Financial Calculation of Long Term Tasks in Mine Water Management

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1. Introduction

Remediation and aftercare jobs in the mining industry are often characterized by their long-term nature. The economical evaluation, e.g. behavioral alternatives, are therefore based on an inter-temporal valuation approach. As the evaluated objects usually do not create revenue, the valuation criterion will be the expense parameter that is expressed as the cumulative cash value of all costs and the investments still to be decided upon and thus relevant for the payments to be made. This expense parameter will have to be interpreted as a negative revenue item, so that the valuation approach introduced herein is a special case of the approach used to determine the capitalized value of potential earning, which is dominating in the mining industry. This paper introduces typical reasons for a valuation, the valuation model and the conclusions for the model drawn from a sensitivity analysis. Problems arising when the model is applied are highlighted in a case study.

The research work as well as training and further training at the TU Bergakademie Freiberg have focused for years now on problems concerning the commercial evaluation of deposits, of mining technologies, of mining projects and of mining companies, but the same problems have also been the subject of the consulting services and expert opinions provided by the University on behalf of governments, authorities and of the mining companies themselves (Drebenstedt and Slaby, 2007; Drebenstedt, 2006; Slaby and Drebenstedt, 2000a, 2000b, 2003; Slaby and Drebenstedt and Ohlendorf 2002; Steinmetz and Slaby, 1993; Wilke and Slaby 1993).

If the insights are summarized that have been gained on different objects of valuation, during different occasions for such a valuation and by considering the different valuation targets, the following three conclusions and the recommendations derived from them will turn out to be of fundamental importance:

- The fundamental approach to any kind of valuation in the mining industry is to consider the capitalized value of potential earnings. Alternative approaches to the valuation, such as to consider the net asset value as it is favored elsewhere, are either completely unsuitable for the valuation of deposits, inventories and projects or only partly suitable for the valuation of mining companies and plants.
- The evaluation strategy must take into account the valuation of deposits, projects and companies in their entirety.
- Conflicts existing between a mining company's internal economics (the pursuit of profit), between external effects (caused by interfering in the environment and in natural habitats) and with the duty to protect the deposits (caused by high extraction rates) can and will have to be considered in the decision-taking process to a reasonable extent on the basis of opportunity or alternative cost accounting.

Triggered off by the declining rate of the mining output (e.g. in the hard coal and lignite industry) and by the elimination of entire mining sectors (such as the Wismut), we have been increasingly confronted in recent months with the problem of a commercial evaluation of the ecological consequences of these mining activities as well as with the search for measures required to ward off the dangers arising from this situation and to secure a sustainable development. The relevant efforts have been focused on remediation, post-closure and long-term projects in connection with the Wismut and lignite mining activities. In view of the fact that the problem is of fundamental nature and that it concerns or affects all mining sectors, the work results and the experience gained during this work are to be made known in the following paper.

2. Conditions for Mine Remediation

Mining will always affect the environment. Regions where raw materials are produced by surface mining are particularly affected in this respect. The changes in nature caused by mining activities are most varied. They include changes in agriculture and thus to the biosphere, the temporary withdrawal of arable land and living space as well as their devastation, at least for some time, infrastructural changes in the region and the interference in natural and anthropogenic water systems. In order to secure the chances of future generations for a sustainable development, the natural balance affected by mining activities will therefore have to be redressed and the living space once given over to mining will have to be revitalized (Slaby, 1992, 1998; Gerhardt and Slaby, 1994, 2000).

The allocation of the professional, legal and commercial responsibilities will have to be based on the principle of causation. This means that the mining industry, i.e. the mining company causing the post-mining damage, will have to assume responsibility, as it is also stipulated in the German mining law. The general principles of providence and causation will then have to be complemented by the principle of burden-sharing, by the user principle and by the principles of feasibility and reasonableness, depending on the overlapping and distinguishing interests of other parties involved, especially as a result of the ongoing social development processes. One will have to bear in mind that, often enough, the mining companies causing the damage do no longer exist at the time when remediation and post-closure measures will have to be implemented (post-mining reconstruction) and when the contaminated sites will have to be recultivated (long-term obligation).

