a proactive attitude for problem solving.”

Juan Castillo said, “The best things of this project were: the empowerment given to the team members, the management support, and the great amount of communication. We all were very committed and wanted to finish the project on time, on budget, and with zero harm.”

8. Organization

CMSA is organized in four main functional divisions: Technical Services, Production, Finance, and Human Resources (See Appendix 7). The Technical Services division has four business units: 1) Engineering B.U evaluates and implements infrastructure projects, 2) the Technology B.U analyses the required changes on production processes, 3) Operation Services B.U provides maintenance services, and 4) the HSEQ (Health, Safety, Environment and Quality) B.U administrates CMSA’s management systems. On the other hand, the Production division is composed by four business units: 1) Mine, 2) Ore Preparation, 3) RKEF, and 4) Refinery which match the main production processes of Nickel. The Finance division is responsible of accounting, payments, information technology services, commercialization, and procurement services. Finally, the Human Resources division is in charge of training, community affairs, labor relations, and human resources administration.

CMSA has a functional organizational structure with vertical lines of authority and stratified levels of management. This strong functional organization structure allows the specialization and availability of technical experts in the civil, mechanical, electrical and instrumentation areas who are assigned as PM or project engineers to lead and administer internal projects. The V.P of Technical Services and the Engineering Manager assign the project managers or project leaders.

In CMSA PMs have a strong technical orientation and the level of authority depends on the size and complexity of the project. There are three types of organizational structures: the functional organization, the project organization, and the matrix organization. Major projects (Investments> $20 million dollars) have pure project structure and the PMs report directly to the President. Medium projects (investments between $1 and $20 millions) have strong matrix structures, and the PMs report to the Engineering Manager or directly to the V.P of Technical Services. Minor projects (investments< $1 million dollars) have functional or weak matrix organizational structures, and the PMs report to the Engineering Manager.

About 80% of CMSA’s projects are minor then the functional and weak matrix organizational structures are the most common. For these projects the PMs have low power and their level of authority is specified in their jobs description. The TEP project had a strong matrix organizational structure and the PM reported to the V.P of Technical Services. “A matrix organization is a combination of both a functional organization and a project organization. Depending on which side, functional or project, the organization can take on a variety of matrix styles. There are the strong matrix, weak matrix, and balanced matrix. The strong
matrix leans more towards a project organization layered over a weak functional organization. The weak matrix leans more towards a functional organization over a project organization. And a balanced matrix is where both the project and functional organizations are equally applicable for the benefit of the organization. These types of matrices differ in the relative power/decision authority.” [17]

The project team was cross-functional and composed by:
- Project Sponsor: Hernán Rincón. V.P of Technical Services. The role of the project sponsor is to appoint the project manager and provide the project manager with the level of authority commensurate with responsibility. The project sponsor supports the project manager and project team during the project.
- Project Manager: Jesús Sánchez. Maintenance Manager.
- Process Engineer: Edgar Escobar from the RKEF B.U
- Mechanical Project Engineer: Marcel Vanín from the Engineering B.U.
- Electrical Project Engineer: Humberto González from the Engineering B.U.
- Instrumentation and Control Engineer: Cristina Barreto from the Engineering B.U.
- Civil Project Engineer: Juan David Castillo from the Engineering B.U.
- HSE leader: Jorge Diaz from the Engineering B.U.
- HSE supervisor: Victor Corena from the HSEQ B.U.
- Purchaser: Riverino Tuiran from the Purchasing B.U.

Training
At CMSA some project engineers have received a formal training in project management given by BHP Billiton’s consultants. The majority of project leaders have learned about project management on the job and through the application of the guidelines given on the internal process manuals. Each engineer of the Engineering B.U receives an internal training about the engineering process and its activities. This process starts with the evaluation of a proposal submitted by an internal client, and finishes with a project start-up if the proposal is feasible and approved by the senior management.

9. Processes

Project phases
Defining a project as a temporary endeavor undertaken to create a unique product or service [18], which has to be completed within a finite time and within a finite budget to a specified standard implies that a series of phases will make up the entire life of the project. These stages from origin to completion of the project are known as project life cycle (PLC).
In CMSA the PLC is defined in five phases:
- Conceptual Phase. The project is defined in terms of general business benefits and the strategic fit with the Organization’s Mission. The budget is elaborated and approved.
- Refinement and planning. The stakeholders are identified and the project team selected. A preliminary schedule and cost plan is prepared.
- Design and definition. The design consultant is selected and the project design approved. Then the construction contractor is defined.
- Supply and construction. This phase includes regular project reports, contracts administration, commissioning plans, the supply of operating and training manuals, the operations training, the operability risk analysis, and the maintenance plans.
- Operation. In this phase the project is formally delivered to the client for its operation.

