STOP PROCRASTINATING! NPV IS DEAD: USE RISK AS A KEY DECISION PARAMETER.

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Abstract: Two case studies: 1) introducing an in-pit crushing & conveying system v.s. shovel & trucking in a large dump reclamation project and 2) long term pumping v.s. encapsulation of a very large, leaching, underground toxic waste storage, are presented to show that risks as a discriminant parameter should be used for successful long term planning at the inception of any project to manage rational decisions. One case is dealt with qualitatively at the pre-feasibility level and the other quantitatively at the preliminary design level.

At the pre-feasibility level it is shown that graphic methodologies coupled with simple procedures can efficiently pinpoint weakness areas, leading to better decisions and thus appropriate mitigations. At the preliminary design level we show innovative approaches, which eliminate the pitfalls of Net Present Value (NPV), a financial evaluator still used by many. The NPV is replaced by an analytical tool called **C**omparative **D**ecision **A**nalysis/**E**conomic **S**afety **M**argin (**CDA/ESM**™), used to compare alternatives in financial terms including: a) life's cycle balance encompassing internal and external risks over a selected duration, b) project implementation and demobilization costs and risks. CDA/ESM has been successfully applied to: rope v.s. road transportation, surface v.s. underground solutions, environmental projects, transportation networks and go/no-go decisions.

Résumé: Deux études de cas sont présentées: 1) Introduction dans une mine à ciel ouvert d'un concasseur couplé à une courroie transporteuse en remplacement de la classique solution excavatrice-camionnage pour la mise en demeure des stériles, 2) Pompage comparativement à l'encapsulation a long terme d'un très grand stockage souterrain des déchets toxiques. Le but est de montrer que les risques devraient être utilisés comme paramètre discriminant pour opérer des décisions rationnelles, conduisant à la réussite de la planification à long terme, et ceci depuis le début de n'importe quel projet. Le 1er cas est traité qualitativement au niveau de la pré-faisabilité, les autres quantitativement au niveau de la conception préliminaire.

Au niveau de pré-faisabilité, il est démontré que les méthodes graphiques de pair avec des procédures simples peuvent identifier efficacement les zones de faiblesse et de conduire à de meilleures décisions, ce qui permet une réduction appropriée des risques. Au niveau de la conception préliminaire, nous montrons des approches novatrices qui permettent d'éliminer les pièges de la valeur actuelle nette (VAN), un outil financier encore généralement utilisé. La VAN est remplacée par un outil d'Analyse Comparative de Decision / Marge de Sécurité Economique (CDA/ESM™), qui sert à comparer des alternatives en termes financiers, notamment: a) le cycle de vie englobant les risques internes et externes, au cours d'une durée sélectionnée, b) le coûts et les risques d'implémentation et de démobilisation . La CDA/ESM™ a été appliquée avec succès au mode de transport par câble contre celui routier; aux solutions de surfaces contre celles sous-terraines, à des projets environnementaux , des réseaux de transport et des décisions oui/non.

Introduction

Two anonymous case studies taken from our day to day practice, thus covered by confidentiality, are presented in this paper to show: a) how risk can be used as a key decision parameter and b) how the commonly used Net Present Value (NPV), which is deterministic and generally does not include properly defined risk, can create distortions and biases when analyzing industrial (or other) alternatives. The two case studies are:

1) Introducing an in-pit crushing & conveying system (IPC&CS) v.s. shovel & trucking (S&T) in a large dump reclamation project we studied in 2008.
2) Long term pumping v.s. encapsulation of a very large, leaching, underground toxic waste storage which we are currently reviewing.

Case Study 1: Introducing In-Pit Crushing & Conveying System v.s. Shovel & Trucking in a Large Dump Project.

A large coal mining company asked us to support their decision making related to a possible change from conventional S&T versus IPC&CS dumping. The operation was experiencing various critical personnel issues and difficulties with the ageing truck fleet which would require a large capital investment for renewal and maintenance (tire costs, etc.). Furthermore, in the long run, the cost of diesel will most certainly rise, again causing concern.

