Environmental Restoration of a 60Mm^3 Dry Asbestos Tailings Dump Using Risk Based Decision Making

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INTRODUCTION

Designs based on codes or recommendations may differ quite significantly from designs based on Risk Based Decision Making (RBDM). Differences may go as deep as selecting different procedures, material hauling system, drainage patterns etc. Alternatives which are perfectly code-compliant and require same investments and maintenance may expose owners to significantly different levels of risk all along the expected life of a project.

RBDM for Reclamation Projects requires robust and simple tools for choosing among alternatives at each and every step of a project life, i.e. conceptual design, construction, maintenance and then necessary performance monitoring and evaluations before reaching the expected life end.

This paper illustrates a case study where RBDM has been used through the feasibility, design and construction follow-up of an environmental restoration of a 60Mm^3 dry asbestos tailings dump.

CASE STUDY

Historic review of operations

The Balangero asbestos open pit mine, located 35km N-W of Torino, was the largest operation of this kind in Western Europe. The open pit was cut into the ridge of an elongated hill. The mill was located on one side of the hill and the dumps on the other.
In 1918, it was foreseen that the mine would extract 26,000m^3 rock per year, but in 1961 the mine extracted 1.3Mm^3 rock. In 1966 a new mill with a capacity of 25,000 metric tonnes of fiber per annum was installed.

The dry tailings were lifted by a conveyor belt from the mill, located at the foot of the hill to a location near the ridge. From there they were conveyed through a tunnel to the opposite side of the hill, and then dumped over a natural slope with an approximate angle of 25 degrees from the altitude of about 830 m a.s.l. to the bottom of the valley at 580 m a.s.l..

As the dumping proceeded, a total surface of about 250.000 m^2 was progressively covered with tailings thicknesses going from a few meters to an estimated maximum of 60m–80m, resulting in an estimated 60Mm^3 dry asbestos tailings dump. This dump as well as all the production facilities were abandoned when the mining company abruptly stopped its activities in the early '80s for economic reasons.

Reclamation Project

In 1992 by RSA, a public company formed by the Province of Torino, the Mountain Community of the Lanzo valleys, neighboring communities and other public stakeholders was mandated by the regional government of Piedmont to organize an international design competition in compliance with regional bylaws.

The goals of the competition was to select the best possible alternative to increase the stability of the slopes (oversteepened, critically eroded and prone to mudflows); reduce the dispersion of fibers (long term hazard to the neighboring population); re-vegetate the slopes for aesthetic and environmental reasons.

RBDM was consistently used by the authors (Riskope) who won the bid. The project started two years ago and is now two years away from completion.

INCLUDING RISK IN DECISION MAKING

Several ways of comparing projects or design alternatives have been proposed in the past in various industries and environments at strategic or tactical level, mostly without any explicit consideration of risk. Tactical level decisions are often driven by expected financial performances, balance sheet forecasts etc., "conveniently" forgetting about related risks

In the Balangero project, as in all the projects studied by the first author of this paper, the evaluation of design alternatives was carried out by evaluating their respective Economic Safety Margin (ESM)[1].

Economic Safety Margin

The ESM includes life long expected gains, implementation costs and total risks evaluated for twelve hazards criteria.

In the same manner as in the field of structural reliability, a large safety margin indicates a strong and robust alternative. ESM has to be evaluated in probabilistic terms, as all its terms are indeed stochastic. The probability of $ESM<0$ indicates the probability of economic failure of the project/design alternative. This approach significantly differs from a classic "provisional balance sheet" approach because risks and uncertainties are explicitly taken into account, as well as the stochastic nature of the costs.

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[1] In structural reliability the safety margin is defined as the difference between Capacity (C) and Demand (D), i.e. SM=C-D, where the capacity is the "strength", and demand is the "loading".

The “strongest alternative” is the one that has the largest ESM, evaluated as the difference between:

- the Project Net Gain (PNG)= Project Returns (PR) – Costs (C) and
- the Total Risk (TR), i.e. the value obtained through this methodology.

$$ESM=PNG-TR=PR-C-TR=PR-(C+TR)$$

The ESM is the difference between the capacity (the “strength” of a project is equal to the Project Returns) and the demand (the “loading” of a project is equal to the Costs plus Total Risks from inception to grave).