The TEP had a slightly different PLC due to the higher investment associated with this project. The owner’s team followed the processes and framework described in the Investment Process Manual (IPM) of BHP Billiton. The ultimate goal of this manual is to have BHP Billiton invest consistently in opportunities that achieve returns in excess of the investment’s cost of capital, thereby increasing BHP Billiton shareholder wealth and company reputation.[19]

The BHP Billiton investment process has five phases: concept, pre-feasibility, feasibility, execution, and operation. (See Appendix 8) The TEP was managed following a fast-track approach which allowed working concurrently in different stages. For instance, the pre-feasibility and feasibility stages were executed as a combined stage to speed up the process. There were reviews and decisions points before starting each phase by the SSM ExCo. During the concept and feasibility stages independent peer reviews were undertaken. A final investment review will be pursued six months after the start-up completion.

Project Planning and Scheduling

Adequate project planning is critical for project success. The techniques of project planning have become a basic skill that every project leader needs to understand and be able to implement. Some of them are: WBS (Work Breakdown structure), RIM (Responsibility interface matrix), Scheduling Networks, Gantt Charts, Network Analysis (CPM/PERT) and project milestones.

For the TEP a detailed Gantt chart was elaborated to control the execution of the construction phase, as well as a list of critical dates or milestones.

The schedule for the construction phase was built using Microsoft Project and assuming deterministic durations. Time estimates were calculated based on the owner’s team experience in similar activities under standard performance of the contractors’ workforce. A formal WBS was not used to build the project schedule, however a detailed list of the main activities to be performed was developed.

Budgeting

Cost budgeting involves allocating the overall cost estimates to individual activities or work packages to establish a cost baseline for measuring project performance. [20] The capital cost of the TEP was estimated by Bechtel based on prices obtained from the equipment suppliers, CMSA’s warehouse, and similar projects with the corresponding scale up. A combination with analogous and bottom-up estimates was undertaken. The operating costs were estimated using current production costs per pound of Nickel.

Project monitoring and controlling

Project monitoring and controlling enable the project manager to recognize gaps and take corrective actions. For the TEP the PM and owner’s team conducted weekly meetings with the V.P of Technical Services, the V.P of Production, the Engineering Manager, the RKEF manager, and the RKEF superintendent to review the project progress in terms of schedule, cost, and safety. The PM also conducted meetings with the project team members to monitor
deliverables progress in a more detailed level, update the schedules, and revise the actual cost. The baseline budget was monitored using SAP, and the schedule using S-curves and Gantt Charts. A 5W-1H was developed to make a follow-up of the remaining activities, showing what should be done, who is going to do it, when, why, where, and how. The weekly meeting minute included the up-dated 5W-1H and the specific agreements defined during the meeting between the owner’s team and the internal client. A monthly report was submitted to the Executive Committee showing the project performance.

**Risk management**

Risk management is the systematic process of identifying, analyzing, and responding to project risk. It includes maximizing the probability and consequences of positive events and minimizing the probability and consequences of adverse events to project objectives. [20] BHP Billiton currently uses a risk planning and identification process called FMEA (Failure Mode and Error Analysis), which is part of their overall EWRM (Enterprise Wide Risk Management) system. (See Appendix 9)

CMSA follows BHP Billiton risk management standards and has a very good reputation on safety performance. For the TEP, a complete Process Hazard Analysis (PHA) was performed following the DuPont standard for Process Safety and Risk Management (PSRM).

Humberto Gonzalez stated, “Risk analysis was something very positive for the project. By this, we achieved a comprehensive and integrated view of risk as part of decision making. Through the workshops we were able to look at all types of risk, particular those that were not quite so immediate and obvious. The active participation of operators and maintenance staff brought new ideas and made possible a detailed identification of risks.”

**Communication management**

Project communications management includes the processes required to ensure timely and appropriate generation, collection, dissemination, storage, and ultimate disposition of project information. It provides the appropriate links among people, ideas, and information that are necessary to success. [20]

One of the techniques used in OE methodology is the stakeholder analysis. Through this methodology the owner’s team identified the stakeholders’ major interests and concerns. In general there was an excellent support from the senior management, functional managers, supervisors, and operators. This helped to speed up the project and build a network of coalitions within the organization. The purposes of communication management where clear for the team members and divulged in the alignment workshop. They included: to provide information, to persuade, to educate, to evaluate and decide, to empower, and to recognize and celebrate.

From the interviews it is possible to conclude that communication and conflict management were not a problem during the TEP. There was only one relevant communication problem with one contractor regarding safety issues, which led to an accident. The accident was investigated and divulged within CMSA. Gustavo Cano explained, “The accident occurred during the structure steel assembly due to an inadequate evaluation of the interferences among craft workers from different teams. We used the PAMS methodology to investigate the event and divulged it across the organization” [13]

The project team used formal communication such as meeting minutes, reports, and memos. Besides, they applied informal communication through emails, phone, informal meetings, and
radio transmitters. The informal project management was based on trust, team work, and cooperation.

**Customer involvement**

The customer was involved in the TEP since the beginning. Supervisors, engineers, superintendents and the manager of the RKEF department took part of the project follow-up meetings. They also participated in the assessment of the basic and detailed engineering. Additionally, the key operators and maintenance people were involved in the workshops for risk analysis during the project construction.