A major feature of the post-mining consequences caused by the elimination of former mining locations is their long-term character and the special risks as regards the expected and the actual scope of work. This applies particularly to remediation, post-closure and long-term objects in the field of water management, such as to objects for the collection, treatment and disposal of contaminated seepage water from mining slopes, dumpsites and disused industrial facilities, as well as to objects for controlling and limiting the rising ground water levels in old mining locations affected in this respect. Alternative technological and commercial options to solve the problems as well as specific technological and commercial risks are typical of these long-term objects, and they often seem to require an infinite duration to complete them, when one looks at these problems from today's point of view. These specific risks concern the insufficient knowledge of the effectiveness and the reliability of the technological solution applied, the time it will take to reduce the contamination, the required consumption of production factors (such as energy, chemicals etc.) in the course of time, the time involved to treat the relevant quantities of water or the inflow of water and, last but not least, the uncertainties as regards the development of the valuation parameters (such as prices and rates) for the consumption of these production factors during that time. The economical valuation of such objects requires necessarily an appropriate evaluation of the time factor and makes it necessary to take the various risks and trend factors into account. In other words, it is necessary to apply an inter-temporal valuation approach (Slaby and Drebenstedt, 2000a, 2003).

In the current practice of remediation mining, the general problem of the economical valuation of long-term remediation objects is embedded mainly in two fields of the decision-taking process.

First of all, as a pre-requisite for determining the most suitable option of technological and commercial behavioral alternatives. The problem to take a decision in this respect is above all characterized by the fact that the available technological options may oppose each other: one of them may require no or hardly any aftercare, but is cost-intensive, while the other one may require fewer investments, but more aftercare. The problem is here to make an inter-temporal comparison of the expenditure involved (i.e. the investments and the operating costs required), depending on the time when these amounts become due. The problem can only be solved by applying financial and mathematical valuation models.

Secondly, the progress made with the remediation creates the prerequisite for transferring the object into the responsibility of a third party. This transfer often comes along with a change in ownership, i.e. the local authority becomes the new owner, so that the supervision by the mining authority ends, as intended. It might be necessary to pursue the long-term jobs, such as monitoring and water management jobs, also in the future and under the auspices of the new legal owner, in order to contain or ward off post-mining damage affecting the general public.

The readiness of the future owner to accept the commercial responsibility for the project will depend on a reasonable funding. The volume of the funding depends on the services and costs for the relevant object still outstanding at the time of transferring the ownership. The calculation of the amount needed, e.g. a one-off payment to the future owner, will be based on a mathematical valuation model of the financial investments required, i.e. on the calculation of the cumulated capitalized cash value of all outstanding financial obligations.

A suitable approach to a solution of both problems is to mathematically determine the financial investment costs.

3. Financial Valuation Approach

This approach makes it necessary to establish the cumulative cash value of all financially assessed expenses required for the valuation projects over a limited or unlimited time horizon (T) and in accordance with the required safety and remediation standards. These "mathematically calculated financial investment costs", referred to hereinafter as the expense parameter (AW), act as criteria when the commercial advantages of alternative options are compared and when a one-off payment is made to the future owner after the financial responsibility has been transferred. The calculation of the expense parameter AW is determined by the cash-layout costs (operating costs requiring payments) to be established for the period t. As well as by cyclic and non-cyclic investments, that may become necessary. These payments are the input for the calculation. Should payments be received during the period T, such as in the form of revenue or investments, they will have to be offset against the payment made in the same period. Any balances from the liquidation are to be included in the calculation at the end of the project period T.