Obviously PR, C and TR are stochastic variables, known at best, at preliminary level by their expected value (mean, average) and their bounds (min/max), or their average and first moment (variance, standard deviation). Thus calculations have to be performed either using a second moment approximation, a point estimate method or the Monte-Carlo simulation. The latter necessitates further assumptions on the type of distributions, generally leading to a false sense of confidence on the results.

If the mean value and variance of each component are known it may easily be shown that, under the assumption that the components are independent, the expected value of a variable Z described as the sum of x components Z_x, noted $E(Z_x)$ is equal to the sum of the expected values of the components, and the variance $VAR(Z_x)$ is the sum of the variances of the components. That is:

$$E(Z_x)=\sum(E(Z_{xi}))$$
$$VAR(Z_x)=\sum(VAR(Z_{xi}))$$

From the above formulae, it results that highly scattered components, i.e. components affected by a greater uncertainty, impact more heavily on the scatter of the function Z_x than the better known or less uncertain components. Indirect components such as the public image cost of an accident are typically affected by more uncertainty than other components because of their very nature, as well as the possible implications of irrational and subjective perceptions of the media, the workforce, the unions and the public.
In most cases these formulae allow the calculation of the mean value and the variance of all the important elements of the ESM and the ESM itself.

As completion time of the alternatives can generally be seen as a constant at the preliminary level of analysis considered here, there is no need to evaluate costs and risks in terms of Net Present Value (NPV), thus avoiding very tedious calculations (Oboni, 2000; see also http://www.oboni.com/cod.html
in www.oboni.com).

Assessing the Life Cycle of a Project/Design alternative

The proposed methodology encompasses and requires a simplified and preliminary Life Cycle Risk Assessment for Projects (LCRAP) to determine TR.

The methodology presented herein does not include a compliance-to-code check and is therefore universal in terms of geographic location, legal environment etc.

Twelve standard criteria are used to assess projects during the five steps of their Life Cycle (LC), from inception to grave. Indeed LC is split into two main phases (i.e. Design/Construction and Usable Life), respectively five steps which include: infrastructure, superstructure, service, maintenance and demolition/ reclamation as displayed in the table below.

<table>
<tr><td rowspan="3">Criteria</td><td>Infrastructure</td><td>Superstructure</td><td>Service</td><td>Maintenance</td><td>Demolition/ Reclamation</td></tr>
<tr><td colspan="2">Design/Construction Phase</td><td colspan="3">Usable Life</td></tr>
<tr><td colspan="2">1.Availability of construction methods, ease of construction
2.Reasonability, sustainability
3.Economy
4. Environmental soundness

NB. No compliance to codes.</td><td>5.Long term planning
6.Scalability
7. Meets the expected performance</td><td>8. Availability of materials
9. Ease of repairs</td><td>10.Easy to dispose
11.Simple to dismantle
12.Easy to recycle</td></tr>
</table>

When applying the methodology for LCRAP to an alternative, the probability of meeting each one of the twelve criteria is evaluated (judgmental probabilities):

- Zero means the criteria is not met at all, never met, totally deficient.
- One means the criteria is met entirely, always met, absolutely positive.

The judgmental probabilities encode the degree of belief expressed by the designers, generally assisted by a risk management facilitator, of meeting each one of the criteria. For example, a solution using a earth brick walls in middle of a desert would receive a very high probability of success for Criteria #1,2,3,4, whereas a solution using an imported material in the same area would receive a low probability for the same criteria.

As each probability for each criteria is paired with a "cost of failure" (i.e. the costs if the Criteria is not met), the risk can be obtained by simple term by term multiplication.

REVIEW OF MAJOR ASPECTS OF THE BALANGERO PROJECT

Remedial works

As already mentioned, the environmental restoration goals were to:

a) Achieve a sufficient stability of the slopes. Gravity and water are the main combined external agents posing a threat to the stability of the over-steepened slopes of the dump. Thus it was necessary to act against gravity to provide the geotechnical stability of the slope and against water to eliminate surface erosion, gullies formation and increase of saturation triggering frequent mudflows along the slope.

b) Minimize the dispersion of asbestos fibers in the area of the mine and surrounding towns during the restoration works and in the long term. The entire restoration process had to include dust minimizing procedures which ended up driving the choice of excavating, hauling and disposing equipment on the steep slopes.

c) Re-vegetation of the area which is located in a densely inhabited area at the Alps foothills. As the dump material is highly sterile and generally too steep to retain humus, a special program of tree and shrubs planting was designed including the plantation of 45'000 shrubs and trees: their root system is treated with special fungi that are helping the rooting/vegetation process in the sterile slope. A general hydro-seeding of the full area is undertaken step by step, operating remotely, from an helicopter, again to reduce disturbance to the steep slope.

