The REHMINE research project: the threefold value of São Domingos abandoned mine rehabilitation in southern Portugal

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Abstract

Although rehabilitation of brownfields is an expensive undertaking, it can also be seen as a valuable initiative for promoting both local and global sustainable socio-economic development. As such, it can go beyond law-abiding practices in general, and become a domain of corporate or governmental social responsibility. The success of this kind of initiatives depends on the commitment of local authorities and other stakeholders, as well as from an understanding of the intrinsic environmental, social and economic value created. In Portugal, the state granted to EDM the concession to design and implement environmental rehabilitation projects and to promote the socio-economic enhancement of areas spoiled by earlier mining. This paper presents the REHMINE research project aiming the designing of a conceptual and methodological framework for establishing the threefold value induced by EDM's intervention at the Portuguese São Domingos abandoned mine. Through a multidisciplinary approach, the project will apply environmental, social and economic valuation methods, namely Life Cycle Assessment, Landscape Ethnography, Contingent Analysis and Multi Criteria Analysis to the value induced of mine rehabilitation in an integrated way.

Keywords: rehabilitation of abandoned mines, social responsibility, REHMINE research project, life cycle assessment, landscape ethnography, contingent valuation, multi criteria analysis.

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1 Introduction

The closure of abandoned mines and their rehabilitation is a vast international problem associated with the mining sector, for which governments are often held accountable. The rehabilitation of abandoned mines is an expensive undertaking, but it can also be seen as a valuable tool for promoting both sustainable socio-economic development and the environmental recuperation of regions depressed by mine closure. As such, it can be propitious ground for practices in the domain of social responsibility (SR). SR refers to the "responsibility of an organization for the impacts of its decisions and activities (including products, services and processes) on society and the environment, through transparent and ethical behaviour that contributes to sustainable development transparent and ethical behaviour that contributes to sustainable development, takes into account the expectations of stakeholders, is in compliance with applicable law and consistent with international norms of behaviour, ..." ISO/DIS 26000:3 [1].

SR is a business case and it contributes to the competitiveness of enterprises (Barnett and Salomon [2]), and of nations (MacGillivray *et al.* [3], AccountAbility and Fundação Dom Cabral [4]) but goes beyond it.

An important aspect of SR is the way in which it exhorts the engagement of stakeholders. Likewise, the short and long term success of a depressed region's rehabilitation also depends on the commitment of local authorities and other stakeholders living aside mining abandoned areas, not to mention the overall acceptance and recognition by the all society of the economic and social value thereby generated.

On the basis of these assumptions there are multiple questions to be answered: Which socio-economic and environmental benefits are effectively generated by post-mining rehabilitation processes? Which benefits are expected by the stakeholders from the rehabilitation of abandoned and depressed mining zones? How do these stakeholders value these benefits? How to integrate the stakeholders' expectations in the rehabilitation process? How to demonstrate the full value of the rehabilitation?

This paper presents a research project aiming to clarify these questions. The REHMINE project, recently launched, is a multidisciplinary project, drawing on a Portuguese case-study for the construction of conceptual and operational valuation tools with important dissemination potential.

In Portugal, the state granted to EDM – *Empresa de Desenvolvimento Mineiro*, *S.A.* – (state own enterprise) the concession to design and promote the environmental rehabilitation and socio-economic enhancement of areas spoiled by earlier mining. Its main activity consists of environmental rehabilitation both in the context of active mining explorations and of abandoned degraded mining areas. EDM was endowed by the state with the task of promoting until the end of 2013 the environmental recuperation of circa 100 mining areas, amongst a total of 175 which have been listed and ranked for purposes of requalification. EDM is therefore the promoter of a fundamental public service, aiming to safeguard public health and security, the enhancement of environmental quality and social

wellbeing and the legacy of future generations. For these reasons, it can be stated that EDM's business strategy is itself socially responsible.

In order to construct the means for assessing the environmental, social and economic global value generated by mine rehabilitation activities, the REHMINE research project deals with one particular case of EDM's intervention: the *São Domingos* abandoned mine, located in Southern Portugal.

On the basis of this case-study, a conceptual model allowing for a global evaluation of the value generated by EDM's intervention will be designed and tested. Although focusing on a single case-study, the research here presented has great potential of dissemination through the impact of EDM's intervention in the sector.

