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AMBATOVY

NICKEL PROJECT
Madagascar



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Project Management

Table of Contents

AMBATOVY
Nickel Project



Official Entry Form/Project Summary

Entry Consent Form

Introductionpage 1

Complexitypage 2

Meeting Client’s Needspage 5

Environmental Benefitspage 7

Innovationpage 9

Social and/or Economic Benefitspage 10

Official Entry Form/Project Summary

AMBATO VY
Nickel Project



Entry Consent Form

Project Entry Binder

AMBATO VY
Nickel Project



Introduction

The Ambatovy Nickel Project is one of the most ambitious industrial undertakings in the history of Madagascar and the western Indian Ocean region. Constructed between 2007 and 2011, it is positioned to become one of the world's largest producers of finished nickel and cobalt products from lateritic ore.

The Ambatovy mine site is located inland, on a mountain-top close to the town of Moramanga (80 kilometres east of the capital Antananarivo), and consists of an open-pit mining operation and an ore preparation plant. The ore is delivered via a 220 kilometre pipeline from the ore preparation plant to a process plant and refinery located a few kilometres from the Port of Toamasina on the east coast of Madagascar. The project also includes tailings management facilities, an extension to the Port and an ocean outfall.

At the peak of the construction phase, more than 20,000 construction workers were assigned to five work sites – mine site and ore preparation plant, pipeline, process plant, port, and ammonia storage area – of which 6,000 lived in construction camps.

Close to 60 sub-contractors from various countries were hired for the final sprint on this colossal construction project.

In January 2014 the project reached its commercial production, and is now in its performance optimization stage to reach the nameplate capacity of 60,000 tonnes of finished nickel, 5,600 tonnes of high purity cobalt and 210,000 tonnes of ammonium sulphate fertilizer annually.

Ambatovy is a joint venture between subsidiaries of Sherritt (40% ownership), Sumitomo (27.5%), Korea Resources (27.5%), and SNC-Lavalin (5%).

1



Complexity

Project Scope of Work & Services

In 2007, having previously conducted the feasibility study, SNC-Lavalin Inc. (SNC-Lavalin) was retained to provide full engineering, procurement and construction management (EPCM) services for the Ambatovy Nickel Project in Madagascar. The scope of work included:

- Mine site infrastructure including:
 - Ore preparation plant; and
 - Slurry transfer pumping plant.
- Process plant and refinery and all associated utilities including:
 - Power plant (3x 40MW coal fired);
 - Water treatment plants;
 - Hydrogen and hydrogen sulphide plants;
 - Sulphuric acid plant;
 - Air separation plant;
 - Limestone comminution, lime calcining and slaking plants; and
 - Ammonium sulphate plant.
- Slurry pipeline (220 kilometres)
- Tailings management facility
- Access infrastructure including:
 - Roads; and
 - 8 kilometres of railway.
- Port facilities (upgrade)
- Plant site facilities including:
 - Administration building;
 - Project offices and training centre;
 - Diesel fuel, naphtha and ammonia storage and dispensing facilities;
 - Laboratory;
 - Potable water treatment and waste treatment;
 - Gatehouse and accommodation facilities.



The ore processing plant, located on the east coast of Madagascar is one of five major work sites.

SNC-Lavalin services also included development and implementation of a Local Resource Development Initiative (LRDI™) program and environmental management.

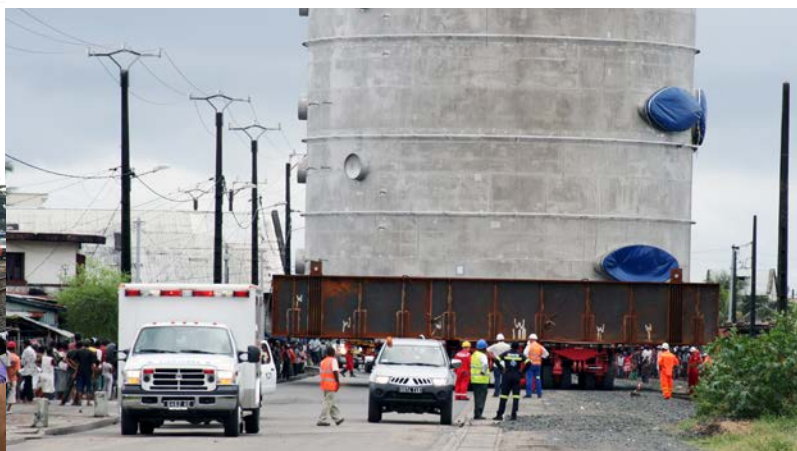
The design and construction of a self sustaining mine and process plants on the remote island of Madagascar presented a number of unique challenges for the SNC-Lavalin team in relation to project management and engineering. With a total construction cost of US \$5.3 billion, the sheer size of the Ambatovy Nickel Project resulted in a level of complexity equal in scale only to large international infrastructure projects such as the upgrade of the Panama Canal. It involved the design and construction of a small town and all related infrastructure. At its peak, the project employed 600 people at SNC-Lavalin's Toronto, Canada design office during detailed engineering, and as many as 20,000 people on site during the construction phase.