In order to alleviate these concerns, and reduce costs, future emissions, and also potential business interruptions due to shovelling problems, the company decided to develop a pre-feasibility study exploring the possibility of implementing a IPC&CS.
At the pre-feasibility level the aim of our actions was to identify situations that could hinder the performances of the project and define issues that needed to be immediately addressed. Our goal was also to identify issues that could generate high risks for an otherwise well designed plan, such as, rejection by the workforce or by nearby residents. The two main areas related to the possible implementation of IPC&CS at the mining operation were addressed by:

1) A preliminary qualitative comparison between the exposure-risk environment of the base case, i.e. S&T, vs. the IPC&CS. Risks can be upside (opportunities) or downside (the “classic” view of risk linked to mishaps).
2) A preliminary qualitative risk assessment of the project which identifies conditions that could adversely impact the IPC&CS. This includes qualitative judgments on their likelihood of occurrence and consequences.

In the process of performing the qualitative risk assessment several hazardous conditions which could be easily managed by design solutions were flagged in the first step of a proactive development plan where risks are used to drive the better design of projects and increased sustainability.

Hazard, Exposures, Advantages & Disadvantages Identification

Advantages and disadvantages of the IPC&CS over S&T (representing the Status Quo), were identified in a facilitated workshop session with the participation of key stakeholders. For example reduced diesel consumption was flagged as an obvious advantage for IPC&CS whereas necessary operational changes were considered a disadvantage. Advantages and disadvantages were defined at first for an "ideal perfect alternative" such as a perfectly functioning IPC&CS where obvious hazardous conditions and risk exposures would be mitigated to a satisfactory level (i.e. the design covers "good sense issues" and represents "good engineering," as discussed later). The advantage/disadvantage session was immediately followed-up by a hazard Identification session. Hazards were categorized and recorded in a specific table which included the Category of Hazard, Probability, Magnitude, Potential Target(s) and Qualitative Consequences.

Our pre-feasibility qualitative risk analysis goal was to reduce the chances of a fatal flaw in the design, by defining proper design parameters and bringing changes to the preliminary design geared towards increasing the chances that the future implementation would work and perform as intended. Of course the newly defined parameters and changes would have to be integrated in the costs estimates in order to avoid the project possibly becoming a "financial fiasco."

A pre-feasibility study should cover a wide array of issues that could be seen as "good sense" or "good engineering" in addition to the classic issues of a risk assessment. "Good sense" issues do not generally require a detailed consequence analysis, to say it simply, if they are not somehow dealt with the system will not perform as intended. This type of study represents a first proactive step in the direction of facility risk management and includes risks as decision making parameters. This concept is better explained with a plot (Figure 1) depicting risk mitigation geared towards reaching specific levels of residual risks vs. mitigative investments.

In Figure 2 and 3, the black hexagon perimeter depicts the level of exposure of the base case. The green and red hexagons represent reduced and increased exposures levels, respectively, for the IPC&CS at this operation. The term "exposure" is used here to make clear the distinction between a standard solution for the IPC&CS (one that is not customized to the company's particular conditions, thus is not mitigated to an appropriate level, and would most likely "not work as intended") and the preliminary design generated after our pre-feasibility study (i.e. a IPC&CS mitigated to such a point that it is equivalent to S&T). Once mitigations actions are finally selected by the design team it becomes possible to develop a residual risk assessment which should be quantitative and not qualitative, to verify the pertinence and level of the selected mitigations alternatives (see Case Study 2).

Thus, Figure 2 depicts the comparison between IPC&CS and S&T at the considered coal mine with no specific mitigations implemented. As a result, in this example, the Fossil Fuel and Tire issues are depicted as lower exposures of the IPC&CS with respect to S&T, whereas extreme cold and winds are depicted as an increased exposure of the IPC&CS (as this graph does not yet take into account possible design mitigations). The Figure 3 concept is identical to the prior one, but it depicts a situation where all the possible design mitigations identified for the IPC&CS would have been brought into the design in order to at least equalize the exposures of the IPC&CS to the ones of S&T.