Calculation of the cumulative cash value of the periodic payments (the mathematically calculated financial investments) related to a base year (0) by taking into account:

- The period required for the relevant measures (T).
- The cash-layout costs at valuation level 0 by taking into account the possibly changing consumption of resources (such as energy, labor etc.) and investments during this period that might become necessary.
- The inflation-adjusted imputed interest (the real rate of interest).
- Trends concerning the changes in the valuation parameters and in the prices for the expense parameter, such as for energy, labor, replacement investments and material.
- A general inflation rate.
- the specific technological and commercial risks concerning the valuation objects.

Investments made and operating costs expended before the base year (0) will be disregarded in the calculation of the cumulated cash value for the payments due, they are irrelevant for the decisions (to be) taken in this respect, they are "sunk costs" by their very nature.

If the expense parameter AW is used as a basis for a one-off payment in the case of transferring the responsibilities, it will be assumed that this capitalized one-off payment made in the base year (0) will be capitalized as an annuity with a safe nominal interest rate over the limited or unlimited time horizon. This periodic annuity is then available with the required amounts to cover the payments, including the calculated trends in the expense and valuation level as well as for specific technological and commercial risks.

$$AW = \sum_{t=1}^{T} \frac{A_{t(0)}}{q^t} \tag{1}$$

where AW = expense parameter; $A_{t(0)}$ = periodic amount for the cash-layout costs and investments in period t at the valuation level in base year (0); q = imputed interest (the real rate of interest).

If AW in equation (1) = constant, the following applies:

$$AW = A_{t(0)} * \frac{q-1}{q(q-1)} = A_{t(0)} * KF \tag{2}$$

where KF = capitalization factor.

The required cyclic and non-cyclic payments, such as for replacement and one-off investments, are included in annuity $A_{t(0)}$ (as an investment annuity) of equation (2). The capitalized expense parameter AW will then be determined by the product of the largest period annuity of all payments and of the capitalization factor. The valuation model shown in figure 1 illustrates the suggested valuation strategy.

