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Research Article

Open innovation and corporate spin-off: analysis of the Desafio MinerALL Program

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Abstract

The mineral sector, despite its relevance to the Brazilian economy, faces a period of great challenges, especially with regard to the development and adoption of new technologies to reduce the environmental and social impacts caused by extractive activities. This study aims to analyze Samarco's open innovation program, called Desafio MinerALL, a technology acceleration program, which involved university students with the objective of bringing to the market technologies for the use of iron mining waste. The challenge came from seventeen technologies previously promoted by Samarco; there were more than four hundred applications from students from different educational institutions in the academic communities of Belo Horizonte, Mariana and Ouro Preto. The eighty selected students underwent various training sessions to analyze the technologies from a technical, economic, commercial and social and environmental impact point of view. In just three months, fifteen detailed studies were generated on the feasibility of implementing the solutions. Of these, six projects turned into potential new businesses (spin-offs), three of which will proceed to the escalation and go-to-market phase, with a view to starting the operation of the pilot plants. For each of the three spin-offs an individual development plan was created, with goals, divided between the scaling and go-to-market activities. The project delivered three startups, two of which are already on the market. Three pilot plants were completed, which in total treated more than 150,000 tons of tailings in one year, with a volume of over four million in sales negotiations. The perspective for the year 2021 is of more than 300,000 ton of tailings treated with these new technologies. In this study, the following parameters are analyzed: program structure, team involved, technology scaling, investment made, results, and lessons learned and main differences and similarities with other corporate spin-off generation practices available in the literature.

Keywords: corporate spin-off, startups, scheduling, open innovation, mining.

1. Introduction

The mineral sector is of great importance in the Brazilian economy, reaching, in 2020, revenues close to R$209 billion. The sector's share in Brazil's Gross Domestic Product is around 4%, including the mineral extraction and mineral transformation segments, in addition to oil and gas. Additionally, there are more than 174 thousand direct jobs and almost 2 million jobs in the entire production chain (Instituto Brasileiro de Mineração, 2020).

Despite all the relevance to the Brazilian economy, the mining sector faces a period of great challenges, especially with regard to the development and adoption of new technologies to reduce the environmental and social impacts caused by extractive activities. Thus, a paradox arises that needs to be better explored: while it is necessary to combat the risks of mining and make activities more sustainable, the country still depends heavily on this extractive activity.

Among different ways to support mining companies in solving this challenge, open innovation initiatives have gained momentum in the country, with projects being developed both individually, by companies in the sector, and collectively, especially through the Mining Hub, the first mining sector open innovation hub in the world. Additionally, most mining companies have research and development projects being developed both by internal teams and in partnership with universities and research centers.

Brazil has about 200 thousand researchers spread over more than 290 higher education institutions with infrastructure available for the development of new technologies. Universities and Institutes of Science and Technology (ICTs) play a fundamental role not only in research and in the personal/professional training of their students, but also in the generation of technical-scientific knowledge for the country's socioeconomic development by inserting their technologies into the market. Considering this context, it is desirable to create

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new arrangements that allow a better use of the competences accumulated in universities and research centers in strategic technological areas, to increase the competitiveness of Brazilian companies when investing and implementing new technologies developed there (Paranhos, 2018; Rapini et al., 2009; Rapini et al., 2017; Sbicca & Pelaez, 2006; Szmrecsáyi, 2006). From a legal point of view, it became possible in Brazil with the enactment of the recent Legal Framework for Science, Technology and Innovation - MLCT of 2016 (Law 13.243/16), several legal and bureaucratic paths that facilitate the innovation processes to shorten the path from university to market. An example is the permission to create innovation environments (ATCI) within the university. The ATCI has a hybrid nature, as it foresees in its constitution the presence of ICTs, companies and other SNI agents, that is, institutions with different vocations. ATCI is also hybrid in terms of the different forms of partnerships it can offer, functioning as a platform for interactions between the participants in the environment, as well as other companies and institutions that can partner with ATCI in RD&I (Crepaldi, 2020). UFMG, for example, is one of the most prepared universities in the country to transfer research to the market through CTIT, its technological innovation center, responsible for presenting what researchers do in their laboratories as a technological showcase for several companies. However, at UFMG there are approximately 1600 intellectual properties and only 6% of them effectively reached the market.

And the number of technologies that come out of the university is even smaller when we talk about hard science technologies, chemical and physicochemical processes. Unlike “soft” technologies (I.T), which have short market entry times, hard sciences are very complex. These technologies require long-term product maturation, increased regulation, lengthy sales cycles, and a non-linear transition from bench-top and industrial-stage development.