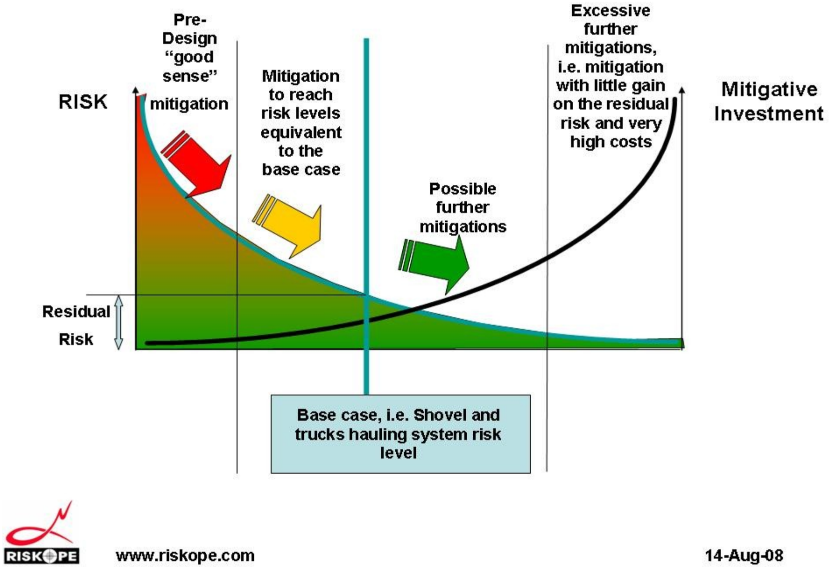

Figure 1. Risk mitigation geared towards reaching specific levels of residual risks vs. mitigative investments.

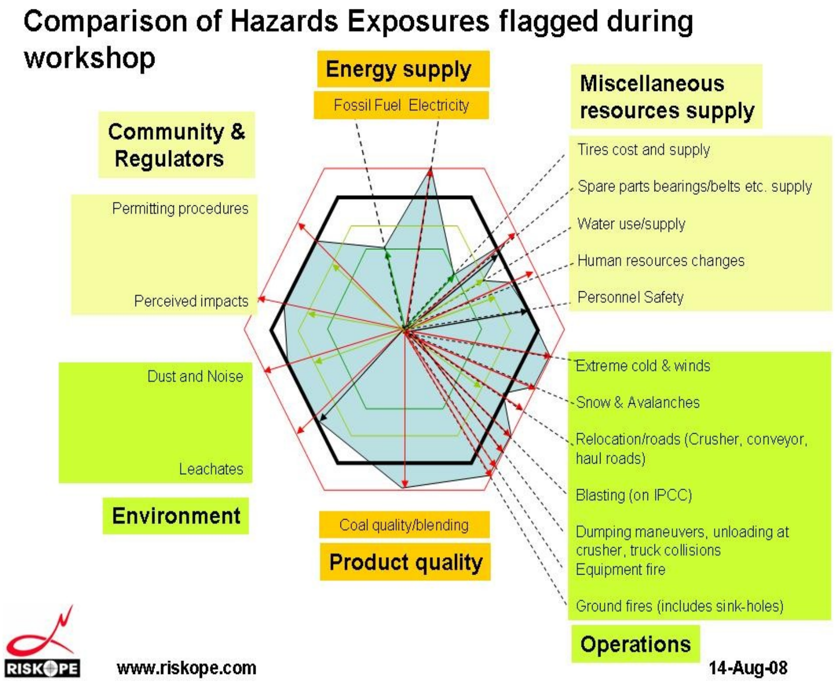

Figure 2. Comparison between IPC&CS and S&T at the considered coal mine with no specific mitigations implemented.

The passage from the initial to the mitigated exposure landscape requires investment and running expenses which have to be integrated in the cost estimates. The optimal solution may be an intermediate mitigation level between the "green" (fully mitigated) and the "red" (non mitigated) landscapes, i.e., the "yellow" line depicted in Figure 4.

