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Environmental strategies for the mining sector: evidences from a Brazilian company

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Abstract

The mining sector in Brazil has grown in the last decades contributing in an expressive form to the economic growth of the country. However, this progress has also contributed to the increase of environmental impacts brought by the mining industries include puts in evidence the need to define strategies well suited to deal with the particularities of each process or company. The main goal of this research was to develop a conceptual model matching environmental strategies with the sustainability dimensions focusing on the mining sector. The model was validated through two empirical approaches, including a Delphi study and a case study. From the Delphi study 28 environmental strategies were identified and classified in a work which is deemed to be relevant for companies targeting sustainability objectives and dealing with different environmental objectives. The case study addressed a large mining company located in the State of Paraiba in Brazil and showed both the relevance of the proposed model to justify the selection of the environmental strategies and the determinant factors for this selection. Endogenous factors are considered to be decisive for the organization to select and implement these strategies and with the exception of environmental legislation, exogenous factors have not exerted an overall important pressure on the organization.

Keywords: Mining sector, Environmental Strategies, Case study.

Introduction

The debate surrounding sustainable development in the mining industry is a drawn-out one, which has gained considerable attention from a wide range of parties for long time. The Brundtland Report emphasizes that no single blueprint for sustainability exists and that the ways in which countries achieve sustainable development will vary among the different economic and political systems around the world (Hilson and Murck, 2000) with impacts on the different economic sectors and on the company's commitment and performance.

Nowadays, given the constrains related to the availability of non-renewable resources (metal, oil, etc.), enterprises are more than ever required to rethink their strategies to ensure the sustainability of their operations (Chaabane et. al., 2012). Examples are provided in studies such as Ageron et. al., (2012) and Dubey et. al., (2015), both of them addressing the issue of sustainability on supply chain management. Also, Jayaram and Avittathur (2014), claimed that a sustainability strategy in turn influences the design and deployment of green supply chain management practices. Luzzini et. al., (2015), see sustainability as an important element of business strategies emphasizing the role of purchasing and supply functions in translating sustainability commitment into performance.

The case of mining and allied industries is particularly evident, with the companies confronted with the challenge of having to control a wide range of potentially serious environmental problems such as acid mine drainage, chronic soil erosion, tailings contaminations, and heavy metal over loading (Hilson and Nayee, 2002). This change towards sustainability have given rise to various environmental approaches that can be located between two positions: a typical one for companies that deploy only the minimum required to meet legislation, and an environmental responsiveness and environmental proactivity one, characterized by companies that voluntarily take steps to reduce their impact in the natural environment (González-Benito and González-Benito, 2008). Although, the first approach can be more restrained and as such easier to implement and even less resource consuming than the last one, managers should be aware that one of the fundamental factors for long-term success for global mining companies is their ability to align their interests with the values of society and in particular with the communities they wish to operate. While executives from most mining companies understand these social needs they should also recognize the practical hazards that this entails them (Esteves, 2008).

For purposes of this research, strategies were defined as ways in which organizations mobilize themselves internally and externally, creating environmental tools and tactics that can respond positively to the environmental impacts of their production processes. Thus, environmental strategies refer to sustainable management approaches for engaging in green process and practices in order to reduce environmental impacts of the firm's activities. These strategies should then be able to contribute to both environmental and social performance of companies where they were applied.

The current literature agrees that incorporating environmental strategies is crucial for business nowadays (Gotschol et. al., 2014). However, there is no consensus in the existing literature on the classification of the environmental strategies

related to the three dimensions of sustainable development, i.e., to identify which strategy can be used to deal with social, environmental and economics dimensions or with two or more simultaneous. Over the year's various environmental strategies were developed and implemented in organizations, but also no consensus regarding the nomenclature of such strategies exists. Some strategies may have the same goal, such as reducing the amount waste produced in an industrial process, but different authors name them differently.

Under such a background, this research aims to investigate the main environmental strategies cited in the national and international literature and with this information creating a model classifying the selected strategies. This model should support the analysis of the strategies used or to be used by a company aiming to deal with specific environmental problems. Given the importance of the mining activities to Brazilian economy as well as its recognized environmental impacts this paper will focus on this sector. The proposed methodology combines a case study representing a large company operating in the mineral sector in the State of Paraíba in Brazil with the expert's views through a Delphi approach for the validation of the proposed model.