Companies look to universities to map technologies that solve their internal problems (processes, tailings, waste, among others) and to create new products. However, industries demand advanced answers about the performance of technologies that, in most cases, are not found in the laboratory stage. The industries, when investing in a technology, hope to understand about the production capacity and efficiency on a large scale, the cost-benefit ratio of the new product/process, the risks involved, the size of the market to be reached, among other aspects. The laboratory step is crucial in this long, costly and excessively risky process. It defines the technological route that will be tested in the future, implemented, its critical parameters (temperature, pressure, agitation) optimized and the products characterized. However, the low maturity stage of the technologies makes the path of direct implementation almost impossible. One of the ways to reduce this gap is to carry out the scheduling of research carried out within the ICTs.

Despite all these efforts, many developed technologies are not properly worked to be applied in scale, which compromises their conversions into innovations and, consequently, into benefits for the company itself and for society. In this context, the main objective of this article is to analyze the mining company Samarco's open innovation program called Desafio MinerAll Program, identifying its structure, strategies, results achieved and lessons learned, both from the perspective of program managers and from the perspective of entrepreneurs of the spin-offs generated, being a rich source of information to support the study discussions.

Therefore, the paper is structured as follows: the next section presents the theoretical framework on innovation in the mining sector, open innovation, corporate spin-offs and technology scaling; the third section presents the research methodology and the description and analysis of the Desafio MinerAll Program; and the subsequent sections present the results, discussions and final considerations, with an emphasis on opportunities for future studies in the area.

2. Theoretical background

2.1. Innovation in the mining sector

Mining can be considered one of the oldest activities in civilization and, although many see this extractive activity as rudimentary, it has always been a source of innovation, seeking efficiency, safety, social and environmental balance in very adverse circumstances (Minalliance, 2012).

In recent years, several factors have motivated mining companies to change their strategies, adopting new technologies and operating models. Market volatility, changes in global demand, new reserves prospecting needs, focus on assets with longer life cycles, commitment to operational excellence and sustainability, among others, are some of the factors that have forced mining companies to explore opportunities to reach new levels of productivity across its value chain (Accenture, 2016).

In fact, with the high growth rates of the population and global economies, there is an increasing demand for minerals, creating many challenges for this industry as the extraction and processing of minerals is becoming increasingly difficult, and the depletion of the Earth's resources and the impact on fragile environments is a growing social concern. According to Writer (2019), digital transformation and the use of new technologies offer a great opportunity for companies to become more efficient, increasing productivity and reducing costs in a safer way. Mining operations are also becoming increasingly "green" and benefit from trends such as electric vehicles and renewable energy sources. Additionally, there are future opportunities for deep sea and space mining and in abandoned mines. In other words, it is an industry that has many frontiers to conquer, in which innovation will be a determinant of success.

In line with this context, Sánchez & Hartlieb (2020) reinforce that innovation plays an important role in the mining industry as a tool to improve the efficiency of its processes, reduce costs, and also to meet the growing social and environmental concerns among communities and authorities. According to the authors, technological progress has also been essential to allow the exploration of new deposits in more complex scenarios, such as with lower ore contents, extreme weather conditions, deeper deposits, harder rock masses and high stress environments.

Some technological trends will shape the mining of the future, starting with the digital transformation, through the adoption and incorporation of a set of tools and technologies to the business, such as robotics, internet of things and digital twins. Other important trends are electromobility, invisible mining with zero waste and continuous mining, reinforcing the need to build a more sustainable and efficient industry, reducing the environmental footprint and increasing the safety of mining operations (Sánchez & Hartlieb, 2020).

Byrne & Engdahl (2021) further reinforce that mining can be the gateway to the world's carbon neutral future, since green energy storage systems are largely dependent on minerals. According to the authors, mining companies must go beyond cost reduction and technology implementation, and the best way to do this is to work with open innovation.

2.2. Open innovation

Innovation is the main factor for economic development, through the introduction of new processes and technologies, upsetting the current balance through spontaneous and discontinuous changes. According to Schumpeter (1961), to survive and remain relevant and competitive, companies need to innovate, incorporating new technologies, developing new products and modernizing facilities and equipment.

Initially, the companies created Research and Development (R&D) areas with the main objective of maintaining and improving production. Thus, R&D functions were aimed at large-scale production, which made it difficult to introduce and create new products. From the internal R&D, many companies started to use the acquired knowledge to develop new products. (Chesbrough & Crowther, 2006).

In 2006, Chesbrough defined open innovation in a single sentece: "Open innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively" (Chesbrough, 2006, p. 1).

Based on these concepts, some authors, such as Nambisan & Sawhney (2007), list several ways in which companies can innovate openly, such as codesign projects, collaborative innovation, joint ventures, open source models, spin-offs and licensing. The more recent definition of open innovation further adds to the view of the non-pecuniary knowledge flow, due to increased attention to non-profit issues (Chesbrough, 2017; West et al., 2014).