The paper starts by analysing the relationships between the mining sector, SR activities and sustainable development, showing the research relevance of this key subject. The *São Domingos* abandoned mine and the intervention planned by EDM are then presented, followed by a short description of the dynamics of local stakeholders that are expected to play a significant role in the process of defining the rehabilitation of *São Domingos*. Finally, the REHMINE project is presented in terms of its four main lines of research.

2 Mining, social responsibility and sustainable development

Mining activities generate several positive outcomes, of which the first is ensuring access to raw-materials that are basic to a global socio-economic development. For similar reasons, the mining industry potentially contributes to a region's sustainable development, the difficult task being to maintain such a potential also during and after mine closing.

According to the legislation currently in place in most developed countries, as well as to the dominant international views and to the best practices by large corporations in this sector, the planning of a mine closure starts at the very beginning of the exploitation phase. In this way, the negative effects of both the exploitation and the post-exploitation phases are mitigated, and limited to the long life-cycle of a mining area. In concrete terms, however, for most countries the planned closing of mining exploitation and associated activities was not mandatory until the nineties. For this reason, the inadequate termination of numerous mines throughout the centuries has left behind desolating landscapes, of abandoned mines and, more often than not, impoverished communities. Such evidence affects, today as in the past, the reputation of the entire mining industry.

Nowadays there is, however, greater awareness regarding not only the negative impacts of mining activities on public health and the environment during the extraction phase, but also in what concerns the negative effects of abandoned mines, its financial implications and the management of shared responsibilities in face of the broad negative aspects of mine abandonment.

The negative mining legacy obscures important efforts being currently made by mining companies and related institutions towards better socio-environmental performances by mining activities (e.g. MMSD [5], ICCM [6], EITI [7],

Lapalme [8], Post Mining Alliance [9], NOAMI [10], Castrilli [11, 12], USGS [13], and CSRM [14]). An analysis of these initiatives shows two main areas of intervention, namely the rehabilitation of abandoned mines and the incorporation of stakeholders' interests and expectations in the activities of mine exploitation and rehabilitation.

The increasing importance of "public participation" law and practice is one of the most significant occurrences in mining and natural resources development in the late 20th century, in line with the Aarhus Convention, which links environment and human rights and stipulates that sustainable development requires the involvement of all interested parties [15]. This phenomenon is expected to become even more central to the successful sustainable development of minerals and other resources in the 21st century (Zillman *et al.* [16]).

Governments are often held accountable for the closure of abandoned mines and their rehabilitation. This is the case in Portugal where, as already mentioned, the state granted to EDM the concession to design and implement environmental rehabilitation projects and to promote the socio-economic enhancement of areas spoiled by earlier mining. The *São Domingos* abandoned mine is one of the areas targeted for intervention by EDM.

3 The *São Domingos* abandoned mine and the planned EDM intervention

The *São Domingos* abandoned mine is located in south-eastern Portugal, on the eroded *Alentejo* plain, at the heart of the Iberian pyrite belt. Geologically the mine area consists of the outcropping of volcanic and sedimentary rocks that vary in age from 542 to 251millions years. A large area - 60km^2 - resulted from the extraction of more than 25millions tons of ore (copper concentrate production) from which 9.9millions tons of cupriferous pyrite were processed as an elementary source of sulphur Carvalho in Gaspar [17].

The present mining landscape owes its configuration to the extraction initiated in the nineteenth century. In possession of a concession area of 798km^2 granted by the Municipality of *Mértola* in 1854, La Sabina was launched with Spanish and French capital. Between 1859 and 1867, Mason & Barry, who have leased it further, initiated mining underground operations, with the pyrite being shipped to England via the *Pomarão* Harbour on the *Guadiana* River. For this effect an 18km long railway linking the two localities was built. For strategic reasons, a treatment plant was later on built on site (*Achada do Gamo*), in order to process poorer ore. From 1868 until its closure, *São Domingos* continued as an open cast exploration. In 1968, due to exhaustion of the ore, the mine area was closed and the equipment was dismantled and taken away by the company (Alves [18], Varanda [19]).

Presently, the post-mining *São Domingos* site still reflects the spatial order created by the mining industry, according to a planned urbanisation that was at time rather innovative for the region [19]. Three distinct areas were defined.