The contribution of this research is two-fold. Firstly, the identification of these strategies would work as a guide for companies aiming to implement strategies directly linked to each challenge either economic, waste generation, process management or socio-environmental. As an example, there are companies generating large quantities of waste in the production process, thus, the strategies linked to waste management dimension can assist these companies in finding approaches to reduce the amount of waste produced, which, in turn, also reduce their environmental impact. Secondly, insights about the determinant factors faced by mining companies for the implementation of environmental strategies are provided.

The remainder of this paper is organized in five main sections as described. In section 2 sustainability in the mining sector is examined and a brief overview of the mining sector in Brazil is presented. In section 3 the methodology proposed in this research is detailed. Section 4, presents the results of the Delphi approach concluding on the environmental strategies classification. Section 5 describes the case study for the select company and analyses the environmental strategies implemented. Finally, the main conclusions and further research are summarized in section 6.

Mining Sector and Sustainability

The activities from mining sector have been frequently associated with negative environmental and social impacts. In fact, the mining sector faces many challenges with regard to the incorporation of sustainability in strategies and operations of the industry, given its extractive nature and the numerous social and environmental impacts related to this productive activity (Gomes et. al., 2014). Nonetheless, this sector can be viewed as a promotor of economic development creating important employment opportunities in many countries.

Many mining companies face environmental problems related to toxic chemical additives such as mercury, cyanide, and surfactants, which are often used in mineral concentration process. Another key issue associated with the extraction and use of energy minerals is depletion of non-renewable resources (Azapagic, 2004). Given the

need to operate accordingly to the environmental regulations, combined with a need to satisfy the demands of community and external stakeholders groups, it is on the best interest of mining operations to ensure that environmental impacts are minimized (Hilson and Nayee, 2002). The reputation problem is an important issue that should not be overlooked by companies. These must then assume that environmental impacts of mineral extraction need to be harnessed through different approaches such as eco-efficiency, community investments or equitable allocation of mineral rents (Fonseca et. al., 2013).

Moran and Kunz (2014), support that in this sector, sustainable development can be conceptualized in terms of how the value/wealth generated by mineral and energy supply, demand, use and reuse is distributed across people, places and over time. By contrast, "operating sustainably" is conceptualized in terms of how well the activities that create a value are undertaken. Also, according to the mathematical model proposed for Phillips (2012), sustainability in the mining industries has not only physical and chemicals impacts, but also cultural and sociological ones associated to the operations processes. On regards to chemical and physical, the main impacts are related to effects on soil erosion, environmental air quality, surface water quality, disforestation and disposal of solid waste. Concerning sociological and cultural impacts these are related to the loss of human life/accidents, changes on landscape, loss of income, negative effects on housing and infrastructure, interference with cultural heritage and reduction of land productivity.

The mining sector has been both a driver for socio-economic development and for environmental damages. It is a sector with the reputation of being highly polluting which was empathized for example with the most recent case of the disaster in the mining company Samarco in Mariana-Minas Gerais - Brazil, which was considered the worst environmental disaster in Brazilian history (Neves et. al., 2016). The impacts on the environmental brought by mining activities and the importance of mining to other industries demonstrate then the need for the analysis of such sector, promoting its development under the assumptions of sustainable development (Gomes et al., 2013a). Mining industry has then a crucial role in the society and on the quality of life of billions of people across the globe (Moran and Kunz, 2014).

The Mining sector in Brazil

The discussion about several impacts originated from the mining sector in Brazil and other countries as well as mining's role for the sustainable development goals was a critical issue in Conference Rio+20. Building upon the achievements of earlier major events such as the Rio World Summit in 1992 and the World Earth Summit in Johannesburg in 2002 (Rio+10), these conferences reiterated the vital role of the mining industry in sustainable development, with The International Council on Mining and Metal (ICMM) on the forefront of these discussions.

The contribution of the mining sector to the macroeconomic indicators in Brazil are deemed to be significant, but vary greatly across different indicators. To this date these impacts have not been properly documented, debated and understood instead and discussions around mining policy reform have often focused narrowly around issues of taxation and the mitigation of negative impacts (Gomes et. al., 2015).

Mining sector in Brazil comprises four main sets of mineral, namely metallic, no-metallic, diamonds and gems and energetic. The role of this sector in Brazil is well evident in studies such as National Department of Research Mineral (DNPM, 2015) demonstrating that in 2015, this sector in Brazil employed around 2.2 million workers directly, apart from the jobs generated during exploration, prospecting and planning stages, and people working in digging and mining. Figure 1 provides information about the evolution of jobs in the last years dived into four categories of products and showing the high importance of the non-metallic sector mainly due to ornamental rocks and kaolin, closely followed by the metallic sector where iron and niobium are particularly relevant.