Furthermore, it is noteworthy that open innovation is usually contrasted with closed innovation, supposedly its predecessor, where companies generate their own innovation ideas and then develop, build, market and distribute on their own (Chesbrough, 2003, p. 20).

Huizingh (2011) highlights that the basic premise of open innovation is to open the innovation process and uses the terms "inbound" to refer to the internal use of external knowledge and "outbound" for the external exploration of knowledge used internally. In addition, the author groups innovation practices, distinguishing between process and result, as follows: i) Closed Innovation, with closed process and result; ii) Open Source Innovation, with an open process and results; iii) Private Open Innovation, with an open process and a closed result; and iv) Public Innovation, with a closed process and an open result.

2.3. Technologies scaling

The innovation process basically consists of transforming an invention into a product/process for the market through competitive advantages. The path to incorporate these differentials into the technology, to test it and validate it, demands time, high risk and costs. In order to reduce the complexity of development, chemical strategies, engineering techniques and market are proposed. These strategies are based on the study of the technology's scale-up, that is, its production on a larger scale so that it is possible, in stages, to answer relevant questions to the reduction of risks such as efficiency, production size, chemical reactions, unit operations among others.

Several definitions and approaches to scale-up can be found in the literature, Bisio & Kabel (1985) define scaling as the work required for the successful start and operation of an industrial production unit, whose operating and design procedures are based in part on experiments and demonstrations carried out at smaller and/or laboratory scales. Other authors approach scaling as a process used in the expansion, replication and adaptation of successful results on an industrial scale, based on previous experiments, which should be framed in the innovation-learning-expansion cycle (Cooley & Linn, 2014).

Although it is a broad concept and with different names (scaling, “Scale Up” or “scaling up”), in chemical engineering it is described as the reproduction of technical results obtained at smaller (laboratory) scales, through chemical operations and /or physical for larger scales in order to obtain a new commercial product (Thorpe & Ridgman, 2016).

But scaling up is not something quick and trivial. The transposition of results obtained in the laboratory to industrial scales has been identified as a great challenge by researchers, who start the development of the technology on the bench and rarely manage to clearly visualize the long path that research must go through to reach maturity in order to finally arrive at an industrial process of transforming raw material into product (Thorpe & Ridgman, 2016). This is a subject of little coverage in the literature, approached for specific cases of what ends up forcing interested researchers to work through trial and error. On the other hand, it generates a load of experience for those involved that should not be neglected, as a bridge is built between knowledge and practical experience.

When moving from bench to scale, the most important engineering bottlenecks in the process become evident. In addition, in this phase, it is possible to carry out the first tests of the product in large quantities, and even make the first sales, as well as the declarations of intention to purchase the product, which are essential to minimize commercial risk (Silva et al., 2019).

In general, three major risks can be considered in the innovation process: Technological Risk, Engineering Risk and Commercial Risk. Technological risk is minimized in research laboratories. In the first Proof of Concept (POC) laboratory research, which is already well known and widespread, is carried out. In POCs 02 and 03, the main aspects of that route that can be optimized in order to ensure greater economic viability of the route and a product/process with the greatest possible efficiency are evaluated on the bench. In addition, at that moment, the first scale increases were started to respond, while still on the bench, to aspects of the next stage in order to reduce risks. The last stage consists of POC 04, which works in detail on aspects of the pilot plant to be validated with the real market customer (Silva et al., 2019).

2.4. Corporate Spin Offs (CSO)

One of the ways in which companies can openly innovate is through the creation of spin-offs. In fact, the corporate spin-off can be an interesting and fast path for companies to explore new ideas and technologies, since the structure is simpler than the parent organization, with a well-defined focus of action, in addition to inheriting the experiences in the organization that generated it. (Clarysse et al., 2011).

Although the concept of spin-offs arose in the 1960s, in Silicon Valley, and is widely disseminated, the number of studies that contemplate corporate spin-offs is still small, and one of the possible causes for this refers to the difficulty of accessing the cases, which are mostly restricted to publications in the press and in the internal context of the organizations themselves. (Luc et al., 2002).

According to Van De Velde & Clarysse (2006), corporate spin-off is an independent legal entity that aims to explore a new business with the objective of developing and marketing new products or services based on a technology or skills of the parent organization. In addition to this context, Cozzi et al. (2008) points out that the term spin-off has been used to denote processes of formation of new companies from existing ones.

Luc et al. (2002) also highlight that both the parent company and the spin-offs can benefit from the process. Parent companies will be able, for example, to focus on their core business, explore new markets, attract talent and strengthen their social role. Spin-offs, on the other hand, will be able to share risks, find it easier to access resources, receive knowledge and support from the parent company, among other factors.