Consequences related to selecting an insufficient mitigation level may range from high to catastrophic as the facility may never work as intended. The optimal solution will be somewhere between the "green" and "red" landscapes presented in Figure 4 and is represented by the "yellow" line. In the next phase of the project we will start looking at the probabilities and residual risks (after a level of mitigation has been selected by the design team based on the results of the feasibility study).

Preliminary Qualitative Risk Assessment

Once the appropriate mitigation level for the issues described in the prior section are introduced in the design, the system will still be subject to two sets of risks: a) the residual risks derived from design mitigated hazards (which depend, as pointed out earlier, on the level of mitigation selected by the design team) and b) risks linked to other issues which may be independent from design mitigation efforts because they find their roots in public/workforce perception:

- Union/personnel unrest
- Public outcry linked to dust and noise and perceived hazards as the new operation is implemented, etc.

If the design mitigation level are not sufficient, then the following situations may arise for the IPC&CS:

- Refusal to accept the changes brought by the implementation
- The system will not reach the promised performance level
- The company will not produce the appropriate product
- Repeated serviceability problems

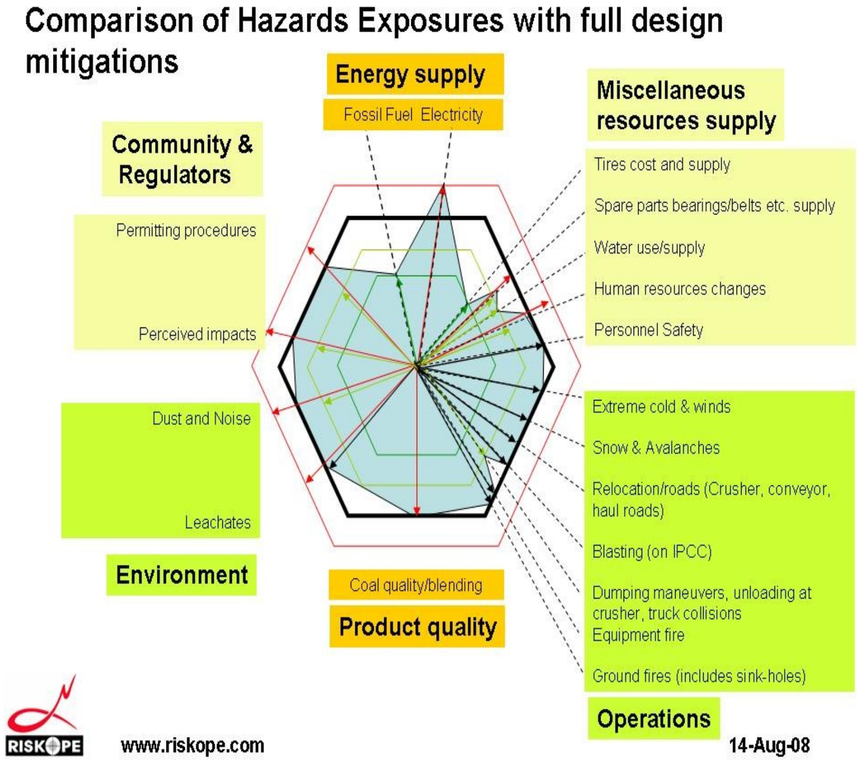

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Figure 3. Same as Fig. 2, but all the possible design mitigations identified for the IPC&CS would have been brought into the design in order to at least equalize the exposures of the IPC&CS to the ones of S&T.

All of the last four points could have large to catastrophic consequences for the project, and probabilities that will depend on the mitigation levels defined by the design team. If the pre-feasibility level is passed by the IPC&CS, the next step will be to review all of the proposed mitigations, define the residual probabilities of failure and evaluate mitigation alternatives.

As per the public/workforce perception issues, a well thought PR and information campaign, including stakeholders participation, will greatly help in solving any arising issue before it becomes a problem. Of course the criticality of the issues will be an inverse function of the design mitigation level, and will directly influence the effort and investment directed to the PR/information campaign.