Project Management

To manage and track such a complex undertaking and to avoid pitfalls related to the coordination of such a large project, SNC-Lavalin relied on integrated data base systems.



Existing roads required upgrades to accommodate increased traffic during construction and operation.

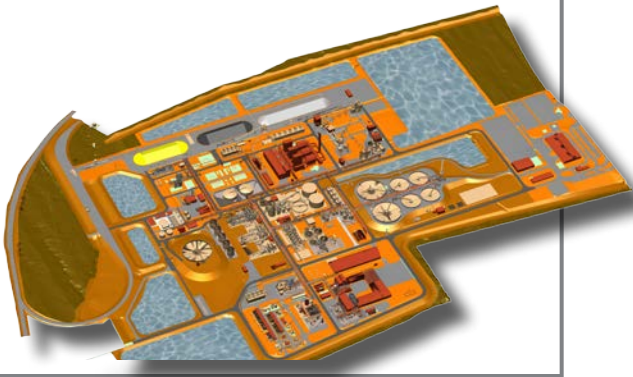


PM+

SNC-Lavalin's in-house project management software, was used to track and monitor over 350 purchase orders, 90 construction contracts, over 2 million home office work hours, 5,000 mechanical pieces of equipment, and thousands of kilometres of bulk materials such as piping, electrical and instrumentation cables, all sourced from hundreds of suppliers from across the world.

3D modeling

Intergraph 3D modeling software was used to build a complete representation of the process plant, including the ground level and underground services and foundations, the equipment, all the steel and piping, buildings and roads. This complex mathematical representation of the plant proved essential for well-organized inter-discipline coordination and clash resolution, bulk material reporting and control, and design reviews with the client's project and operation teams. Furthermore, the use of this integrated 3D design tool allowed multi-office execution of the project by the Toronto home office where the core engineering and project management teams were based, and by specialized SNC-Lavalin teams in Santiago, Chile, for the nickel refinery and Edmonton, Canada, for the ore preparation plant.

**Technology**

A crucial layer of complexity on the project was the use of High Pressure Acid Leach (HPAL) technology in the process plant. The high pressure (60 bar gauge) and high temperature (270°C) requirements in the HPAL section of the plant required design

and engineering methods, techniques and expertise that are common only to oil refining or even nuclear industries. It also required the addition of elaborate safety systems associated with the handling of hazardous intermediate materials such as anhydrous ammonia, sulphuric acid, hydrogen sulfide and propane.

**Madagascar**

The country of Madagascar had little mining or industrial activity prior to the Ambatovy Nickel Project making the delivery of a world-class mine and process plant a significant challenge. Executing such a large scale project required special considerations for:

Safety Culture

At the beginning of the project, local contractors in Madagascar had minimal safety culture. In order to meet the high safety expectations set for the project, a comprehensive safety training and safety inspection program was implemented to establish a "zero-harm" safety culture on site. To ensure full compliance, training was conducted in French and Malagasy languages and local performing artists were hired to stage industrial theatre performances.

Remoteness

The mine site is located near Moramanga in east-central Madagascar. In this area, existing access roads were not suitable for the high traffic expected during construction and operations. SNC-Lavalin provided upgrades and extensions to all roads and accesses. In addition, a slurry pipeline was required to transport ore over 220 kilometres of difficult terrain from the ore preparation plant at the mine site to the processing plant on the eastern coast.

Political Instability

The government was overthrown in 2009. The interim government drew many international sanctions against Madagascar and its people. Against this backdrop of political / governmental uncertainty, project execution continued.