Gustavo Cano, the RKEF B.U manager stated, “The decision of encouraging the supervisors and operators to participate in the assessment of the basic and detailed engineering made them feel as an important party of the project team. They were really motivated to contribute and bring new ideas.” [5] Jesus Sanchez described the participation of the client, “RKEF had a continual participation. They gave us people for the elaboration of the new extrusion process manuals. On the other hand, the investors were indirectly involved through the SSM ExCo revisions and the independent peer evaluations of the project. Furthermore, the appraisal team and board of directors will undertake a post-investment review of the TEP when the project completes six months of operation.” [13]

**Contractor and Vendor management**

In CMSA safety is very important, therefore all contractors should go through an induction process that covers the hazards that they will be exposed to at the workplace. In the TEP, representatives of the contractors participated in the workshops for risk analysis (HAZOP). The identified risks and actions were divulged to the supervisors and the craftspeople. Additionally, a more detailed risk analysis was undertaken on site to evaluate the specific activities and working conditions of the day. The safety standards for CMSA’s contractors and employees are clearly written. For the contractors, these standards are stated in the contract agreement.

The interaction with vendors and contractors for the TEP was conducted by the project engineers of each specialty. Each project engineer carried out site inspections and meetings with the contractors to evaluate project performance. When it was necessary the project manager, set up a meeting with the project engineers and contractors to discuss specific topics. In general there were not major interaction problems with the contractors during the execution phase of the TEP.

Jesus Sanchez stated, “Something that was done different in this project was the appointed of an exclusive purchaser, Riverino Tuiran. He was in charge of dealing with the vendors and monitoring the delivery of each purchase.”

Humberto Gonzalez described the interaction with vendors and contractors, “The vendors of specialized equipments visited the field when we were in the commissioning of their equipments. It was important to involve the vendors during this stage to make sure they would provide the specified guaranties. CMSA staff coordinated the interactions between vendors and contractors on site. There were only minor difficulties with the supplier of the compressor. Fortunately, they gave us the required assistance when we needed it.”
10. Tools

The power of project management is at its historic peak, primarily because it has become a business strategy of choice. Conventional wisdom holds that individual project management tools are enabling devices to reach an objective or, more specifically, a project deliverable. [21] A company should have a project management toolbox that supports its competitive strategy. In CMSA the project management tools are described in the investment process manual of BHP Billiton. This parent organization has a project management office in charge of defining the processes and tools of the project management system, which are transferred to the subsidiaries of the different customer sector groups (Aluminum, Petroleum, Stainless Steel Materials, Coal, Carbon Steel, Base Metals etc).

**Common project management applications**

CMSA has not formally implemented WBS, however a list of the key activities of each project is defined to build the budget and schedule of each project. Additionally, accounting packages are created in SAP for cost controlling. The most common packages are: basic engineering, detail engineering, construction, commissioning, and administrative expenses. Appendix 10 shows the list of main activities or packages for the TEP. This project was selected using a scoring model (See Appendix 1) and economic methods. The financial evaluation was based on a life of 15 years, in agreement with the current life mine plan, which exhausts in fiscal year 2018. The NPV with a discount rate of 11.14% was US11.4 millions, the payback 28 months, and the IRR was 45.2%. [8] A sensitivity analysis of the variable parameters such as the nickel price and fines processed by the third extruder was undertaken to analyze the impact of the on the NPV. A spider graph and Tornado sensitivity chart were elaborated. (See Appendix 11) The methodology used to identify and evaluate risks was the FMEA (See Appendix 9). The main deliverable was a written HAZOP or risk response plan. To maintain keep dynamics weekly meetings were carried out with the owner’s team, the V.P of technical Services, HSE supervisors, and representatives of the internal client. The schedule was controlled using S-curves of the planned and actual performance, while the budget was controlled using SAP. A comparison of the actual and planned costs was undertaken. The safety indicators were controlled comparing the target KPIs with the real ones. (See Appendix 4)

**Documents**

Each phase of the project life cycle has a key document. There were six main documents: concept study, feasibility study, investment approval request, authorization for expense (AFE), close-out report, and post-investment review. Additionally, there were monthly progress reports and weekly meeting minutes. The 5W-1H document was used to register the remaining tasks, their progress, and the assignment of responsibilities.

11. Integration Management and Adaptation

Project Integration Management includes the processes required to ensure that the various elements of the project are properly coordinated. It involves making tradeoffs among competing objectives and alternatives to meet or exceed stakeholder needs and expectations. The project management integrative processes are: project plan development, project plan execution, and integrated change control. [20] The TEP is a good example of how the outputs
of the strategic planning process can be used to give direction and determine the most appropriate projects for the company. Since the beginning, this project was driven by the low cost and nickel recovery strategy. It was very integrated with the objectives of the organization, creating a sense of urgency in the project team. Furthermore, the procedures of the Investment Process Manual fitted the project type and the senior management strongly supported the execution of the project.