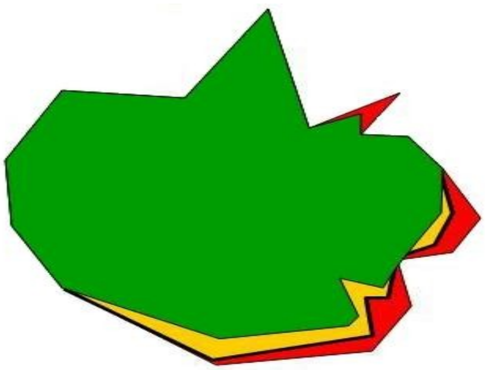


Figure. 4 The difference between the two exposures landscapes requires investment.

Case Study 2: Long Term Pumping v.s. Encapsulation of a Very Large, Leaching, Underground Toxic Waste Storage.

This case considers a large underground storage of a toxic water soluble compound with the potential to leach into the water table. In order to prevent the leaching a pumping system has been installed. In the Status Quo, the permanent pumping system keeps the underground water level below the lower level of the storage. However, water percolates from the surface and some of the compound is dissolved, leading to the need to treat the pumped water. In the Status Quo, we will assume there is negligible risk to the ecosystem and human health. The “financial parameters” and risks linked to maintaining the Status Quo are summarized in Table 1 (in Million $, noted M).

Cause/Hazard for Status Quo alternative	**Probability**	**Cost M$**
Capital investment will be necessary at start on the treatment plant	90%	5
Energy cost (diesel for the power plant) has a yearly chance of	30%	to double
Climate changes has a yearly chance of	15%	to triple

Table 1. “Financial parameters” of the Status Quo alternative.

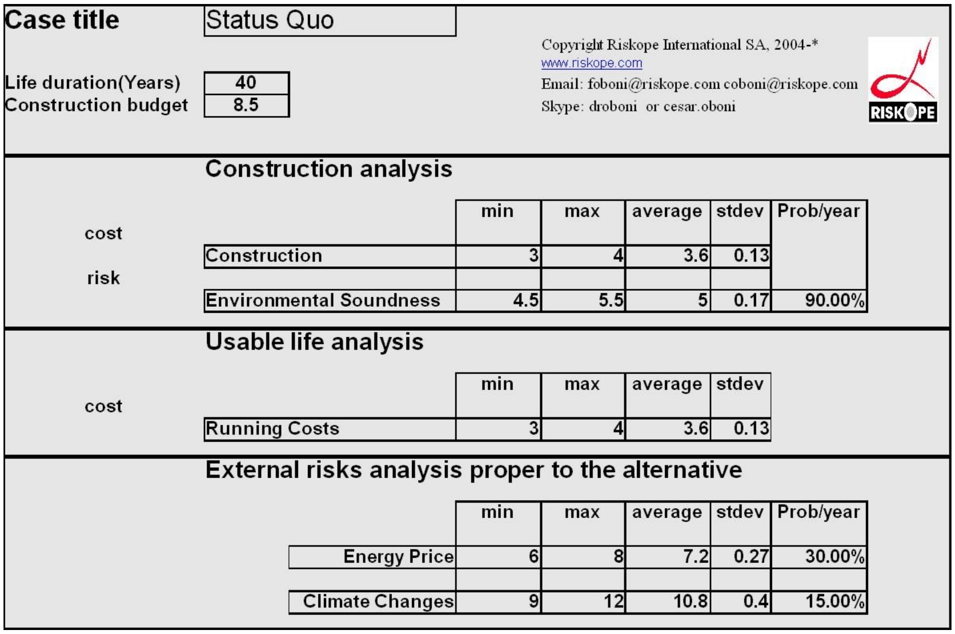
The alternative to the Status Quo would be a Rehabilitation of the site, i.e. Encapsulation of the underground storage (how that's done is not within the scope of this paper). The encapsulation would require a large capital investment (120M), but afterwards the permanent pumping and treatment would be reduced considerably.