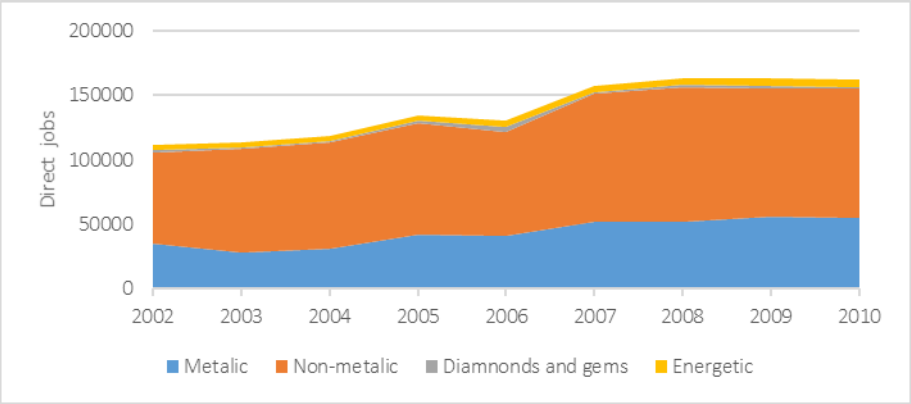

Figure 1: Evolution of jobs in the Brazil's mining sector.
Source: DNPM, (2011)

According to IBRAM (*Instituto Brasileiro de Mineração*), Brazil's minerals export played a key role in the impressive turnaround of the country's overall external balance, from a highly negative position at the height of the "real "currency crisis in the late 1990s to a positive figure of US$ 50 billion annually by 2010. In Brazil, minerals grew to account for 33% of Brazil's total exports by 2010 (from around 22% in 1995). The most dramatic change has been in the share of ferrous ores and metals in total exports, which rose from 6.3% in 1995 to 16.7 % in 2010 (IBRAM, 2012). Cabral (2006), also highlighted the role of Brazilian mineral activities, assuming them as the more important segment for the Brazilian economy. As illustrated in the figure 2 iron is the most important mining commodity in the Brazilian exportations followed by gold, niobium, copper, ornamental rocks and kaolin. As for importations, mineral coal, potash and cooper are the most relevant ones.

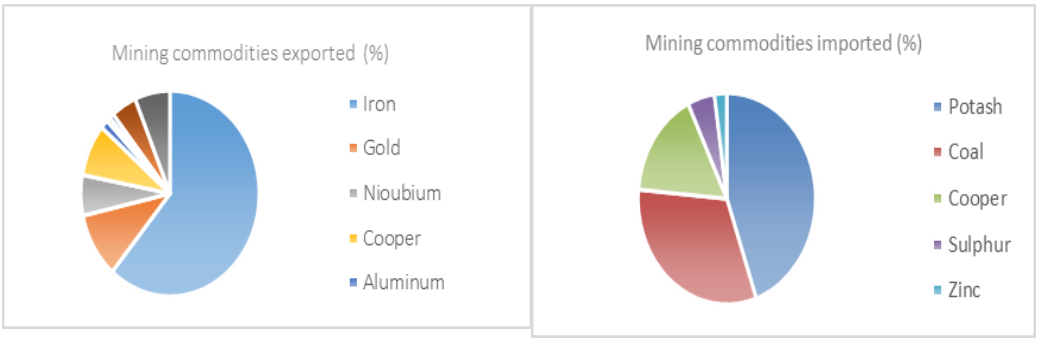

Figure 2: Distribution of Brazilian mineral commodities exported and imported by product.
Source: DNPM, (2015)

Brazil's position in the international market of mineral commodities is justified due to the privileged geo-diversity and continental extension (8.514.876,599 km²). The country is then a key player in the international market of mineral commodities. Nonetheless, as illustrated in figure 3, from 2013 onwards the world economic crisis has been contributing to decrease of amount of the value generated by this sector.