The project plan development started in the feasibility study with the strategic fit analysis. Then, it was integrated with the risk management plan, the procurement management plan, the contractor management plan, and the scope management plan. The project plan execution was controlled through status review meetings and performance reports. The hierarchical organizational structure level fitted the project type and was flexible enough to facilitate the decision making process of the project.

12. Learning

Pre-Project Learning

One of the key benefits of the decision to install a duplicate extruder was the mitigation of technical risks. CMSA had gained a wealth of knowledge and understanding of the extrusion process, through the optimization of the extruders in line 1 and 2. The strengths and limitations of the extrusion process were well known before installing the third extruder. Hernán Rincón explained the pre-project learning, “The conceptual phase of the project was developed using Six Sigma tools. The leader of this phase was an experienced couch. He communicated the lessons learned of previous Six Sigma projects to the team members. The organizational structure of the owner’s team was similar to the one of the Expansion Project. On average the owner’s team had 15 years of experience in project management and 8 years of experience working in CMSA. The appointed project manager was a key member of the Expansion Project with a very good knowledge of BHP Billiton project management standards.”[22]

On-Going Learning

Team alignment was very important to accomplish the project objectives. The communication of a clear purpose helped overcome resistance and build coalitions. Everybody was very committed and it was possible to apply a fast track approach. The senior management was very supportive, speeding up the decision making process. A successful project requires a satisfied client at the end of the project. The key to having a satisfied client is to ensure at the start of the project that all of the client’s requirements are known and can be specified in a measurable way. This involves determining the scope of work for the project and freezing the designs at the appropriate moment. By this it is possible to avoid scope creeps, which may lead to budget overruns and project delays.

Humberto González stated, “The active participation of the client brought very valuable ideas to the project, based on their experience in the operation of the extruders 1 and 2. It was very important to have the alignment workshops at the beginning of the project, involving people from the production process, engineering, purchasing, security, HSE, and the contractors. Moreover, the risk analysis workshops with the operators and the maintenance people
increased awareness on safety issues. The better selection of contractors is an opportunity for improvement. We faced many difficulties due to the lack of experience and under production capacity of the structure steel supplier.”

Marcel Vanin mentioned that, “The planning, monitoring, and controlling processes were fundamental for the success of the project. Corrective actions were defined in a timely way during the meetings of project performance assessment. Additionally, the proactive attitude and open communication enhanced the early resolution of technical and safety problems. From my experience I can conclude that this project was successful due to: the alignment and good consolidation of the project team, the good definition of project goals, the effective and intensively use of risk assessments, the pre-project learning of the extrusion process, and the application of BHP Billiton investment process guidelines.”

Jesus Sanchez described the on-going lessons learned, “The inputs for the estimates of duration should be obtained from more reliable sources. We need more detailed information to create better project schedules. Project quality management can be reinforced appointing a controller in the field who oversees the achievement of project specifications. Additionally, we need to improve the selection of contractors. In the TEP it was mainly driven by the cost and the delivery date.”

**Post Project Learning Assessment**

In CMSA there is not a formal process for communicating the post project learning. The lessons learned of the project are registered in the close-out report and everybody has access to it. There is a documentation department in charge of

### 13. Major Problems and Changes

**Major Problems**

The major problem on the project was the structural steel contractor. As Hernan Rincon stated, “During the fabrication of the structural steel there were some delays due to the lack of controlling and quality assurance. The corrective action was to hire an external controller in charge of supervising the manufacturing process in the contractor’s plant and reporting to the owner’s team. To speed up the fabrication of the structural steel, direct negotiations were undertaken between CMSA’s presidency and the contractor General Manager.”

Gustavo Cano added, “At the beginning of the project there was a problem related with the procedures and formality required to obtain the funds approval.” Furthermore, as Cristina Barreto stated, “The initial budget elaborated by HATCH for the concept study was very low compared to the detailed budget estimated by Bechtel for the feasibility study. It was necessary to justify the additional budget, freeze other projects, and minimize the project cost.”

**Changes**

The original defined project scope and integrated performance baseline must be maintained by continuously managing changes to the baseline, either by rejecting new changes or by approving changes and incorporating them into a revised project baseline. [20]

There were not major changes in the TEP. Since the beginning the owner’s team and the client
agreed to freeze the designs, avoiding scope creeps. This makes the TEP an excellent benchmark for future projects. As Jesus Sanchez stated, “There were only minor improvements suggested by the client, which were approved because they did not have any impact on the budget and schedule.”

14. Critical Evaluation of the Project Management

**Quality of project management**

Overall the project management of this project was excellent. It was very strong in several key areas: scope management, matrix organizational structure, senior management support, leadership, owner’s team commitment, risk management, and project performance monitoring.

The TEP had a clear scope and well defined objectives. It was very aligned with CMSA main strategies of low production cost and long term sustainability. This project helped to decrease the operational costs and minimize the emission of fines to the environmental. From the interviews that were conducted, it was evident that the clearly defined vision enhanced team members’ motivation and avoided conflict over differing goals. As Jesus Sanchez stated, “Scope management was essential to meet the project budget and schedule, there were not major changes, just minor improvement suggested by the client”.