Personnel

Due to the lack of a large skilled labour pool in Madagascar, and compounded by the limited ability of the government to support labour development strategies, addressing labour requirements was immensely challenging. To address the shortfall in competent local construction labour, SNC-Lavalin developed and implemented a LRDI program. More than 6,100 nationals were trained in various aspects of construction and operations activities. A remarkable 95 per cent trainee placement rate was achieved with SNC-Lavalin and various contractors and suppliers in the country, positively impacting the local community's commercial and cultural life.

Procurement Logistics

Scheduling and transporting necessary equipment and materials to site was a project management challenge that required freight forwarding logistics and detailed tracking. The existing jetty at the Port of Toamasina needed to be extended to manage the additional cargo. As Toamasina is the major entry port for most Malagasy national supplies including critical petroleum products, construction could not interrupt continuous delivery operations and necessitated the installation of a temporary underwater petroleum-unloading pipeline. A tube conveyor was also specified to enable the loading of rail cars with potentially dust producing products amidst a very sensitive food warehouse environment. A 10 kilometre batch ammonia transfer pipeline was buried along the existing and upgraded railway to cover the distance between the Port and the plant through a very densely populated area. Although a great deal was

imported to site, local materials and equipment were sourced as much as possible to reduce transport and import delays.

Climate

The mine site is located at an elevation of 1,150 metres above sea level, while the plant site is located at sea level near Toamasina on the east coast. The climate in Toamasina is severely humid and hot, with daily temperatures exceeding 30°C. The area is subject to severe annual cyclones and high winds, and experiences



Extreme climatic conditions such as high wind contributed to construction challenges

an average of 1,500 mm of rain during its wet season, from November to May. These extremely challenging construction conditions would often bring construction to a halt for days at a time. In order to reduce the impact of weather conditions on the project timeline, the schedule was adapted to complete most major earthworks during the dry season.



By the close of the project, approximately 24 million m³ of earthworks were moved, 360,000 m³ of concrete were poured, including more than 6,000 piles, 34,000 tons of steel were fabricated, 330 kilometres of piping and an additional 220 kilometres of pipeline were assembled and 1,700 kilometres of cables were pulled. The plant site covers more than 320 hectares.

Meeting Client's Needs

SNC-Lavalin was involved in this major project from the feasibility stage through to plant mechanical completion and commissioning. This long-term involvement allowed for intimate knowledge of the selected process technology and related challenges and a unique opportunity to understand the success factors and the fundamental needs of the client.

SNC-Lavalin consistently met the following client goals:

Community Involvement

The client had an objective to fulfill the Malagasy government's desire to maximize local benefits. SNC-Lavalin's implementation of a LRDI program was a resounding success. Over 6,100 nationals were trained and over 95 per cent of the trainees placed. More than 50,000 hours of small-medium-micro enterprise (SMME) training and mentorship were provided and over 700 contracts to local SMMEs awarded. The regional government presented SNC-Lavalin with a Certificate of Recognition for the success of the LRDI program.

Production Ramp-Up

Despite some routine mechanical issues during construction that were diligently addressed by the field engineering team, the plant was ramped-up to commercial production and it is now primed to develop into the most efficient in its category in terms of on-line availability.



Top Quality, First-Tier Nickel Product

The client's proprietary technology was selected for its reliability in terms of product quality and specification. Therefore, SNC-Lavalin concentrated on improving the detail design to ensure minimum interruption during the operation through a continuous and constructive review of all aspects of the process with experienced maintenance and operations experts in the field.

Flexible Execution Plan

Flexibility in the execution and contracting plans was essential to ensure the viability of the project until commercial operation, especially during the 2008 financial crisis at the peak of the construction effort. To meet successful project completion despite these challenges, SNC-Lavalin's adaptive approaches were integrated into the project, such as a diverse multi-country supplier sourcing strategy and the establishment of quality contracting partnerships for fabrication and erection.

Health and Safety

Fully trained health and safety officers and shop inspectors ensured all construction personnel at site were well-trained. Health and safety compliance of all suppliers and contractors was also required to meet project standards. Having recently completed several large scale projects in similar conditions, the team had hands-on experience in applying the best approaches for meeting training requirements. To address the major challenge of implementing safety among workers the training effort was conducted in both the French and Malagasy languages and local performing artists were also employed to stage industrial theatre performances illustrating training concepts to thousands of workers.



Health and safety training was conducted in both the French and Malagasy languages to ensure full comprehension & compliance.

Environmental Considerations

A mining project as large as Ambatovy - developed in an area as biodiverse and ecologically sensitive as Madagascar - naturally attracted both local and global scrutiny. SNC-Lavalin identified risks at the project initiation stage that were continuously reviewed and managed during the many years of design and execution.