Van De Velde & Clarysse (2006) also propose a model that recognizes the role and importance of different components for the performance of a CSO: i) motivation for creating the CSO, including the objective of exploring new markets, new technologies and new models of business; ii) division of the relationship, differentiating the spin-offs generated without the parent company's consent as hostile and those encouraged by the parent company as friendly and iii) recognition of the environment and control, extending the link between the environment and the formulation of strategies for the corporate spin-off scenario.

Regarding the theoretical spin-off models available in the literature, the model proposed by Ferraz & Teixeira (2015) stands out, which is based on the analysis of the phases of the process by Tubke (2005) combined with the resources used by Clarysse et al. (2005) in the spin-off creation phases. In Tubke's (2005) model, the corporate spin-off is originated by a process sequenced in three phases: i) pre-separation, which especially involves the evaluation to support the decision to start the spin-off; ii) separation moment, in which the new company starts and serves the first customers; and iii) post separation, with the operation independent of the parent organization.

Clarysse et al. (2005) explain the creation of a spin-off through a process in the form of a funnel, starting with the invention, passing through the transition until reaching the actual innovation. Thus, the initial ideas must be evaluated throughout the process, and only the most promising and validated ones continue development and become spin-offs. According to the authors, the emergence of spin-offs is directly impacted by available resources, in particular: human, social, financial, physical, technological and organizational resources. Additionally, the more involvement and resources the parent organization contributes to the spin-off, the more intense the relationship will be.

Thus, the model by Ferraz & Teixeira (2015), used in this study and exemplified in Figure 1, allows us to analyze in parallel the three phases of creation of spin-offs proposed by Tubke (2005) and the resources exchanged in each of these phases, which may vary according to each case.

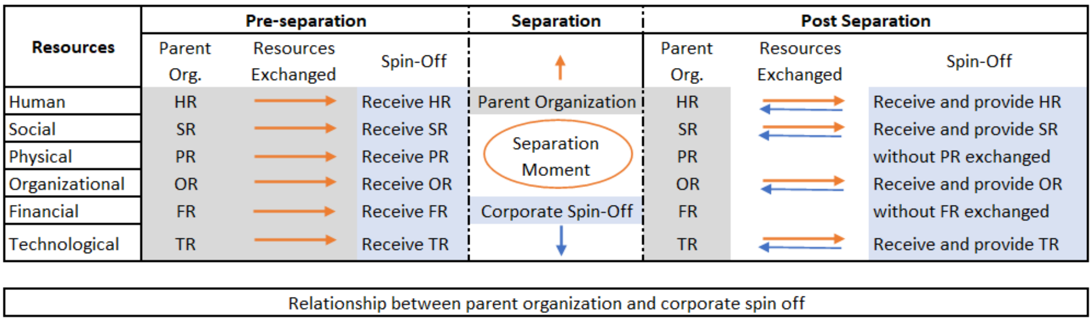

Figure 1. Spin-off generation conceptual model. Source: Ferraz & Teixeira (2015).

3. Research Design and method

3.1. Data collection and its analysis

This article uses the case study as a methodological approach, which, according to Yin (2001), consists of a comprehensive and empirical method that involves planning, collecting and analyzing data. The choice of this approach can be justified by the following facts: (i) researchers have little control over events; (ii) the implementation context is relevant and there is an opportunity to compare the practice with the literature; and (iii) the topic is current, with intense discussions in recent years. The methodology used encompassed the four essential phases for the case study, presented by Gil (1995): i) delimitation of the case-unit; ii) data collection; iii) selection, analysis and interpretation of data and iv) preparation of the report.

The unit selection that constitutes the case was intentional, as the researchers had access to data and information from the parent organization and the three spin-offs generated in the program. Additionally, several sources were used in the research, highlighting the monitoring of the spin-offs development process, meetings with company managers, access to generated information and base technologies, and unstructured interviews with the managers of the parent company and the entrepreneurs of the spin-offs generated.

The variables analyzed include: (i) for the manager: motivation to create the program, program structure, allocated team, investments made, initial results and lessons learned and (ii) for the entrepreneurs of the three spin-offs: technologies involved, main difficulties faced, main benefits perceived and other lessons learned. In all, four interviews lasting approximately 40 minutes were carried out, which were transcribed and validated before the analysis.

The qualitative data collected in the exploratory phase and the information obtained from the literature review were selected, analyzed and interpreted, seeking to compare the literature with the real process. Data selection considered the objectives of this article and its limits, in order to determine which data would be useful or not. The case, detailed in the next session, was built later, after the end of the program, in order to ensure that the report represents the real situation investigated.