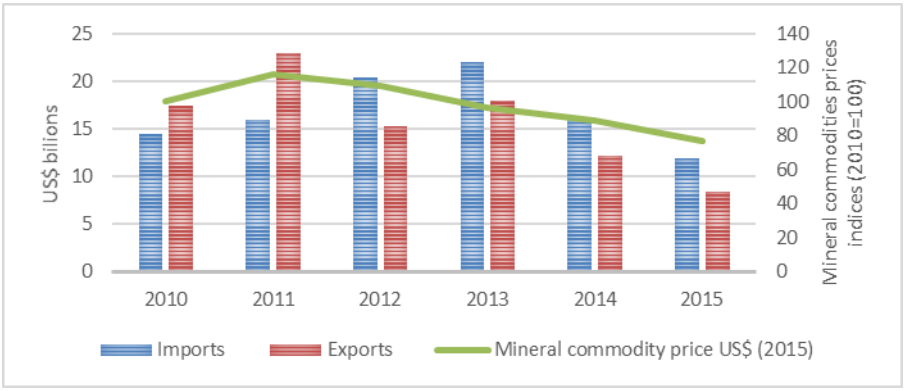

Figure 3: Trade balance of exterior commerce for the mining industry in Brazil in the last years in billions of US$.
Source: DPNM, (2015), World Bank (2016).

As illustrated in figure 3, the international prices of minerals commodities have been presenting a generalized decrease since 2011. The average real price index (US$) of fertilisers, metals/minerals, basic metals and precious metals in 2015 decrease respectively, -1.7%, -15.0 %, -8,8% and -8.9 when compared with the first semester of 2014 and decrease of 4.2% (fertilisers), -13.9% (metals/minerals), -12.2%(basic metals) and -4%(precious metals) when compared with the second semester of 2014 (data from World Bank (2015)).

Evidences from World Bank Group show that the decrease of prices of metals and fertilizers are explained by the low global demand for metal (specially in China), oversupply and high stock and also influence of American dollar. Is important to highlight that the increase of iron mineral offer, caused by new markets operations and increase of the production capacity in Brazil and Australia have been contributing to iron mineral price decrease which is one of the main mineral commodity in Brazil (DNPM, 2015).

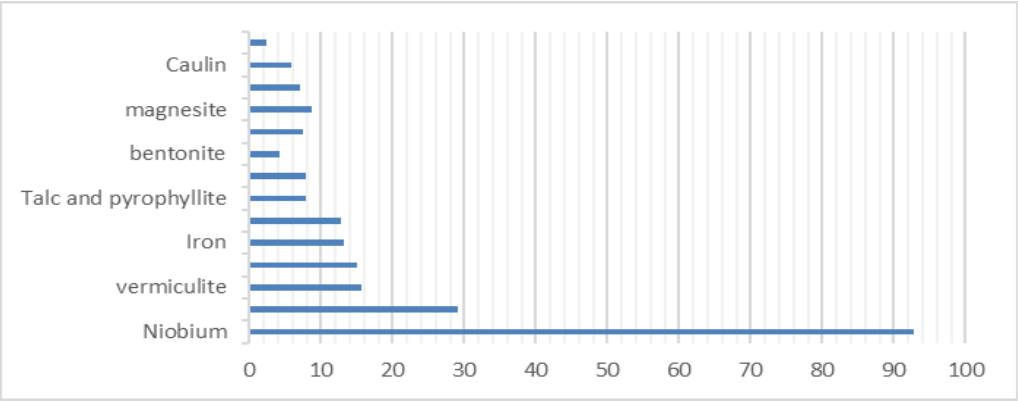

Figure 4: Brazil's participation in the mineral production in the world in 2015 (%).
Source: DNPM (2015).

In this context, the mining sector must be understood as a sector with essential potential to support the economic development in different countries. As illustrated in figure 3, Brazil is an important player on regard to supply mineral for many countries. In 2015, Brazil was the largest producer of niobium and played also a very significant role in world market for other minerals including iron.

While this sector is highly relevant to Brazilians' economy contributing to many aspects, such as economic development, jobs generation, development of new regions, is important to highlight that the current literature has been demonstrating that the mining activities are directly associated with severe environmental impacts (Neves et. al., 2016). Following these arguments, environmental strategies have a key role guiding and contributing to minimize negative environmental impacts as well to increase sustainability in mining companies in Brazil.

Research Methodology

This paper proposes creating a model to analyze determinant factors of environmental strategies on a Brazilian mineral sector company and also the management strategies applied by them. A Delphi method was used for the selection of the environmental strategies and for the formulation and validation of model. The research was structured in 6 steps as shown in figure 5.

Figure 5: Steps of research
Source: the Authors, 2017.

Listing environmental strategies

For selecting environmental strategies, a literature review on the topic was conducted. Environmental strategies aiming to minimize environmental impacts originated by operation process for companies were revised addressing also social and economic aspects. The identified set of strategies were described, in order to explain how they should be applied, as well as the focus of each one of them.