Adhering to stringent environmental standards resulted in many of the project's key features such as the burial of the slurry pipeline, pipeline route selection, site reforestation, species relocation, tailings management, monitoring of air, water quality and soil erosion.



Environmental Benefits

Madagascar's rich biodiversity and unique fauna and flora are world-renowned. As an isolated island, drifting alone from the split of the original Gondwana continent, it is also well-known for its struggle to contain and limit the pressure on its remaining wilderness areas.

Given the sensitive nature of the region's natural environment, the impact of the entire life-cycle of the Ambatovy Nickel Project demanded serious consideration. To minimize effects on the unique and sensitive natural environment, environmental standards were set high: SNC-Lavalin designed and executed the project as per IFC Standards.

Individual environmental protection plans were prepared for the mine site, the slurry pipeline, and the process plant and port facilities (including tailings management facilities). More specific discipline-related environmental management plans were developed for hazardous material handling, waste management, air and noise management, soil management (erosion and sediment controls), and water management for the overall project.

Slurry Pipeline

To minimize environmental risk, the 220 km slurry pipeline was designed to consist of a single pumping station at the mine site and a completely buried pipeline, eliminating exposed boosting stations and above ground installations. The combination of directional drilling techniques, complete soil remediation and the development of access roads for pipeline inspection and maintenance proved to be of a minimum impact to this sensitive environment. With regular inspections of the wall thickness, monitoring of pipeline condition with in-line travelling devices, and the use of a pressure monitoring leak detection system, the contained pipeline represents a model of achievement in terms of proper environmental handling for transfer of ore from a mine site to a processing plant.

Process Plant

Located on the east coast of Madagascar the process plant site experiences frequent rainfall (3,000mm/year) and dangerous hurricanes typical of tropical latitudes. To secure a relatively dry site for the construction phase and best dewatering capacity of the entire site, as well as any construction spill containment and minimum release of surface-water sedimentation effluent to the environment, a circumferential canal was built around the plant site, complete with silk barriers, cascading sedimentation ponds and erosion control banks. For permanent water flow control, SNC-Lavalin also designed double liner sedimentation ponds, leak control systems on thickeners tanks, emergency containment ponds, process water treatment and recycling to ensure reliable and sustainable plant operation.



Site dewatering and erosion control

Port Facilities

The 10 kilometre ammonia pipeline between the Port of Toamasina and the process plant site crosses a very densely populated area. Risk of exposure was minimized by using a buried pipeline and a batch transfer approach at low temperature and in the liquid phase.

The transferring of potentially dust-producing products like coal, sulphur and limestone from port to plant was resolved through the use of the latest tube conveyor technology and a negative-pressure train loading station equipped with an automatic water spray system. This approach achieved complete dust control for the material transfer operation in the middle of the existing Port and in the direct neighborhood of food warehouses which are critical to basic national supply.

Other Considerations

In addition, SNC-Lavalin introduced monitoring of air and water quality and soil erosion. These are still being monitored and managed today. The mining activities are in line with the most stringent international standards – areas are revegetated after mining has occurred and continually monitored. Also, local farmers are being trained to embrace sustainable methods instead of the normal slash-and-burn farming methods.

A tube conveyor was used for the transfer of coal, sulphur and limestone at the Port to minimize exposure to dust.

Upgrades and an extension to the Port of Toamasina was completed without interruption to critical activities at Madagascar's busiest port.





Ambatovy uses HPAL technology, solvent extraction and hydrogen reduction to produce nickel and cobalt.

There were many aspects of the work for which the design team had to apply their engineering skills in an innovative manner in order to address the scale of the project.

High Pressure Acid Leach (HPAL) Technology

SNC-Lavalin implemented HPAL technology on this project. To date, only a handful of projects have used this technology on a similar scale. The use of this innovative technology introduced an added complexity to the engineering development; in terms of the need to avoid potential throughput bottlenecks in the process, ensuring sufficient redundancy in the pumping and processing equipments, and most importantly in the careful selection of the material of construction for the very corrosive and erosive services involved.

Slurry Pipeline

Aiming to optimize the 220 km pipeline path through difficult terrain while avoiding settlement of the solid portion of a two-phase flow, designers used modern simulation tools to undertake computer modeling of the most advanced level possible. The simulation included not only the assessment of the local fluid velocity and pressure at every point in the line but also a very detailed dynamic analysis to ensure no water hammer or other transient loads could jeopardize the integrity of the pipeline. The pipeline was designed to ensure a continuous yet safe operation for the full 30+ years of expected mine life.