3.2. Startups interviewed

For confidentiality reasons, we will use fictitious names to refer to spin-offs in this article. The first spin-off interviewed was Alpha, which uses mining tailings for more sustainable paving, especially for local roads, mine access, subdivisions and condominiums and ecological parks. The second, called Beta, develops different products with a high silica content based on mining tailings. The third startup, called Gama, produces cementitious floors and coatings with low environmental impact and high performance, aligning the design with a new concept of using iron mining tailings.

4. Results

This topic presents the characterization of the Desafio MinerAll Program and its specificities from the perspective of managers and the three spin-offs generated, allowing a rich discussion on the process of creating corporate spin-offs, technology scaling and relationships with the parent company.

4.1. The Desafio MinerAll Program

The Desafio MinerAll is an open innovation program developed by Samarco, a Brazilian mining company founded in 1977, with units in Minas Gerais and Espírito Santo, whose final product is iron ore pellets. The program's main objective was the development of innovations and new businesses from 17 technologies related to the use of mining tailings previously developed by the company. Thus, through the generation of spin-offs, Samarco is able to provide a more sustainable destination for its tailings, in addition to stimulating economic diversification in its area of operation.

A manager of the mining company responsible for the program was defined, as well a support team with company employees, covering various areas such as legal, communication, operations and new business. Additionally, the company hired professionals who are experts in technology scaling and new business development to support it throughout the program. Throughout the execution of the project, Samarco received monthly reports from the contracted specialists, containing developments in relation to technologies and new businesses. The three macrop-hases of the Desafio MinerAll Program are detailed below.

4.1.1. Phase 1 – Feasibility study and pre-acceleration

The program began with the main objective of carrying out a technical and economic feasibility study for seventeen technologies, with the aim of bringing new solutions for the use of mining tailings. This is an open public innovation process, in which the technologies developed by Samarco were released for study by undergraduate, graduate, master's and doctoral students, with the aim of forming groups to develop the business aspects of each one of the technologies.

There were more than 400 students enrolled, with around 85 of them selected by the organizing team and divided into 17 teams to develop the feasibility aspects. Phase 1 had a total duration of 5 months, with the teams receiving training and mentoring from Samarco professionals and contracted specialists.

The training in this phase was divided into 4 modules. In module 1 – vision/team fit, aspects of leadership and self-knowledge, startup mindset, communication and public speaking focused on pitch, productivity, agile project management and how to become an efficient team were addressed. In module 2 - problem/solution fit, aspects of customer vision, strategy canvas, business strategies in hard science, introduction to regulatory aspects, cost and revenue structure, competitive advantage and validation were addressed. In module 3 - product/market fit, aspects of market segmentation, market definition, end user profile, how to estimate the size of your market, defining the persona, how to position yourself in the market, how to adapt your product to demands market, life cycle use case (description of the product that will be used in the persona's routine), high level specs (detail of the product with specifications and properties), quantified value proposal, competitive position chart (visual organization of your position in relation to the competition in a matrix), pricing framework (designing a model to test possible pricing), how to generate value and differentiate in the world of startups (open innovation in large companies), how innovation generates value for the market, aspects of intellectual property, development of innovative solutions and methodologies and tools for planning and executing the results-focused R&D process were addressed. In module 4 - market/business fit, aspects of partnership models for innovation, partnership models with companies, financial management for life science startups, valuation, investment and fundraising, fundraising for hard sciences startups, legal aspects for innovative startups and pitch training were addressed.

Preliminary technical and economic feasibility studies were also carried out in order to estimate the costs involved in the development of the product to support decision-making on the feasibility or not of the business. Following the previous economic study, market points (segment, identification of stakeholders, added value, logistics, legislation and environmental analysis) and technical feasibility (production process, logistics, waste generation, potential consumption, technological maturity and complexity) were studied.

At the end of the process, the 6 most promising projects were selected for the Program's second phase.

4.1.2. Phase 2 - Pre-scaling and acceleration

The second phase had the main objective of conditioning and preparing the technologies for the construction of pilot plants, lasting 8 months. It is important to delimit that in Phase 2 the teams were not expected to develop such plants, but that all the information necessary to understand the technology and its market was determined. With this objective in mind, the teams were exposed to various content that provided an environment of intense learning and collaboration.

For the market and business development, the hired specialists supported the teams, with presentations about the knowledge of the market's value chain, segmentations and trends, with the objective of initially identifying the existence of a real opportunity. In addition, hypotheses of market pain with potential future customers were raised and validated, identifying the market fit to insert a possible solution. Using agile methodologies, the teams also created product proposals, raising and testing business model hypotheses. To structure processes and understand the financial functioning of each startup, contents for developing a list of prospects, structuring a sales process and financial projections were taught.