Although the company has a very hierarchical organization that seems bureaucratic, it was flexible enough to speed up the decision making process and apply a fast-track approach. The strong matrix organizational structure used for the TEP had some advantages, such as the optimal use of internal resources and the active participation of staff from the client department. The majority of the owner’s team members were assigned full time to the project. Furthermore, the RKEF B.U, which was the internal client, encouraged the participation of operators and supervisors in the engineering, construction, commissioning, and start-up stages. Another advantage was the availability of technical expertise in the civil, electrical, and mechanical areas from the Engineering Department. Furthermore, appointing a full time purchaser was fundamental to obtain an excellent procurement management.

Jesus Sanchez strong leadership, senior management support, and team members’ commitment were essential for project success. The project manager maintained team dynamics through empowerment, a good delegation of tasks, and an “open door” communication without hidden agendas. Since the beginning the TEP was classified as high priority. Therefore, senior management supported the project during its life cycle and conducted tollgate reviews at the beginning of each phase. The project team members were very proactive, accountable, and resourceful. They were focus on getting results and meeting project objectives.

CMSA is characterized by having well-established procedures to perform risk management in projects and operations. The technical, environmental, and economic known risks of the project were evaluated in the feasibility phase. During the execution phase various workshops for risk assessment were conducted to come up with a well defined risk management plan. Several workshops were conducted to asses the: basic engineering, detail engineering, construction activities, tie-ins, commissioning, and start-up.
The final point of strength came from the clear definition of KPIs, which were monitored and control along the project life cycle. Implementing control actions resulted from the project meetings and the status reports produced. There were several ways of conduction project progress monitoring: weekly meetings within the project manager and owner’s team, monthly reports submitted to the Steering Committee, fortnightly client-supplier meetings, daily meetings between the project manager and the internal client, and weekly reports to CMSA ExCo. Reviews were conducted on the basis of Progress to Date and Forecast to Complete. Progress to Date looked backwards to compare actual progress to the plan whereas Forecast to Complete looked forward to estimate what remained to be done. Several project management tools were utilized: Scoring Models, Economic Models, SWOT analysis, Gantt Charts, S-curves, Cause-Effect Diagrams, Progress reports, 5W-1H reports, and postmortem reviews.

The project did have its weak points. There are opportunities for improvement in some areas: contractor selection, cost estimating and control, lessons learned communication, and project closure.

From the interviews a common comment was the lack of an appropriate procedure to select the contractors. In the TEP the selection was mostly based on cost and time. The implications were a delay in the schedule due to the low capacity and experience of the structural steel manufacturer. Fortunately, the project team found the way to close the gap and meet the delivery date.

In the TEP there was a significant difference between the budget elaborated in the concept study and the one submitted for capital approval. The initial estimates are usually elaborated with considerable uncertainties, but they should become more accurate as the project continues. Understanding what exactly an estimate and cost baseline mean calls for concrete definitions of their components. [21] In CMSA budget control is based on the comparison between the planned value and the actual cost. A forecast is elaborated adding up the committed and not committed values. This approach is not as proactive and predictive as the earn value analysis (EVA), which allows the calculation of the real value added by the work performed.

CMSA’s steering committee requires a written feedback of any project as part of the post investment review. The main objective of this report is to document the successful, and not so successful aspects of the project, and to provide a historical record of events and costs. The major weakness of this report is that usually it takes too long to be completed. Furthermore, there is not an active participation of all team members during its elaboration. Once the close-out report is completed it forms part of a project database. Usually the lessons learned from previous projects are not communicated or used in future projects.
15. Recommendations

In reviewing the project the following recommendations are suggested: improve the contractor selection process and solicitation, use EVA for cost control, and communicate the lessons learned to all interested parties.

By improving the contractor selection process, the owner might obtain better project execution results and thus, lower costs. Furthermore, the company could ensure that the contractor and their employees have the knowledge and skills to undertake the job safely. Contractor selection should start with an explicit planning process and end with the award to a specific contractor. The first step in planning is to identify and assign a priority to the project objectives. From this point, the owner should decide what type of contract would be most appropriate. Concurrently, the owner needs to sketch a profile of desired qualifications in his contractors and use it to screen candidates. One essential sometimes overlooked is allowing enough time to the selecting with care. The two main questions to be determined are the capacity of the contractor to do the work and his ability to manage the project in a satisfactory manner, including adverse and unforeseen matters that may arise. Some ways of collecting information about contractors’ ability are: asking for references from previous clients, reviewing owner’s previous experience with the contractor, and know current contractors workload. Furthermore, the company should have a procedure to ensure contractors hold the required certificates and permits to undertake the work safely. Ask the prospective contractor to submit a plan of how they intend to manage schedule, health, and safety in relation to the proposed work.

In the bidding process, clarity and understanding are essential. The most common criteria considered by procurers during the pre-qualification and bid process are those pertaining to financial soundness, technical ability, management capability, and the health and safety performance of contractors.