Modularization

To improve quality, optimize cost and facilitate installation at site, SNC-Lavalin made use of pre-

fabricated modules, wherever possible, given the shipping limitations to the site. For example, the electric sub-stations were built and assembled overseas, with all internal components installed in the shop. The sub-stations were transported by ship and road, lifted in place over piers allowing the safe and efficient routing of the cable trays, loaded with control and power cables from underneath. This technique is now becoming standard for similar applications.

Port Extension

Extending the jetty at the Port of Toamasina for receiving bulk consumables without disruption to critical petroleum product importation, proved to be a major challenge. SNC-Lavalin resolved this through innovative planning and sequencing of the piling activities and the installation of a temporary underwater petroleum-unloading pipeline. By working closely with the offshore piling contractor and using state-of-the-art battered pile technique, it was possible to finish this major upgrade despite constraints imposed by Madagascar's busiest and most strategic port.

Mine-Site Dams

The use of locally manufactured gabions as energy dissipaters for the emergency spillway at the mine-site dams also represented an innovative and economical approach to an often difficult construction aspect of a critical dam.

Social and/or Economic Benefits

The Ambatovy Nickel Project had the potential to affect 85,000 people in and around the mine site and over 200,000 people around the port city of Toamasina. To maximize local benefits of the project, reduce construction costs, and address government requirements and community expectations on the positive impact of this large-scale project, the client formulated the following project sustainability strategy:

"The Management of the Ambatovy Nickel Project is committed to maximizing sustainable benefits to the local community using a combined strategy of development and use of local goods, services and personnel without compromising Project objectives."

The demographic profile of the Malagasy population posed major challenges for the project in its effort to maximize local labour employment in a labour market that had a shortage of qualified/skilled people and to maximize the procurement of goods, works and services from a local market that lacked capacity.

To support the project sustainability strategy and maximize the use and development of local resources during the construction phase, SNC-Lavalin developed and implemented a comprehensive LRDI program featuring three principal pillars:

Local Training Program

A local labour training program was designed to provide basic training in civil, mechanical, piping, electrical and structural construction trades. More than 25,000 work seekers were registered and a total of 6,100 were selected and trained, with an emphasis on a health and safety culture at an international level. This also represented a long-term employment opportunity for some of the skilled operations and maintenance personnel over the next 30+ years of the expected mine life.

Local labour training programs provided potential employment opportunities for the life of the mine.



Local Procurement Strategy

A local procurement strategy and a SMME development program involved training and mentorship. SMMEs were encouraged not only with an extensive 50,000 hours of training, but with a total of more than 700 contracts, generating almost US\$ 900M worth of local procurement. Smaller national design engineering firms were contracted for some aspects of the project requiring local input (e.g. buildings, permitting, etc). Some of these businesses, producing items such as safety vests and soil stabilization mats, will continue to operate in the longer term and for the future benefit of the national economy.



A number of businesses developed via the SMME program will continue to operate, serving Ambatovy for the long term.

Community Development Program

A community development program promoted agricultural production and marketing in the region and addressed development issues related to food price inflation, gender equity and community resettlements.

SNC-Lavalin's LRDI program exceeded all of the objectives set by the project within two years of its inception. Two training centers provided basic workplace orientation and advanced training in trades and occupational health and safety. An additional 3,000 people in rural communities along the slurry pipeline received basic safety training and were hired for short-term work to clear sites and replant vegetation along the pipeline. Overall achievements during the development of the project included 64 per cent of the workforce being Malagasy, a 95 per cent placement rate of trainees and over 1,500 jobs for women.

Ambatovy Nickel Project

BY THE NUMBERS

- Total Construction Cost \$US 5.3 billion
- 600 employees in SNC-Lavalin's Toronto office
- 20,000 workers on-site during construction
- 6,000 workers lived in construction camps
- 6,100 locals trained
- 2 million home office hours worked
- 50,000 hours of SMME training and mentorship
- 700 local contracts
- US \$900 million in local procurement
- 1,500 jobs for women
- 60 sub-contractors
- 90 construction contracts
- 5,000 pieces of equipment
- 24 million m³ of earthworks moved
- 360,000 m³ of concrete poured
- 34,000 tons of steel fabricated
- 330 kilometres of piping assembled
- 1,700 kilometres of cables pulled
- 220 kilometres of pipeline installed



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