Parallel to market and business activities, the team of specialists in scaling immersed the teams in various contents on planning and management techniques and on technology development. Some of the contents aimed at reflecting on the circularity of technologies, project management, process design, software and production costs. To define the technological aspects, definition of routes and the best parameters for their validation, two projects were developed: conceptual and basic. The first aims to develop the technology concept from an identified problem or business opportunity and the second to develop what was technically proposed. In this way, technological development followed in parallel with market and business development. The specific steps were:

a) Business model: study based on the Business Model Canvas tool, widely used in the innovation ecosystem. After completing the tool, startups were able to see how their company generates and delivers value to its customers;

b) Prospecting for strategic partnerships: essential for startups to be able to validate their technology or even get customers interested in buying their products and/or developed processes, the prospecting was done to find potential partners/customers who have pain that the potential solution of startup could resolve. Without active prospecting, the startup's survival in the market is practically null, therefore, based on the information collected by the Business Model Canvas, and with the help of a CRM platform, startups prospected possible partners/customers and made commercial presentations to be able to validate technology in a relevant environment and/or fostering technological development and/or even being potential customers;

c) Proof of Concept in a relevant environment – MVP: it is a product developed with the minimum possible resources, but maintaining its main functionalities. It is used for the entrepreneur to present to potential customers, test in a relevant environment and obtain feedback to improve the product and/or the process used in the development. The experiment was structured using the MVP Experiment Canvas tool, which comprised a structured approach for planning and launching the MVP for validating the solution;

d) Technical and Economic Feasibility Study: an essential study for decision-making regarding the technological, market and economic-financial future of the project, as it seeks to identify the technological risks involved in all product development, understand the market in which the startup proposes to insert and verify if the financial investment in the project will bring considerable profits to the company. The points evaluated in the study were: production process, production model and production capacity; technological maturity and complexity; process yield; waste generation; logistics; market analysis and benchmarking; identification of stakeholders; relevant legislation; financial indicators; possible investment scenarios and competitive analysis;

e) Pre-Scaling: in order to plan the scale-up step, it was determined what would be necessary for industrial production, providing an initial technical notion of how the process would work on the desired scale; knowing in detail the stages of production, equipment, necessary materials, implementation area and logistics; and getting an overview of the process, including: dimensions, risk analysis, feasibility and safety.

The teams received training and mentoring from Samarco's team and the contracted specialists. The training in this phase was divided into 4 modules. In the Module 1 - Critical analysis of technological routes, technological mappings and evaluations of alternative technological routes were carried out, process construction tools were used, and a feasibility study was built. In Module 2 - Product and process validation, gradual scale-up activities were carried out - benchtop optimization, courses on Proof of Concept x MVP x Pilot Plant x Prototype, validation of products and processes, training with specific tools on planning and operation of POC and MVP and Technology Roadmap. In Module 3 - Hard science projects - notions of management, market positioning and financing, project and risk management, sustainability and ESG were teached, in addition to how to structure a commercial presentation for resource prospecting and use a CRM plataform, how to get investment for hard science technologies and structure a pitch for an investor. In Module 4 - Structuring and Feasibility of a pilot plant, the conceptual, basic and executive project of a pilot plant, and a final pre-scaling project were structured.

4.1.3. Fase 3 – Scaling up and Go-to-market

The third phase, lasting 12 months, had the main objective of developing the pilot plants and carrying out the proof of concept of the three most promising solutions defined in Phase 2. Surveys were carried out to map the main players that could be interested in the solutions, meetings were held with potential customers and partners and the main business models to be adopted were defined.

Parallel to market and business activities, the contracted team of scaling specialists support the development of technological routes and proof of concept. The technology scaling stage is one of the biggest bottlenecks in the development of the production process in strategic areas for the country. Therefore, to boost and facilitate the entry of these startups in the market, this step will address the preparation of the process design, which covers the steps from the initial selection to the preparation of process flowcharts, which includes the selection, specification and design of equipment; the plant design, including the detailed mechanical design of the equipment, the structural, civil and electrical design, and the specification and design of auxiliary services and the operation of the pilot plant to validate all aspects related to the industrialization of these startups.

In addition, a work plan was drawn up, involving the chosen technological routes and the tests to be carried out in the projected plant. This plan contained the tests that would be performed, the operating variables for the proposed increase (temperature, pressure, flow, etc.), the necessary chemical inputs (quantities, chemical specifications, values and suppliers), the critical variables that would be analyzed in each process/operation, the products generated, and finally a test plan of the final product with the customer to gather necessary information for advances in development.

The Escalab team designed a testing schedule for the proposed pilot. In this schedule, time management was carried out, involving all the activities necessary to validate the chosen routes and technologies, in addition to risk management for the operations.