The next recommendation is to use earn value analysis for cost controlling. The main advantage that this method offers is the integration of scope, cost, and schedule measures to assess project performance. EVA involves calculating three key values: the planned value, the actual cost, and the earned value. The implementation of EVA could help to generate an early-warning signal. I would be beneficial to compare the planned amount of work with what has actually been completed, to determine if cost, schedule, and work accomplished are progressed as planned. It is conceptually simple and relatively easy to learn. This method is more realistic than just comparing the gap between the budget and the actual cost. Usually it does not reflect if there is a budget overrun until the project is completed.

The final recommendation is to elaborate a timely close-out report and communicate the lessons learned throughout the organization. The project manager should carry out meetings and workshops to discuss the project and final outcomes. Input must be obtained from all the relevant parties with the final report distributed to all appropriate personnel. Data collection should commence at an early stage of the Execution Phase to achieve a staged preparation of the report, rather than a post completion exercise. Sharing information across projects and summarizing project lessons should become a common norm and no new project should start before the project manager has learned the relevant lessons from previous projects.
16. Project Lessons Learned

<table>
<thead>
<tr>
<th>Lessons Learned</th>
<th>Implications for Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team alignment and a clear definition of objectives.</td>
<td>Enhances team dynamics and communication</td>
</tr>
<tr>
<td>Scope management</td>
<td>Optimizes project performance and minimizes changes, reducing schedule variations and budget overruns.</td>
</tr>
<tr>
<td>Better selection of contractors</td>
<td>Facilitates contract administration and ensures better project execution results.</td>
</tr>
<tr>
<td>Promote the active participation of the client</td>
<td>Helps to meet customer’s expectations and requirements.</td>
</tr>
<tr>
<td>Analyze the lessons learned from previous projects</td>
<td>Avoids making the same mistakes</td>
</tr>
<tr>
<td>Have an full time purchaser for the project</td>
<td>Improves procurement and vendors management</td>
</tr>
<tr>
<td>Reinforced project quality management since the beginning of the project</td>
<td>Helps to: control project performance, assess KPIs, and ensure stakeholders’ satisfaction.</td>
</tr>
</tbody>
</table>

17. Analysis of Lessons Learned

The major things learned were:

- Strategic issues in successful projects deals with those aspects that are relevant to project success throughout the entire project life cycle. They are strategic in the sense that they provide a sustainable advantage for the project and the company. Nowadays, the projects should be strategically managed. It means they should be focused on achieving business results, rather than on simply getting the job done.
- Project success comes from the combination of many factors such as: leadership, management support, a committed project team, clear defined scope, goals, and KPIs, periodic monitoring, stakeholder management, application of project management tools, risk management, and continuous improvement.
- The implementation of project management tools should be based on the organizational culture. Project management is a strategy. The tools are merely mechanisms to transform the project inputs into outputs or results.
- Many processes must be integrated when managing a project: initiating, planning, executing, controlling, and closing processes.
- The TEP was a very successful project. Therefore, the procedures applied during its life cycle should be extrapolated to the upcoming projects with the corresponding scaling.

Things learned from the paper creation aspect:

- The strategic project leadership framework was very useful to create the project outline.
- The questionnaire was very useful to pursue the interviews but from my personal opinion some questions are redundant.
### Appendix 1. Preliminary decision matrix at onset of project

<table>
<thead>
<tr>
<th>Preliminary Alternative</th>
<th>Operation UF</th>
<th>Maintenance SF (buffer)</th>
<th>Confidence in solution</th>
<th>Safety</th>
<th>Tie in time/cost</th>
<th>Time to construction</th>
<th>Known Technology</th>
<th>CAPEX</th>
<th>Total Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighting (MAX score 290)</td>
<td>10</td>
<td>10</td>
<td>7</td>
<td>10</td>
<td>9</td>
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Source: Concept Study Third Extrusion Project CMSA

### Final decision matrix for conceptually studied options

<table>
<thead>
<tr>
<th>Final Decision Matrix</th>
<th>Weighting</th>
<th>Briquette Preparation</th>
<th>Extruder Ore Preparation</th>
<th>2nd Extruder RKEF</th>
<th>Extrusion Dryer</th>
<th>Insufflation</th>
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<tbody>
<tr>
<td>Operation UF</td>
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<td>4</td>
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<td>4</td>
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<td>Maintenance SF</td>
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<td>5</td>
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<td>4</td>
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<td>5</td>
<td>5</td>
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<td>Tie in time/ Cost</td>
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<td>4</td>
<td>3</td>
<td>4</td>
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<td>5</td>
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<td>Project time to completion</td>
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<td>2</td>
<td>3</td>
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<td>5</td>
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<td>5</td>
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<td>CAPEX</td>
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<td>2</td>
<td>3</td>
<td>5</td>
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<td>Future potential 195 tph</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Operability (robustness)</td>
<td>8</td>
<td>3</td>
<td>2</td>
<td>5</td>
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<td>OPEX</td>
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<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