Creating sustainability dimensions

Secondly, in order to reach a better understanding about the contribution of each strategy to different environmental problems and concerns, a set of sustainability dimensions able to group the above identified strategies were identified. This step resulted on four main dimensions, namely waste management, environmental management, environmental socio-responsibility and environmental economics. Each dimension is related with the three pillars of sustainable development, although a large emphasis was put on the environmental aspects as being the core of the proposed study.

Waste management dimension can be understood as the way in which organizations deal with the waste generated from its production processes. In the other words represents what the company perceives as the most appropriate way for final disposal of waste throughout the life cycle of a product, thinking of the waste generated from the beginning to the end of the production process. As such, environmental strategies related to waste management dimension should always focus on the main goal of minimization and treatment of waste generated by industrial processes.

Strategies related to the environmental management dimension should aim for the definition and/or implementation of instruments or tools to minimize or manage the environmental impacts of business activities creating a formal or informal system for this. These strategies show the way in which organizations respond internally or externally about its commitment to environmental issues, in the other words, they represent the mechanisms used to translate the companies' concern over natural resources and also impacts caused by its production model.

Environmental socio-responsibility is mainly related to the social dimension of sustainability. Strategies under this dimension should focus on the definition of ways to ensure a closer link between the company and stakeholders, including local community, with the final goal of both increasing environmental perception and contributing to communicate environmental programs and actions.

Strategies for environmental economics dimension aim to provide an analysis of the costs bared by companies to handle the environmental impacts and also to define ways of compensating the community for the negative impacts.

The main motivation of business agents is the generation of profits and those are also main drivers for local and country development and as such for social well-being. As such, strategies linked to the environmental economic dimension are strongly related to the main goal of maximizing the economic performance of the company allowing to relate environmental impacts to economic performance through direct or indirect valuation techniques.

Grouping environmental strategies

Thirdly, each strategy was grouped into one of the four dimensions suggested above, taking into account the potential contribution of each one of them to support the underlying goal of each dimension. For example, strategies which were aspects related with waste reduction, or recycling were grouped into the waste management dimension, otherwise, strategies which aim to support companies in the socio-responsibility concerns were grouped into the environmental socio-responsibility dimension.

Application of Delphi technic

A Delphi method was then applied with a set of experts with high work experience in environmental strategies aiming to analyze their concordance with the proposed grouping. The experts were consulted by email. They were informed of the objectives of the research and asked for the contribution to answer a web based questionnaire that contained 28 strategies raised through the literature review (see Table 2), and grouped into four dimensions proposed by the researcher. For this, seventeen Brazilian experts were invited and agreed to participate. These experts were identified as authors in international journals and national publications related to environmental management and also published books within in the theme. The experts were identified through keywords search, namely: Environmental Management, Sustainability, Environmental Strategy, Strategy of Environmental Management and Environmental Management of System, in major databases and journals that discuss environmental issues, both within the general framework and within the business domain.

The web-based questionnaire was designed with an initial classification of the environmental dimensions and the strategies deemed to be relevant to be included in each dimension according to the previous literature survey. The experts were then asked to give their feedback expressing their level of agreement with the proposed classification. To analyze the degree of agreement of the experts a Likert scale with five points was used. The experts were also invited to proposed additional strategies that hitherto had not been identified in the research and/or propose to move the strategies between the proposed dimensions. The procedure required 4 rounds and results were analyzed using the coefficient of concordance.

Development of the first round

In a first round, experts were asked to respond individually by quantitative means (Likert scale with five points as mentioned above) on a questionnaire about their agreement with regard to the positioning of each of the strategy in each dimension.

During this first round some technical experts suggested some strategies to change their location in the model. For example, the lifecycle analysis strategy was initially located into the dimension of waste management and migrated to the environmental management dimension, the other case was the strategy responsible care program that was part of the environmental management dimension and migrated to the socio environmental – responsibility dimension.

Development of the second round

In this second stage, the experts received a new questionnaire with the changes suggested in the first phase of the technique, where some strategies changed their position on the dimensions proposed by the initial conceptual model.

After this phase, in the second round some experts considered that socio-environmental responsibility dimension was still fragile with regard to the number of environmental strategies. As such, one of the experts suggested the consultation of the social indicators of the Global Reporting Initiative to turn the dimension more robust. After such consultation, strategies related to the support to environmental NGO's (Non-governmental organization) and responsible acting program were included in the dimension.