Cause/Hazard for Encapsulation alternative	**Probability**	**Cost M$**
Capital investment has a chance to double (additional 120M) of	10%	120
Energy cost (diesel for the power plant) has a yearly chance of	30%	to double
Climate changes can force to still pump like today despite the encapsulation work, with a chance of	5%	3.6

Table 2. “Financial parameters” of the Ecapsulation alternative.

As this encapsulation constitutes a “first in the world,” a Risk Assessment has been performed which has shown that there is a significant chance that the encapsulation may cost twice as foreseen. The “financial parameters” and risks linked to building and maintaining the Rehabilitation are summarized in Table 2 (in Million $, noted M).

Finally, because of uncertainties (construction, long term climate change, etc.) there is also a chance that after developing the encapsulation as above (i.e. with the chance it may cost twice the initially foreseen amount), it may be necessary to maintain pumping as in the Status Quo. This means that despite investing in the encapsulation the project still does not work properly, which is an example of a failed rehabilitation case or a worst case scenario.



Case title Status Quo

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Life duration(Years)	40
Construction budget	8.5

Construction analysis

		min	max	average	stdev	Prob/year
cost	Construction	3	4	3.6	0.13	
risk	Environmental Soundness	4.5	5.5	5	0.17	90.00%

Usable life analysis

		min	max	average	stdev
cost	Running Costs	3	4	3.6	0.13

External risks analysis proper to the alternative

	min	max	average	stdev	Prob/year
Energy Price	6	8	7.2	0.27	30.00%
Climate Changes	9	12	10.8	0.4	15.00%

Figure 5. Status Quo data sheet, as per the Riskope's CDA-ESM application

Traditional NPV Analysis

As usual in mining projects let's use a Rate of Return of 9% for this analysis and consider a life duration of forty years as an example. NB: the NPV are always marked as negative values in this study to stress the fact that the project generates only expenses and no profits.

- Rehabilitation: 120M$ construction, then 0.3M$/yr, 40 years life span NPV: -123.23M$
- Status Quo: 3.6M$/yr, 40 years life span NPV: -42.33M$

What makes this case study particularly strong in building an argument against using NPV for alternative selection is that most of the expense in Rehabilitation is upfront, and the yearly expenses (as traditionally done, without the risks) are small, meanwhile the duration is very long — in this case the NPV almost “nullifies” any expense coming after approximately 20 years.
It can be inferred by this simple analysis that the Status Quo has by far a better NPV value than

the Rehabilitation which we will show later is a wrong estimation because of the long life of the project, and the risks that need to be included. There are two ways such an analysis could be altered to include risks. One would be to add the yearly risks as an additional cost and another would be to increase the rate of discount to "include uncertainties" as we have seen some do. Both these attempts would fail to yield pertinent results as we discuss below. Whenever used the NPV would strongly indicate the Status Quo as the most viable among the two alternatives in this case study.

Suppressing NPV and Using Risk as a Key Decision Parameter.

As with this case study, innovative approaches which eliminate the pitfalls of NPV have been used at the preliminary design level (Oboni and Oboni 2007, 2008; Oboni 1999-2000, 2005). The adopted replacement analytical tool is called CDA/ESM™ and is used to compare alternatives in financial terms, including: a) life's cycle balance encompassing internal and external risks over a selected duration and b) project implementation and demobilization costs and risks. CDA/ESM has been successfully applied to: rope v.s. road transportation, surface v.s. underground solutions, environmental projects, water treatments alternatives, transportation networks and go/no-go decisions. Figure 5 displays the data sheet for the Status Quo alternative.

CDA/ESM results at the 40 year time horizon for the three alternatives: Status Quo, Rehabilitation, and the Failed Rehabilitation case are displayed in Figure 6. Figure 6 shows that the Status Quo alternative will cost cumulatively twice as much as the Rehabilitation in virtue of the risks afflicting each alternative, such as an increase in energy costs, which were included in this analysis with a chance of 30% (see Tables 1 & 2 and the sensitivity analysis below). The cumulative cost analysis eliminates the "zeroing effect" of NPV on long term analyses. As explained above, the Rehabilitation has potential for a worst case scenario failure which could lead to a financial fiasco: more studies should be devoted to understand the probability of such a scenario, and the possible mid-life mitigations of such risks.