Score (Max 380) | 380 | 274 | 258 | 318 | 260 | 244 |
Rank            | 2   | 4   | 1   | 3   | 5   |     |

Source: Concept Study Third Extrusion Project CMSA
Appendix 2. Competitive Forces in the Primary Nickel Supply Business

![Diagram of competitive forces]

Appendix 3. S-Curve for Schedule Control

### Appendix 4. Safety Indicators Performance

#### Third Extrusion Project Safety

<table>
<thead>
<tr>
<th>Pre-Contact Indicators</th>
<th>Period</th>
<th>Cumul.</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feb</td>
<td>March</td>
<td>April</td>
</tr>
<tr>
<td>Safety meetings</td>
<td>2</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Planned inspections</td>
<td>1</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Preventive safety observations (OPS)</td>
<td>1</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Incidents &amp; conditions reported</td>
<td>1</td>
<td>10</td>
<td>21</td>
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</table>

| Post-Contact Indicators | CMSA | Contractors | | | | | | |
|-------------------------|------|-------------|-----|-------|--------|--------|-------|
|                        | LDC  | RWC         | MTC | FA    | LDC    | RWC    | MTC   | FA    |
| CMSA                   | 0    | 0           | 0   | 0     | 0      | 0      | 0     | 0     |
| LDC                    | 0    | 0           | 0   | 0     | 0      | 1      | 0     | 1     |
| RWC                    | 0    | 0           | 0   | 0     | 0      | 0      | 0     | 0     |
| MTC                    | 0    | 0           | 0   | 0     | 0      | 0      | 0     | 0     |
| FA                     | 0    | 0           | 0   | 0     | 0      | 0      | 0     | 0     |

<table>
<thead>
<tr>
<th>Contractors</th>
<th>Schrader (Installation)</th>
<th>Vendors</th>
<th>Bustillo (Civil works)</th>
<th>Daniel J. Fernandez (Roofing &amp; Siding)</th>
<th>Socimet (Grounding) &amp; PID (Drawings)</th>
<th>Trane (A/C)</th>
<th>Dfs (Sump pump, tie-ins)</th>
<th>Mdoe (Manuals)</th>
<th>Maquirrenta (Haul truck renting)</th>
<th>Sub-Total Contractors</th>
<th>Cmsa</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>2880 8500 17540 6740 5292</td>
<td>0 0 0 0 0</td>
<td>0 0 0 0 0</td>
<td>0 0 0 0 0</td>
<td>0 750 378 36</td>
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<td>2880 10000 18024 11081 14469 19818 13928 90200</td>
<td>672 940 1175 1576 1628 1947 3890 11828</td>
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<td></td>
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<td>7345 12555 9792 33869</td>
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<td>513 80 593</td>
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<table>
<thead>
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<th>Worked Hours</th>
<th>Period</th>
<th>Cumul.</th>
<th>Target</th>
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<td>DANIEL J. FERNANDEZ (Roofing &amp; Siding)</td>
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<td>MDOE (Manuals)</td>
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## Appendix 5. Cost Control Table

### Extrusion Project - Costs Status at August 31, 2004 - US$ 000

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<th>Description</th>
<th>Expenditure</th>
<th>Unpaid Commitment</th>
<th>Total Commitment</th>
<th>Uncommitted Work</th>
<th>Total Forecast</th>
<th>Budget</th>
<th>Escalation</th>
<th>Difference in Exchange</th>
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<th>(Over) Under</th>
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<td>400</td>
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<td>464</td>
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<td>6061</td>
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Appendix 6. SWOT analysis - Key Strategic Factors of the TEP

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
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<tbody>
<tr>
<td>• Increases overall nickel recovery from RKEF and hence overall recovery.</td>
<td>• Additional RKEF plant equipment and people to manage and maintain.</td>
</tr>
<tr>
<td>• Will contribute about 1% increase in ferronickel to CMSA production.</td>
<td></td>
</tr>
<tr>
<td>• Permits full utilization of Line 2 design capacity at 175 dtph, without loss of fines.</td>
<td></td>
</tr>
<tr>
<td>• Easy add on, majority of infrastructure already in place.</td>
<td></td>
</tr>
<tr>
<td>• Aligned with CMSA five-year plan objectives.</td>
<td></td>
</tr>
<tr>
<td>• Strategic fit with other plant activities to reduce Ni losses (e.g. increase in fines transport system capacity, increased green fines elutriation from dryers)</td>
<td></td>
</tr>
<tr>
<td>• Lower impact on the working capital due to the reduced quantity of spare parts.</td>
<td></td>
</tr>
<tr>
<td>• Short learning curve</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Threats</th>
</tr>
</thead>
<tbody>
<tr>
<td>• More flexibility to manage the two RKEF lines and maintenance.</td>
<td>• Extrusion pellet quality has been shown to be very dependent on vacuum pressure in system.</td>
</tr>
<tr>
<td>• May be possible to recover fines already in ponds and add back to process through spare capacity in the extrusion system.</td>
<td></td>
</tr>
<tr>
<td>• Possibility to align with the ‘Nickel Recovery from Slag’ project and use the spare extruder capacity to add back in the fine magnetic product from slag recovery.</td>
<td></td>
</tr>
<tr>
<td>• Could permit future ramp up in kiln feed rate, subject to other process bottlenecks being resolved e.g. furnace power availability.</td>
<td></td>
</tr>
</tbody>
</table>