Development on the third round

In this phase of the research the questionnaire was sent once more to experts showing the results of two other rounds of questions. The concordance level increased for all dimensions, and even reached 100% for environmental management. All coefficients of concordance were higher than 80% and were considered acceptable, as described in table 1. It was however decided to proceed to the fourth round because the strategies lifecycle of the of the dimension Waste Management was moved to Environmental Management by suggestion of one of the experts. Thus, a new consultation of the experts again was required.

Development on the fourth around

In the fourth and final round the conceptual model already containing all the amendments suggested by the consulted experts including new strategies was again presented to experts. During this round, agreement among experts was achieved. The model was not only validated but also the various strategies were adjusted to the dimensions that most closely matched their characteristics.

Design of the final conceptual model

Departing from the information collected and relying on the experts' feedback a final conceptual model for strategies classification was proposed, including 4 dimensions and 28 strategies.

Application of the conceptual model on a case study

Once the conceptual model was validated by experts, this research aimed also to validated the model trough a case study application in a mining company in order to provide a sustainability analysis taking into account the environmental strategies developed by the company studied. According to Miguel (2012), the benefit of using a case study approach is the possibility of development of a new theory and also to increase understanding of real and contemporaries things. On regards to the case, the study addressed the company Cristal Global Millennium Inorganic Chemicals, more precisely the Guaju Mining, aiming precisely to check how the strategies proposed on the conceptual model can be implemented.

Environmental Strategies Classification

For this research twenty-eight environmental strategies were identified in the literature and a first attempt was made to group them into four dimensions: Waste Management, Environmental Management, Social Responsibility and Environmental Economics. Following this, the experts were consulted through a questionnaire to analyze the strategies selected and their position in the conceptual model suggested, following a Delphi approach. According to Terence et. al., (2000), the Delphi technique aims to search for consensus opinions of a group of experts about future events. For this, the consensus was assessed through the calculation of the coefficient of agreement proposed by Hurtado et. al., (2013), and described in equation (1).

$$Cc = (1 - Vn / VT) * 100) \quad (1)$$

Where, *Vn* stands for the number of experts disagreeing with the placement of the strategies and *VT* represents total number of experts.

The Delphi process included four rounds until an acceptable level of consensus was achieved (higher than 80%). The coefficient of agreement by dimension obtained through the four rounds is showed in the table 1.

Table 1- Coefficient of agreement between experts for the four rounds

ROUND 01							ROUND 02
Dimension	**Σ**	**μ**	**Cc (%)**	**Dimension**	**Σ**	**μ**	**Cc (%)**
Waste management	51	3.00	**58.8**	Waste management	51	3.00	**76.5**
Environmental management	52	3.06	**64.7**	Environmental management	65	3.82	**82.4**
Environmental socioresponsibility	45	2.65	**52.9**	Environmental socioresponsibility	50	2.94	**70.6**
Environmental economics	52	3.06	**70.6**	Environmental economics	42	2.47	**52.9**
ROUND 03							**ROUND 04**
Dimension	**Σ**	**μ**	**Cc (%)**	**Dimension**	**Σ**	**μ**	**Cc (%)**
Waste management	64	3.76	**94.1**	Waste management	71	4.18	**100.0**
Environmental management	67	3.94	**100.0**	Environmental management	69	4.06	**94.1**
Environmental socioresponsibility	65	3.82	**82.4**	Environmental socioresponsibility	65	3.82	**88.2**
Environmental economics	63	3.71	**88.2**	Environmental economics	61	3.59	**82.4**

Σ- sum of experts' score by dimension; μ- average score from experts; Cc- coefficient of concordance of expert (coefficient of agreement). * This reduction of Cc was due to a change suggested by one of the experts for one strategy. Even so, the Cc value remains much above the threshold of 80%.

The results demonstrate the high level of consensus achieved for all dimensions and allowed to propose the final conceptual model relating each one of the identified strategies to the different dimensions as described in table 2.