A residual Risk Assessment process can be used at this point to evaluate the probability that failures of the system of Rehabilitation will cost more than the Status Quo. Like in the coal mine case study the cost of the mitigative actions has to be introduced in the analysis before the next step of the design process.

It is now interesting to try to explicitly consider risks in the NPV evaluations. It appears that, in this case study, the Rehabilitation CDA (average) result is roughly equal to the NPV with risks (Table 3) and not far from the "traditional" NPV. This happens because the initial amount spent is very large compared to the yearly spending which seems, indeed, negligible. However, as we will see below the results of both NPV analyses fail to steer decision makers in the proper direction.

As we can now see the NPVs of the Status Quo with (Table 4) and without risks are lower than that of the Rehabilitation. NPVs are plain inadequate when integrating alternatives' specific risks in the comparison process (see link in references) because their "discounted nature" annihilates the effects of long term expenditures, and makes it essentially impossible to consider risks in a proper way.

Table 3. Evaluation of the NPV of the Rehabilitation modified with Expected Return values.

Financial Parameters	**Costs**	**Probability**	**Expected Return**
Construction	120M$	N/A	132M$, i.e expected fixed initial expenses including "average risks"
Environmental Soundness	120M$	10.00%	
Running Costs	0.3M$	N/A	0.66M$/yr, i.e. expected yearly expenses including "average risks"
Energy Price	2*0.3M$	30.00%	
Climate Changes	3.6M$	5.00%	
40 years life span NPV			**-139M$**

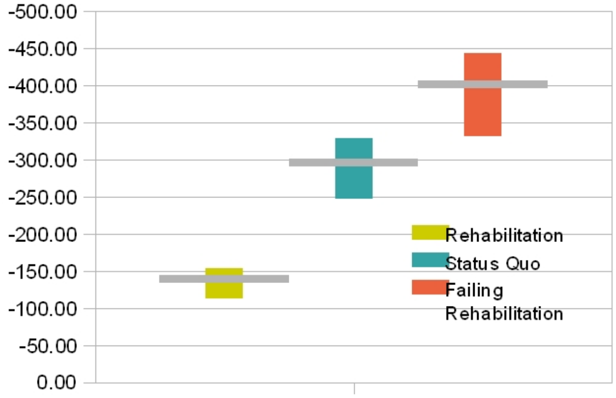

Figure 6. For each analysis: min, max, average of the cumulative cost at forty years.

Table 4. Evaluation of the NPV of the Status Quo modified with Expected Return values.

Financial Parameters	**Costs**	**Probability**	**Expected Return**
Items as listed in Table 3, with appropriate average values			11.88M$ i.e expected fixed initial expenses including "average risks"
			7.36M$/yr i.e. expected yearly expenses including "average risks"
40 years life span NPV			**-90.2M$**

Furthermore, as depicted in Figure 7, for all probabilities of energy cost increase, the Rehabilitation (yellow bar) is more costs efficient than the Status Quo (blue bar), once all the three considered risks are included. So, again, if we consider the probabilities that the costs of energy might be triple or more at any value of energy, the Status Quo alternative is less appealing than Rehabilitation. Should more risk scenarios be included in the analysis, then we would see that the Status Quo alternative is even less attractive than depicted above.

Conclusions

Two Cases Studies taken from our day to day practice have been presented to show that risks should be used as a discriminant parameter from the beginning of any project for successful long term planning and to manage rational decisions. One case was dealt with qualitatively at the pre-feasibility level, the other quantitatively at the preliminary design level.

At the pre-feasibility level it has been shown that graphic methodologies coupled with simple procedures can efficiently pinpoint weaknesses and lead to better decisions and appropriate mitigations.