Appendix 7. CMSA’s Organizational Chart

CERRO MATOSO S.A-ORGANIZATIONAL CHART

President
Bert Nacken

V.P of Technical Services
Hernan Rincon

V.P of Production
Carlos Ruiz

V.P of Human Resources
Eduardo Garcia

V.P of Finance
Wayne Clowery

Op Services
Orlando Medina

HSEQ Manager
Manuel Torres

Technology Manager
Julian Kift

Accounting Manager

Maintenance Manager
Jesus Sanchez

Project Leader 1

Project Leader 2

Project Leader 3

Project Leader 4

Project Leader 5

Security Manager

Cerro Matoso S.A.

Op Services

HSEQ Manager

Technology Manager

Accounting Manager

Maintenance Manager

Project Leader 1

Project Leader 2

Project Leader 3

Project Leader 4

Project Leader 5

Security Manager

Cerro Matoso S.A.
### Appendix 8. Investment Process & Project Life Cycle

<table>
<thead>
<tr>
<th>Concept</th>
<th>Pre-feasibility</th>
<th>Feasibility</th>
<th>Execution</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>To identify possible alternatives to be assessed in further detail during the Pre-feasibility phase.</td>
<td>To select the simple preferred go-forward alternative. The single go-forward alternative will be further studied and optimized in the feasibility phase.</td>
<td>To optimize the selected single go-forward investment alternative.</td>
<td>To deliver the investment to achieve the targets stated in the investment approval.</td>
</tr>
</tbody>
</table>
| Activities | - Clear statement of the project’s objective/s.  
- Statement of strategic fit (why should we do this project).  
- A preliminary plan of the project development such as the project “Roadmap”.  
- User requirement specification.  
- Anticipated business benefits.  
- Preliminary resource plan.  
- Preliminary schedule.  
- Preliminary cost estimate.  
- Nominated project manager and key team members | - Evaluate various alternatives and select the preferred alternative.  
- Demonstrate that the most valuable alternative has been recommended.  
- Establish and select a single go-forward alternative.  
- Ensure technical and commercial viability.  
- Ensure there are fatal flaws that could negate all investment value. Plan for the feasibility phase. | - Based on the selected alternative, optimize total life cycle and NPV for the investment.  
- Complete a full evaluation of the investment including the risk profile.  
- Finalize scope, cost, schedule, and other KPIs.  
- Establish a NPV risk profile and understand any uncertainties in the NPV risk profile.  
- Establish a clear project execution plan.  
- Funding approval | - Deliver the investment consistent with business and project KPIs including safety, scope, cost and schedule.  
- Detail engineering and design.  
- Regular project reports.  
- One page monthly summary report.  
- Detailed commissioning plans.  
- Agreed hand-over process.  
- Supply of operating and training manuals. | - Operate and evaluate the investment to ensure performance to specification and maximum return to shareholders. |

Appendix 9. Risk Management. FMEA Process Diagram

1. Establish the context of the FMEA
2. Brainstorm and group possible failure modes for each step
3. List one or more potential effects for each failure mode
   Answer the question: If the failure occurs, what are the consequences?
4. Assign Severity Rating for each effect
   Assign an Occurrence Rating for each failure cause
   Assign a Detection Rating for each failure
   Calculate Risk Priority Number (RPN) for each effect
   Use the RPNs to select high priority failure modes
5. Plan to reduce or eliminate the risk associated with high priority failure modes
   Carry out the actions planned
   Re-calculate RPN
Appendix 10. Work packages for the TEP

Basic Engineering
Detail Engineering
HAZOP
Site Development
Earthwork
Concrete
Structural Steel
Architectural
Mechanical Bulks
Mechanical Equipment
Piping
Electrical Equipment
Raceway
Wire & Cable
Instrumentation
Close-out report

Source: TEP Budget and schedule reports.
Appendix 11. Economic Analysis of the TEP – Spider graphs

Spider graph for sensitivity analysis impact of variables on project NPV

Spider graph for sensitivity analysis impact of variables on project IRR

Source. TEP Feasibility Study
Appendix 12. Economic Analysis of the TEP – Tornado Sensitivity Chart

![Tornado Sensitivity Chart]

Ni Price US$3.93/US$3.17
Mass Balance 2.6 - 4.8 t/h
Opex (+/-20%)
Capex (+/-20%)

Change in NPV

Source. TEP Feasibility Study
References

[7] Interview with Juan David Castillo, Civil Engineer, October 24th, 2004.
[13] Interview with Gustavo Cano, RKEF Manager, October 21st, 2004
[22] Interview with Hernan Rincon, V.P of Technical Services, November 29th, 2004