Inside the mining area itself, we find the ruins of the processing plant constructed at *Achada do Gamo*. Decades ago, a set of lagoons were created in

Figure 1: *São Domingos* and degraded area's localization (source: COBA Report, Vol. 1. Fig. 1.3 (2000) in EDM, SA [20].

this area, in order to obtain the old mine's acide drainage. The current landscape is both problematic and fascinating. The nineteenth-century processing infrastructure, now in ruins, is surrounded by dumps containing milled ore, building debris, bedrock and sediments derived from the acide mine drainage. The acidity of the water in the lakes (pH=2.4) contaminates the soils, the local ecosystems and the surface and underground water. Simultaneously, however the resulting landscape attracts visitors for its bizarre beauty and offers a habitat for different species. This mining complex includes as well the remainders of the railway access to the *Pomarão* Harbour, now a settlement of circa 30 inhabitants and a small recreational harbour.

Outside the mining area, mainly degraded today, differentiated spaces include the administration and residential buildings, gardens and leisure/service areas. Two separate residential areas were constructed, according to class differences. For the miners a whole village was built, using the local materials and techniques

(adobe). For the administration, larger buildings following a new typology were constructed [18, 19].

Additional spaces within the *São Domingos* area include the eucalyptus forest, which at the time afforded fuel for the mining activity and two large water dams – the *Tapada Grande* and *Tapada Pequena* – which provided the necessary water for washing up the mineral. After the closing of the mine, the *Tapada Grande* and the *Tapada Pequena* became a focus of interest for recreational purposes, by the local population and regional tourists [19].

According to EDM's analysis, the environmental rehabilitation of the old *São Domingos* abandoned mining area should combine the minimization of acid effluents formation with the highest environmental and landscape requalification possible. A favourable cost-benefit relation is also important.

The proposed intervention includes an area of 450ha and a diversity of observed environmental impacts in relation to which significant improvements will be undertaken and monitored. In the light of the technical appraisal carried out by EDM so far, the main environmental requalification should include the rehabilitation of the drainage system and associated soils (including treating and reforesting an area of around 250ha), the confinement of heaps, the development of systems for the treatment of acide mine drainage and for environmental monitoring. Along with this concern with the environmental recuperation of the post-mining site EDM has considered the socio-cultural requalification of *São Domingos*. As such, actions regarding the promotion of *São Domingos'* cultural heritage and the promotion of tourism, recreation and educational use were also planned. These include actions such as the promotion of a museum site related to industrial archaeology, evaluating the possibility of using the remaining railway for ecotourism and launching an environmental interpretation programme. The stimulation of cooperation with the neighbouring Spanish mining territory (*Rio Tinto*) is also planned.

A first intervention phase already took place in the years 2004/2005, in which areas of greater accident risk were enclosed and signalised. The evaluation and assurance of the stability and safety of the dams was also made, along with a hydro-geological study and the analysis of the dynamics of water-level in the open-pit.

4 *São Domingos* and the current stakeholders' dynamic

São Domingos is part of an area of Mediterranean climate and poor/ shallow soils that is known in Portugal mainly for its remoteness, located as it is on the socio-economically marginalised Portuguese inland. It belongs to the district of *Mértola*, one of the largest but most-sparsely populated districts in Portugal (6 inhabitants/km^2) and Europe. Between 1950 and 2001, emigration in search of employment (in which the mine closing in 1968 also played a role) caused a loss of 70% of *Mértola*'s population (Carmo [21]) and has left behind an aged and unqualified population. Nowadays, whilst the younger residents still emigrate easily, many of the current inhabitants consist of natives who returned to the district when their professional life ceased, meaning that they can rely on

retirement pensions for permanency in the area. As for the active population, there is high dependency on the public sector for employment, along with important unemployment rates (circa 12%). The dominant productive activity is agriculture, based on the established extensive agro-sylvo-pastoral system (Marañón [22]). This activity is however declining. In the later decades and in association to the European Union Common Agricultural Policy (CAP) a major shift is taking place from cereal production to stockbreeding (sheep and cattle). The conversion of farming land into afforested areas is also in place. A new and florescent activity in the area is hunting, which has been increasingly significant since the launching of new legislation allowing for the commercial use of the hunting right.

Having said this, there are also positive trends to signal, which are more apparent at the local and regional scale, but may reveal themselves key to the promotion of development also at a wider scale.