In addition, an in-depth technical and economic feasibility study was carried out in order to estimate the costs involved in developing the product on an industrial scale (CAPEX, OPEX, fixed costs, product pricing) to build a projected cash flow with generation of indicators (NPV, IRR, IL, discounted payback, breakeven point, total free profit and EBTIDA) to support Samarco's decision-making regarding the viability or not of the business. In this phase, only two spin offs were able to validate the solution with clients and partners. The details of the activities are described below.

4.2. Spin-off 1: Alpha

Alpha offers a low-cost paving service through a new, simple process solution using mining slurry as an input. In addition to solving the problem of paving side roads, it can also serve mining companies that suffer from the problem of dust. This situation is illustrated in Figure 2a which it is possible to visualize the dust generated and in Figure 2b the effect of the proposed solution. When presented by Samarco in Phase 1, the base technology had TRL 2 (technological concepts/applications) and, after Phase 2, it reached TRL 4, with functional validation in the laboratory. As critical points of technology development, Alpha uses ore tailings as the main raw material, followed by the use of binding additives to obtain the paving product. As soils can vary in quantity and concentration of nutrients and minerals, it was necessary to carry out case studies for each soil where the material was applied.

In Phase 3, the objective was to develop the technology and business, for the separation of the spin-off. Thus, Alpha's planning sought to carry out two POCs, namely: i) paving a 2 km stretch, in the municipality of Mariana, with a consumption of around 15,000 tons of tailings and revenues close to R$ 2.3 million; and ii) paving of a private land, with about 2,000 m^2, without cost, and with a consumption close to 440 tons of tailings.


(a) (b)

Figure 2. (a) - Land before applying the solution; (b) - Land after application of the solution.

Both planned POCs were executed with their particularities. In the execution of POC 1, there were problems in relation to the schedule and execution time, motivated by contract issues with the City Hall, climate, partners, delay in receiving tailings and management. These points were bypassed and, even late, the work was carried out as planned, but consuming a smaller volume of waste, around 12,000 tons. In POC 2, there was a delay involving partners, but at the time of execution there was still a critical situation in which equipment broke and required maintenance, preventing the completion of the work. During Phase 3, Alpha reached TRL 8, validating its solution in a direct application with the customer, that is, starting its insertion in the market.

4.3. Spin-off 2: Beta

Beta developed a mortar solution aimed primarily at the repair and restoration industry. With a material capable of reducing the cure time by a third of that offered by competitors, with twice the resistance to compression and 10 times more resistant against acids. They also use the sandy mining waste in their composition. When presented by Samarco in Phase 1, the technology had TRL 2 (technological concepts/applications) and, after Phase 2, it reached TRL 4, with functional validation in the laboratory. As a critical point in the development of the technology, the production of the main input, silicate, stands out. Thus, the team initially focused on the production of geopolymers.

In Phase 3, the Beta planning sought the execution of three POCs, namely: i) floors in a public area; ii) industrial floor; and iii) small objects.

During the POCs' execution, the Beta team continued testing the properties of the geopolymer at the partner laboratory of the Federal University of Minas Gerais (UFMG) located in Pedro Leopoldo (Figure 3a no floor application and Figure 3b with floor application). The execution of POCs included some changes in scope, such as not carrying out POC 3, as recommended by the Samarco team; change in the place of application of POC 1, previously in the Chemistry Department at UFMG, now being applied in the laboratory in Pedro Leopoldo. On the other hand, POC 2 was carried out as expected, despite some delays caused by the arrival of inputs and availability of application of the industrial floor.


(a) (b)

Figure 3. (a) - No floor application; (b) - With floor application.

Looking at the big picture, Beta's technology advanced to TRL 7, validating its process in a direct application with the customer, but unlike Alpha, with an even more restricted market space.

4.4. Spin-off 3: Gama

In a context in which the ferroalloy industries have energy among their main expenses, Gama proposes to reduce these expenses through a briquette technology using mining tailings. In addition, the customer can obtain reductions in raw material costs, logistical and process simplification. When presented by Samarco in Phase 1, the technology had TRL 1 (basic principles) and, after Phase 2, it reached TRL 3, with the establishment of a critical function in an analytical way. As a critical point of technology development, the physical and mechanical properties such as resistance to abrasion, drop and density, for the formation of briquettes, stand out.

The planning of Gama in Phase 3 consisted of initially validating the technological route, as this step was behind schedule from the previous phases, and subsequently executing a POC with the market. The testing and production of briquettes had some routes, and a partnership agreement was signed with a company that allowed Gama to perform preliminary tests free of charge and negotiate the subsequent production step, using the company's infrastructure.