One of the major challenges faced by this project was related to the large amount of material to be excavated and disposed of within the mine area in order to unload the over steepened head of the dump slope. Between the top and the bottom of the slopes 4.5 km of dirt track were present. The preliminary design demanded for the removal of about 280.000 m3 of residues (mainly sand and gravel) with mixed random asbestos fibers.

The use of trucks (Criteria #1, high Availability & ease of construction) was quickly discarded due to the environmental risks (Criteria #4, high Pollution from exhaust fumes and fiber dispersion from the excavated material) and the need to upgrade the tracks to roads. A far better ESM was obtained with the alternative of installing a temporary aerial tramway. This device was designed with a single span of 960 m between the two terminal stations (Criteria #7 high Meeting expected performances; Criteria # 5, high Avoiding hazards (settlements, instability of intermediary piers).

The cable car will be removed at the end of the works (Criteria #6, high Scalability, #10, very high Easy to dispose). The excavated material is wetted at excavation time and remains wet during the full trip from the source to the final resting position to reduce fiber dispersion. So far, after two thirds of the excavation completed, the process has proved very efficient and only a couple of times, with very strong winds, the dust monitoring instrumentations have displayed critical concentrations of aero-dispersed fibers in the surrounding area atmosphere. The aerial tramway produces electricity which is sold to the grid (Criteria #3, very high Sustainability).

The selected slope stabilization procedure received a high ESM based on high probabilities and low costs (of failure to meet the criteria) for Criteria #1,2,3,4,6,8 & 9). It can be summarized as follows:

- Unload of the upper part of the slope by digging three big berms and by storing the excavated material at the bottom of the slope on an artificial earth fill 8 m high via the cable car. The engineered fill is geared towards protecting from possible residual mudflows originated in the steeper eastern part of the slope (up to 42°) the lower part of the slope, the creek etc.
- Cut a series of 8 “path-ways”, i.e. small berms 2.5 m wide, along the slope at regular height intervals. The “pathways” are about 600 m long and were designed to minimize the volume of material to be evacuated. Indeed, the material excavated upslope is deposited down-slope in the same cross section. This procedure dramatically reduces the hauling needs down the slope in the steepest part of it, thus the minimization of fibers dispersion in the atmosphere during works. Furthermore the “pathways” create an access to the slope for present and future works/observation. The “pathways” are reinforced with small palisades built with wood logs (20 cm diameter on the average) increasing the use of natural materials and reducing the need for concrete and steel.
- Build whenever deemed necessary composite wood-earth structures to retain the steepest parts of the slope, or create necessary platforms.

From the hydraulic/water control point of view, surface erosion created deep (up to 3 m) gullies on the slope in the past. The remedial measures undertaken are the following:

- General control of all the surface water falling on the area in form of rain or snow via a net of small wooden channels (on the average 50 to 100 cm wide). These channels collect surface runoff on the slope thanks to the access created via the top berms and intermediate “pathways”. The small dimensions of the channels have been designed to limit the use of heavy equipment on the slope and the need for large excavations for their construction
- The collecting system is relayed by secondary segments of channels located running on top of the berms and on the “pathways”
- Thus the collected runoff is concentrated into 4 main channels located on the slope along the steepest gradient: these channels – called “water chutes” – are built with wood logs and stones.
- The 4 “water chutes” finally converge into a unique main canal – built again just with logs and stones – that allows the water to reach the Fandaglia creek at the foot of the slope. Before the final exit to the external environment the collected

runoff water flows through a decant basin where the fine material and the fibers can be retained.

- Finally, subhorizontal drains are drilled on the slope to control underground water.

CONCLUSIONS

Risk Based Decision Making (RBDM) was used at each and every step of the Balangero's environmental restoration bid. As a result, the project has several interesting points related to environmental management, like for example the use of an aerial tramway that allows the reduction of fossil fuel use, dusts, and even produces energy sold to the regional utility company.

The integration of hydraulics, geotechnique, pedology and risk management within the group has led to a well balanced and sustainable project which will be turned into a "living museum" by the authorities when completed.