To our days, the village of *São Domingos*, the mining complex *Achada do Gamo-Pomarão* and the recreational space of the *Tapadas (Grande and Pequena)* are well known locations at the regional scale, within the so called '*Guadiana*'s Left Bank', which reveal potential in terms of their socio-cultural development and tourism. There is evidence of an increasing interest in the area for recreational purposes, including for instance mountain-biking and water sports (e.g. canoeing), with an impact on local businesses, more directly related to tourism (accommodation and restaurants). This is not unrelated to a local development process promoted in *Mértola* (the district) since the seventies, in which the district's cultural and natural heritage were taken as key resources for development (Nuno [23]). The initiative '*Mértola Vila Museu'* (Mértola town museum), leading to the establishment of a network of museum poles, is its most visible facet. According to Nabais [24] this is one of the particularly interesting initiatives in Portugal in the domain of the so called 'new museum' movement. Core aspects of this process were the capacity of attracting to the area a cluster of research activities, of which the most known is archaeology, as well as the process's reliance on a partnership between different institutions, in particular the *Mértola*' Municipality, the *Mértola*'Archaeological Camp (CAM) and the local Association for the Promotion of Cultural and Natural Heritage (ADPM) [23]. As a further outcome of this dynamics, in 1995 the Natural Park of the *Guadiana* Valley (PNVG) was launched and an emphasis on the district's territory and natural heritage complemented the earlier work regarding the town's cultural assets. Focusing on the *Guadiana* River, the natural park covers a wider area (three districts), which includes *São Domingos*. The PNVG has the purpose of preserving the *Guadiana*'s fauna, flora, geomorphology, landscape and historical and cultural characteristics, considering that they are threatened by the disappearance of the established land-use systems. In coherence with this dynamics amongst local stakeholders, the potential of *São Domingos*, as an "industrial" cultural heritage site has been emphasised. By way of example, *São Domingos* is referred in one of the itineraries currently suggested by the PNVG to visitors, 'The Ore Route' (*Rota do Minério*) ICNB [25], which regards specifically the mine and what it can teach visitors on the basis of its earlier

activities. In 1990 the *São Domingos* mining complex was classified "of public interest", and in 1998 the local urbanisation plan was approved, in line with the Municipality's aspirations towards the historic-cultural valorisation of *Mértola*'s region.

5 The REHMINE research project

The REHMINE research project is planned along four main lines, required for an accurate estimation of the global value induced by mine rehabilitation. These will involve an assessment of the environmental impacts potentially induced by EDM's intervention, an account of the social wellbeing generated and the estimation of the economic value of the planned intervention. Finally, on the basis of a creative combination of qualitative and quantitative methodologies, the conceptual model for the threefold valuation of impacts by mine rehabilitation will be designed, tested, and further used in the preparation of a tool for supporting decision-making by stakeholders and in the context of public policies.

The environmental impacts of the planned rehabilitation will be assessed through a life-cycle impact assessment (LCA). LCA has the unquestioned capacity to assess the environmental impact on a broad scale and to quantify not only the environmental effects but also the impacts of these effects. Although LCA is standardised in ISO14040 [26] and LCA research regarding mines has already been carried out (Norgate and Rankin [27], Durucan *et al.* [28], Reid *et al.* [29]), none of it has been oriented towards the rehabilitation of abandoned mines. This will require some adaptation, including translating the environmental impacts into a single value indicator. Also, whilst the standard four step research approach of the LCA method (goal and scope definition, inventories, impact assessment and interpretation) still applies, adjustments need to be made with regard to goal and scope definition. By showing the environmental performance of the mine before, during and after the rehabilitation for each chosen scenario, it is expected that not only the overall performance of the rehabilitation will be shown but also where the "hotspots" in the rehabilitation process lay, in terms of very high and very low environmental performance.

The social value induced by the rehabilitation will be accounted for in detail through a Landscape Ethnography, that is, the cultural description of the relations established by different users with the post-mining *São Domingos* landscape. This description will include an account of the current practices and meanings through which this landscape plays a role in the lives of particular social groups, as well as an identification of perceptions held by current users of *São Domingos* with regard to the planned rehabilitation. The connections between these conceptions and broader notions of value, emerging in other discourses about that particular physical environment, will also be analysed. This line of research maps out and characterises both the shared meanings about the nature and value of the *São Domingos* post-mining landscape, as well as the spectrum of different viewpoints held by a diversified range of users. Value is here qualitative, since it is contextual, and will be described rather than measured. Whilst the field of landscape ethnography and social values has been

developing since the nineties (cf. Hirsch and O'Hanlon [30]; Feld and Basso [31]) the articulation of this approach with those of other disciplines through a focus on value criteria is innovative.