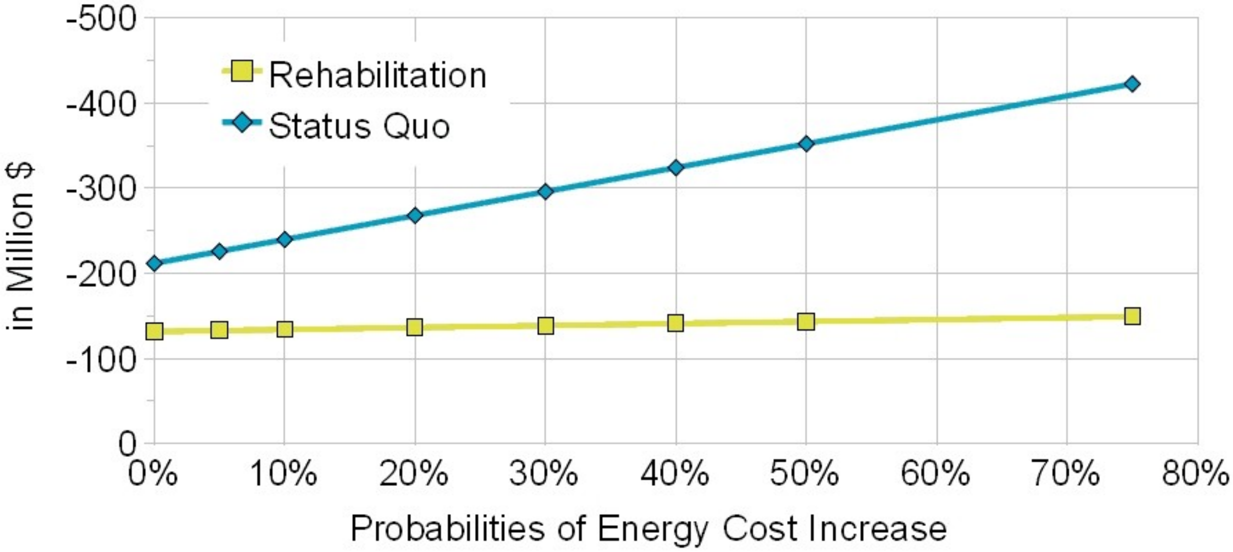

Figure 7. Sensitivity of alternatives to variation in the probability of the raising costs of energy.

In the process of performing the qualitative risk assessment several hazardous conditions which could be easily managed by design solutions were flagged. Indeed a pre-feasibility qualitative risk analysis should reduce the chances of a fatal flaw of the design, by defining design parameters and bringing changes to the preliminary design geared towards increasing the chances of the future implementation to work and perform as intended. Of course the newly defined parameters and changes have to be integrated in the preliminary implementation and running costs estimates in order to avoid the possibility the project becomes a “financial fiasco.”

The over-costs of these mitigations have to be integrated in the pre-feasibility construction and running cost estimates to verify the economic sense of the project. At that point the system will still be subject to two sets of risks: a) residual risks deriving from design mitigated hazards (which will depend on the level of mitigation selected by the design team) and b) risks linked to hazards such as union/personnel unrest, public acceptance issues, etc., which may be independent from design mitigation, as based on public/workforce perceptions.

At the preliminary design level it was shown that this innovative approach eliminates the pitfalls of NPV, an obsolete financial concept still used by many. The evaluation of a project should of course include the annual risks potentially afflicting the project, construction risks, and risks of malfunctioning, and possibly also the demolition/reclamation costs. It has been shown that the NPV can lead to erroneous conclusions in terms of the overall cost of a project, in particular for very long term projects. Because of this the NPV is particularly dangerous when dealing with long term environmental rehabilitations.

The tool used to avoid the NPV pitfalls is called CDA/ESM™ and is used to compare alternatives in financial terms, including: a) life's cycle balance encompassing internal and external risks over a selected duration and b) project implementation and demobilization costs and risks.

The approaches described above have been successfully applied to: rope v.s. road transportation, surface v.s. underground solutions, water treatments alternatives, transportation networks, go/no-go decisions.

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