Table 2- Conceptual model

Conceptual Model Final Version	
Waste Management	**Environmental Management**
Waste water treatment/ Inventory of solid waste/ Design for environment/ Reverse logistic/ Recycling/ Energy efficiency/ Water consumption/ Prevention and control of pollution/ Minimization of raw material/ Eco-design/ Clean Production/ Reuse	Environmental management system/ Certified ISO 14001/ Environmental policy/ Environmental audit/ Environmental license/ Lifecycle analysis/ Green Protocol
Socio-Environmental Responsibility	**Environmental Economics**
Environmental education/ Responsible acting program / Support environmental ONG's	Environmental valuation / Environmental liability / Environmental compensation/ Polluter pay principle/ Carbon Credit Market/ Environmental Insurance

The grouping of these strategies obtained through the formulation of the proposed conceptual model should contribute to obtain a clearer picture of how these strategies are linked and applied in organizations. Although these strategies seem to be mainly addressing the environmental aspects, in fact all together they represent a clear contribution to engage industries in the practical implementation of the sustainability concepts. Sustainable development should be seen as an integrated concept and as such issues of environmental deterioration and human development must be solved simultaneously (Robinson, 2004). Under a sustainable development perspective, waste management and environmental management strategies are closely linked to the environmental dimension, social responsibility is linked to the social dimension and environmental economics can be relevant under both the environmental and economic dimensions. As such, each of these strategies has specific benefits if taken in isolation, but additional gains can be achieved with an integrated approach.

Case Study: An Illustration

This section describes the case study used to illustrate the application of the conceptual model at company level, analyzing the different environmental strategies used in the company, checking how these strategies fit in the 28 ones previously identified ones and how well do they match within each dimension. A Brazilian mining corporation was then selected and a brief description of its activities is presented below.

The company Millennium Inorganic Chemicals – Cristal Global Company

The Millennium Inorganic Chemicals – Cristal Global Company is the second largest producer of titanium dioxide (TiO_2) of the world and has eight manufacturing plants of TiO_2, three on them located in the United States of America, two in UK, one in Saudi Arabia and another in Brazil (Cristal Global, 2013). The Brazilian plant use as main resources the ones coming from the Brazilian mine, named as Guaju Mining. Besides producing Ilmenite (a natural titanium-iron oxide mineral) other minerals area also produced in this mine including Zircon, Kyanite and Rutile. Table 3 shows the total of production of these materials and their main uses. Guaju Mining of the Cristal Global Company is the main focuses of this work.

Table 3: Products of Cristal Global in Guaju Mining, Brazil (Cristal Global Report, 2013)

Product	Production/ year	Destination	Mains Uses
Ilmenite ($FeO\ TiO_2$)	120 tons	Bahia-Brazil and France (40%)	Plastics, paper, cosmetics, pants, etc.
Zircon ($ZrSiO_4$)	20 tons	São Paulo and Minas Gerais – Brazil	Ceramics, refractory and high precision casting.
Rutile (Zro_2Sio_2)	1800 tons	São Paulo and Minas Gerais – Brazil	Applied to welding electrodes and metal alloys
Kyanite (Al_2SiO_5)	400 tons	São Paulo	Raw material to refractories

Guaju Mining is located in the State of Paraíba, city of Mataraca. The mining employs 278 people. The process of mineral extraction of the company has several environmental impacts. Findings of the case study provided information about the impacts of company operation including, chemical, physical cultural/sociological ones. An important impact that was identified was the radioactivity caused by monazite $(Ce,La,Nd,Th)PO_4$. *Monazite* is radioactive material left from the production process of *Ilmenite* ($FeO\ TiO_2$) manufacturing, this material causes an undesirable waste that is responsible for a high environmental negative effect. The environmental strategies currently being used are seen as good options to minimize these impacts. These include for example the involvement with the community, participation in education projects and certification for environment management (ISO 14001) and for health and work safety (ISO 18001).

For a better understanding about the strategies used for Guaju mining, the model presented in section 4 was then applied to this case study aiming to identify and justify environmental strategies selected by the company. For this, technical reports of the company were consulted and interviews with the company manager were conducted.

Model implementation

From the documental research and interviews with the environmental managers of the company, it was possible to identify a set of environmental strategies currently being undertaken by the company. These include a few related to environmental management, responsibility acting programs and other ones, accounting for a total of twenty out of the twenty-eight strategies proposed under the created model. The strategies implemented by Millennium Inorganic Chemicals – Cristal Global Company in Guaju Mining are shown in the table 4.