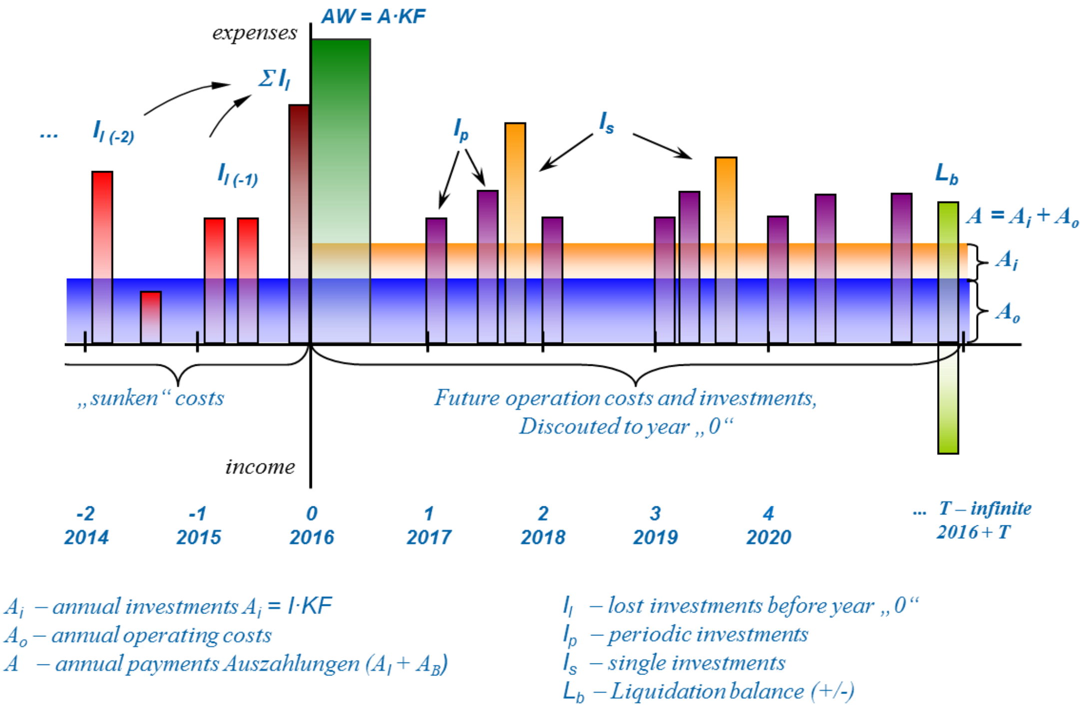

Figure 1 *Valuation strategy*

Prerequisites for calculating the expense parameter AW on the basis of equation (2) are therefore:

- The calculation of the payment/expense annuity $A_{t(0)}$. This includes the preliminary calculation of the cash-layout for the operating costs and other cyclic and non-cyclic payments that may become necessary as well as their calculation as representative expense annuity over the period T.
- The calculation of the capitalization factor KF. This requires decisions to be taken over the period T, decisions as to the rhythm of the cyclic investments (renewal cycle) and the determination of the imputed interest rate q.

If the object to be evaluated is subject to price increases for the consumption of production factors (such as prices and labor rates) to and specific technological and commercial risks, it is recommended to calculate a modified interest rate q, which will then have to be taken into account, and the expected inflation rate as well. Assuming that there is a continuous and steady development over the period T (with the same percentage), the imputed basic interest rate (the real rate of interest) will have to be modified as follows:

$$q = q_R * \frac{q_{Infl.}}{q_V} - \frac{p_R}{100} \tag{3}$$

where q = imputed interest rate now modified; q_R = original imputed real interest rate; $q_{Infl.}$ = inflation factor; q_V = summarized object-related modification factor of the valuation criteria (prices) for the expense factors, such as for labor, energy etc.; p_R = discounted interest rate in % p.a. to take specific technological and commercial risks into account.

The calculation of the expense parameter *AW* on the basis of equation (2) with the given capitalization factor *KF* and an expense annuity $A_{t(0)}$ that remains constant over the period *T* is recommended, when payments for the objects remain unchanged over the period *T* and when the expense parameter *AW* does not change, either. In the case of any deviating conditions, such as changing expense curves and liquidation balances, the calculation regulations will have to be modified further. Should the expense curve fluctuate, the calculation will have to be made on the basis of irregular amounts being paid over the period *T* according to equation (1). In practice, it may be typical that the trend of expenditure is decreasing which can be mathematically described by a digression of the changing amounts. The expense parameter *AW* will have to be interpreted as a negative revenue item.

As a result of the sensitivity analyses carried out and depending on the model input, the following conclusions are generally valid and can be drawn with regard to the sensitivity of the target parameter "capitalized expense parameter" (*AW*) (Drebenstedt, 2006).