Finally, an economic appraisal of the planned intervention needs to take into account a complex bundle of social and private benefits generated by the rehabilitation. From an economist's perspective, the rehabilitation of the mining area of *São Domingos* is equivalent to a process of damaged natural capital restoration, providing a variety of environmental services and goods that are valuable to the society. In order to consider all different types of benefits from the point of view of sustainable development, the concept of Total Economic Value (TEV) enables the distinction between direct use values and passive (non-use or existence) values. Improvement (in terms of the rising of individual utility associated to the restoring project) will be measured by means of a Contingent Valuation Method (CVM) (Mitchell and Carson [32]), specifically the individual willingness to pay compensated (WTPC), which refers to the amount each individual is willing to pay to secure the change related with the rehabilitation of the mine area. This is the only existing method that allows us to know the individual WTPC in terms of TEV and is capable of evaluating a plethora of sustainable issues that cannot be captured by other valuation techniques. Although this method has been used to assess the impacts of mining activities (Venkatachalam [33]), to our knowledge there are very few applications (Barton and Mourato [34]) concerning the assessment of environmental values or the application of the CVM to Portugal, none of them concerning the mining activity.

As a result of these three lines of research, we should be able to both describe (qualitatively) and measure (quantitatively) the values generated by EDM's SR practices applied to the rehabilitation of the *São Domingos* abandoned mine, according to the social, environmental and economic dimensions of sustainable development.

As already mentioned this will lay the ground for the further construction of a conceptual framework capable of accounting for value variations or differences regarding concomitantly the environmental quality, social welfare and economic performance of particular Brownfield's rehabilitation plans or degraded industrial areas.

An important outcome of this research process is the fact that it takes into account the views of the rehabilitation's stakeholders and is geared at supporting the decision-making process. In order to do this, the fourth line of research, using Multi Criteria Analysis, will take place after the accomplishment of the three just presented. The multi criteria decision making method allows the modelling of complex decisions in a hierarchical structure of criteria, sub criteria and alternatives. Additionally, the best weighting having in mind the optimization of decisions and public policies in the field of CSR and rehabilitation Brownfield's areas will be studied. This fourth line of research starts by taking into account the various criteria on which both the damage caused by abandoned mines and the benefits of a rehabilitation process could be assessed, according to the knowledge gained with the previous research (research lines 1, 2 and 3).

Damage and benefits will be estimated either by their absolute value or the comparison of the relative position of each one with others.

The valuation of different possibilities for the rehabilitation will be made using two approaches: 1) Analytical Hierarchy Process (AHP) developed by Saaty [35], with a hierarchical structure, the model allows endogenously generated weights that reflect the value of each option; and simultaneously testing the consistency of the valuations of each option. The resulting weights are then used in a weighting function that maximizes the CSR results by selecting the best performing interventions with the lowest use of financial resources. The overall score for each alternative is obtained from a weighted sum, and thus reflects the attractiveness of that option. 2) Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH) is a multi criteria decision analysis approach that requires only qualitative judgements about differences of value to help a decision maker quantify the relative attractiveness of options (Bana e Costa and Vansnick [36]). The approach, based on the additive value model, aims to support interactive learning about the evaluation problem and the elaboration of recommendations to prioritise and select options in individual or group decision making processes. The choice of the best combination/ set of interventions for rehabilitation of abandoned mine is defined, having in mind the goal of maximizing the tri-dimensional benefit of these interventions.

As already mentioned, due to the case-study selected, there are good prospects of further testing and applying the outputs of this research, since EDM is responsible for the rehabilitation of a large number of post-mining sites in the near-future. This will prepare and facilitate the further dissemination of the conceptual framework and resulting tools through the entire sector.

6 Conclusion

The paper assumed the rehabilitation of abandoned mines benefits from the engagement of local authorities and other stakeholders and from the comprehension of intrinsic environmental, social and economic value created. The REHMINE research project was presented, aiming the design of a conceptual and methodological framework that integrates stakeholder's views, to establish the threefold value induced by the rehabilitation of the Portuguese *São Domingos* abandoned mine, contributing to the improvement of public policies regarding the rehabilitation of depressed industrial areas.

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