Table 4: Environmental strategies implemented in the Cristal Global Company- Guaju Mining

Model applied to the case study	
Waste Management	**Environmental Management**
Waste water treatment/ Inventory of solid waste/ Design for environmental/ Reverse logistic/ Recycling/ Energy efficiency/ Water consumption/ Prevention and control of pollution/ Minimization of raw material/ Reuse	Environmental management system/ Certification ISO 14001/ Environmental policy/ Environmental audit/ Environmental license
Socio-Environmental Responsibility	**Environmental Economics**
Environmental Education	Environmental valuation / Environmental liability / Environmental compensation/ The polluter pay principle

According to table 4, waste management represents the dimension with a larger number of implemented strategies. The importance of this dimension is easily understandable taking into account the amount of waste generated during the activities and its high polluting characteristics. Among the strategies included in this dimension, the company assumes as the most important one the materials' reuse, implemented in different processes and including different materials: waste sugarcane (biomass resulting from the vegetation removal from dunes), water used in the separation of minerals, organic materials (composting plant), sludge from the waste treatment (composting plant).

For the socio-environmental management dimension only one strategy was identified related to the environmental education. However, it should be stressed that an attempt to work under the strategy related to support environmental NGO´s (Non-government Organizations) was made earlier. However, the company decided to withdraw this support due to what they considered to be some lack of transparency of some of the NOG's supported. This shows then an interest of the company for this strategy and reveals the need further explore this approach relaying on more formal and transparent mechanisms for the effective implementation of the strategy.

For the environmental management strategy, it is worth mentioning that the company already has an environmental management system in practice, certified by ISO14001. According to the company, the formalization of this system allowed for a clear improvement of processes with the joint effort from all collaborators.

As for the environmental economics, the company highlights that the implemented strategies aim to provide an analysis of the costs bared by the company to handle the environmental impacts and also to define ways of compensating the community for the negative impacts, including for example a plan to reintroduce the local fauna and for reforestation. As for the polluter pay principle, it is only mentioned to make clear that the company is aware of its existence although in practice it was never applied as for the moment.

As for the main factors leading the company to adopt and select environmental strategies in their manufacturing processes, those can be divided into two groups: endogenous (culture, employees, costs reductions) and exogenous (investors, consumers, suppliers).

The endogenous factors represent internal aspects that may motivate or influence the company decision making towards the environmental strategies. These

endogenous factors were analyzed addressing issues related to cultural organization (if the company contemplate environmental concerns on policy and strategic decisions), employees (if they actively participate and contribute to the companies' environmental policies) and cost reduction (if this factor affects or guides the selection of environmental strategies). This allowed to conclude that all these aspects are considered equally important for the company managers and that ecological conscience and protection of the nature resources are embedded in the cultural environment of the company.

Concerning exogenous factors, those are related to external factors exerting pressure on company and consequently on the selection of the environmental strategies. These factors came from different sources as consumers, society, environmental legislation and competitors and other stakeholders. However, the company strongly highlights the environmental legislation as the main external factor affecting the environmental strategies.

Conclusions and Further Research

This paper aimed to make a contribution to the classification of environmental strategies according to a set of dimensions, contributing then to facilitate the decision-making process by matching their general sustainability requirements with well-directed and effective strategies. A conceptual model was developed and the environmental strategies were grouped in four dimensions according to their characteristics. This model was analyzed and validated by expert through a Delphi approach.

Twenty-eight environmental strategies were proposed to be included in the model. After this, the conceptual model was applied through a case study analyzing if and how a large mining company implemented or plans to implement these strategies. The results obtained in the case study demonstrated that the company has implemented a large number of the previously identified strategies covering the four dimensions. This can be explained by factors such as: (1) being a multinational company most of its programs and policies are replicated across all plants located in different places; (2) the activity sector is characterized by extensive environmental impacts and as such the company must attended diverse environmental legislation and requirements to operate, and finally (3) the company own culture.

This last aspect, justifies the importance assigned to the endogenous factors as drivers of the selection and implementation of the strategies. It is also evident the importance of the legislation as the most relevant external factor and the lack of influence of other stakeholders such as NGOs, consumers or even local population. This, highlights the need to understand the motivations for this apparent no interest of the local population, which may be related to general acceptance of the plant, to the company efforts to compile with all the legal requirements and even going beyond it, or even to the population unawareness.

The current literature of the mining sector showed that sustainability concerns are extremely complex issues for the mining companies in Brazil. As such, the conceptual model suggested in this research should be considered as an important tool to guide mining companies in Brazil towards sustainability, by providing insights on a number of environmental strategies that would encourage mining companies to

improve their environmental and social performance. Future work aims to use the conceptual model developed in this research to address other mining companies in Brazil in order to analyze which strategies are implemented by these companies, as well as, which factors are limiting or supporting the selection and implementation and how this affect the overall performance of the companies and stakeholders' awareness and acceptance.

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