The POC was not completed, with only part of the preliminary testing and sending of these first samples to partner customers. Observing adaptations in the route, a new work plan was designed, which in turn was also not implemented due to problems in the team such as internal restructuring, delays in deadlines, and also external factors such as a change in the panorama facing the partner company, unavailability of use and delay when sending waste.

In light of these facts, a palliative solution was to change the scenario, aiming only at the execution of bench tests, upon approval by the Samarco team. However, Gama did not continue the work developed and was not able to validate the technology in a relevant environment. In this way, Gama reached TRL 5, reaching the stage of validating important technological issues for the customer, but without being able to move forward and solve these points, such as not defining the binder to be used.

4.5. CSO creation and resource exchange phases

Regarding the phases of creating a CSO, although each spin-off evolved differently throughout the program, as shown above, it can be considered that the resources shared with the parent company were very similar.

The pre-separation of Alpha and Beta extended between Phases 1 and 2 of the Desafio MinerAll Program and has not yet occurred for Gama. During this period, although there was no transfer of human resources, the parent organization provided mentoring and training (organizational resources) and transfer of technology and know-how for all spin-offs (technological resources). It is also noteworthy that the parent company hired specialized services in acceleration and scaling to support new businesses, in addition to the mining company's network (social resources). With regard to physical resources, Samarco facilitated access to tailings at no cost, including taking care of delivery logistics. Finally, in relation to financial resources, the Beta and Gamma spin-offs received resources to enable the POCs development, while the Alpha spin-off did not need such support.

The post-separation phase took place for the Alpha and Beta spin-offs, and the link with the parent company continued. Social resources were driven by the spin-offs, in particular the relationship network to get the first customers, in the case of Alpha, and develop the POCs, in the case of Beta. Regarding organizational resources, although the partners manage Alpha, there was still a limitation in terms of autonomy to approach new clients, which has not yet been identified for Beta. There is also a relative dependence of the spin-offs in relation to the obtaining and logistics of the tailings (physical resources) via the parent company, a fact that can make the large-scale application of the solutions unfeasible. For the other resources there were no exchanges at this stage.

It is also noteworthy that Samarco's main objective is not to obtain revenue from the spin-offs generated, but rather to make economic use of the tailings generated by the mining company. Thus, the company is able to foster new businesses and diversify the local economy while reducing its environmental liability by converting tailings into value-added products.

5. Conclusions

The main objective of this article is to analyze Samarco's open innovation program from the perspective of scaling hard science technologies and generating corporate spin-offs, which use mining tailings as the basis for their solutions.

Many researches are developed in Brazil, however, few, in fact, solve society's problems, since the path for the technology to leave the bench stage is complex. The Desafio MinerAll Program took important steps in this path, which is technology scaling and business modeling.

The purpose of the scaling was to ramp up the technology that consists of transforming the bench scale into an industrial scale. Business modeling, on the other hand, was the assessment of the market, customers and mainly validation of the potential of that technology to become a viable business. These pillars come together in a climbing format to generate a positive impact on the economy and on people's quality of life.

Before spending time and resources to build a pilot plant and open a company, it is necessary to define the maturity stage of the technology, its technical feasibility and, in parallel, its economic feasibility. This phase of the project allowed the teams to determine the best technological alternatives and get closer to the market, validating their solutions with potential customers and partners.

The results achieved made it possible to determine the feasibility of building industrial plants and continuing technological development already in the market.

Additionally, the program offered some challenges such as the formation of teams to lead potential new businesses, aspects of secrecy and technology transfer, dependence on partner support for the scaling and testing of solutions, dependence on inputs and logistics to make viable the solutions.

It is observed that the model by Ferraz & Teixeira (2015) is effective in allowing analysis of the three phases of spin-off creation and the resources exchanged with the parent company. In the case of the Desafio MinerAll Program, despite the exchanged resources being very similar between the mining company and the spin-offs, it was observed that some entrepreneurs managed to evolve faster, even conquering the first customers, with expressive revenues. Some factors leveraged this differentiation, among which the following stand out: degree of technology maturity at the beginning of the program; synergy and skills of the teams formed; market moment facing the pandemic and opening of partners to carry out the tests.

In this study, it was also verified that Public Open Innovation is a viable path for companies that have internally developed technologies and want to apply them. By making the technologies available to the market, Samarco was able to encourage the emergence of new businesses that, at first, it would not develop internally. It is a sustainable path for the economic use of tailings, diversification of the economy, generation of qualified jobs and reduction of environmental impacts. Thus, through the initiative, the mining company generates benefits for itself and for society.

The article contributes to the expansion of studies on the generation of hard science spin-offs through open innovation programs, serving as inspiration for industries and scholars on the subject. Future research may consider the performance of the spin-offs after separation, the critical success factors of the new businesses generated and the relationships with the parent company.

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