- AW responds rather sensitively to changes in the modified interest rate q and shows an exponential growth with a declining interest (rate). *AW*'s sensitivity is therefore felt more strongly in areas with a high interest rate than in areas with a lower interest rate. This, in turn, makes it necessary to define q thoroughly, i.e. the influencing factors must be taken into account in this respect. For the mine closure activities with long term character and risks, a reasonable funding is necessary. The basic of the calculative real interest rate therefore can be only long term and safe investments. Interest rates from such investments are comparable low, in Germany in the rage from 2.5%/a to 3.5%/a.
- The decisions on the structure of these parameters, including the capture of detailed data for individual cost items, will be pushed in the background, while the decisions on the rate of the inflation-adjusted basic interest (q) and on the interest rate for risks involved (p_R) will be given much more priority, although the cause/effect relationship between price increases (q_V) and inflation ($q_{Infl.}$) as well as the adjustment between the effects of this relationship on q will have to be given due consideration.
- The influence of *T* on the amounts involved in AW is considerable over a 20 to 30-year period (*T*), but will decline when *T* is in excess of 30 years. This fact points to the necessity that T for the objects with a limited duration must be determined very carefully.
- The safe knowledge of the amounts involved in the expense parameter and of the expense curve in the case of projects with a long (*T* longer than 30 years) and an infinite duration as well as the required knowledge of possible liquidation consequences is less important and fades in the background. The influence of long-term jobs tackling so-called permanent mining damage on AW is almost irrelevant under the aspect of a commercial valuation when T = 50 years. The one-off payment in the case of a constant expense annuity over the period $T = \infty$ and a modified interest rate q = 1.05 amounts to only 9.55 percentage points above the amount which would have been due if *T* was 50.
- The expense curve over the period *T* (either constant or declining) is of decisive influence especially on objects with a limited duration. This explains the demand to determine the expense curve for these projects over the period *T* very carefully, apart from the demand to also limit this period T to a reasonable duration.
- Irrespective of the project duration *T*, the statements about the expense volume and the development of the expense curve for a period of up to 20 - 30 years are of the essence.

- In general, AW shows a higher sensitivity in areas with a lower interest rate, also when T, L_T and the expense curve change. Consequently, the claims for funding of these parameters will be higher at a lower interest rate than at a high interest level.
- Should AW be used as a criterion for determining the commercial advantages of (different) options, any variations in the interest level may change the advantageousness of the option hitherto preferred. A higher interest rate favors options and makes them more advantageous, where most of the required expenses become due in the far-away future. In other words: a low interest rate promotes behavioral alternatives requiring a less intensive aftercare, but requiring higher investments.

4. Case study

4.1 The problem

The following typical example often meets in practice: The residual hole of a disused opencast mine is filled with water and used for local recreation. In order to ensure the safety for the general public, it becomes necessary to regulate the water level in the lake and prevent it from rising beyond a specified level. A water level higher than the specified one could cause geo-technological dangers, such as landslides. In order to regulate the water level permanently, two technically feasible solutions are available (Figure 2):

- Option 1: The permanent operation of a pumping station. This option requires comparatively little funding in form of a one-off investment, but incurs comparatively high costs for the cyclic replacement investments and the operating costs.
- Option 2: Construction of a free outflow from the lake. The advantage of this option is that the operating costs and the cyclic replacement investments are fairly low once the free outflow has been constructed, although the initial funding requirements are comparatively high.

4.2 Initial Data and Calculation

In order to compare both options under commercial aspects, all expense-related facts will have to be reviewed.

Option 1

A stationary pump will have to be installed for permanent operations.

- Investments: The investments made in recent years comprise electrical connections, a passage under the road and a building for discharging the water into a near-by creek and have a reinstatement value of some € 21,600. The renewal cycle for these plants has been fixed to be 40 years. Further supplementary investments amounting to approximately € 71,300 are required for the pump station (€ 40,900), the pumping equipment (€ 20,200) and the site mobilization (€ 10,200). As the pump is only used periodically, a reserve pump will not be required. In order to establish the recurring expense items, a distinction must be made between cyclically renewable and one-off investment costs. The one-off investment costs include the site mobilization. The pumping equipment will have to be replaced every 12 years, while a useful life of 40 years is assumed for all other investments.
- Operating costs: The operating costs of € 18,600 can be broken down as follows: energy (€ 0.03/m³ of water), labor costs for the supervising personnel (10 hours/week at € 23/hour), service and maintenance (2% p.a. of the investment sum over a useful life of 40 years and 8% p.a. of the investment sum over a service life of 12 years) as well as charges and fees (insurance, rental of the land etc.).
- Risk: In order to dimension the pump, a 50-day pump test has been carried out. This period is not considered to be sufficient for making a reliable forecast as to the water quantities to be pumped. This uncertainty will be taken into account by a risk discount of 0.5% on the interest rate.

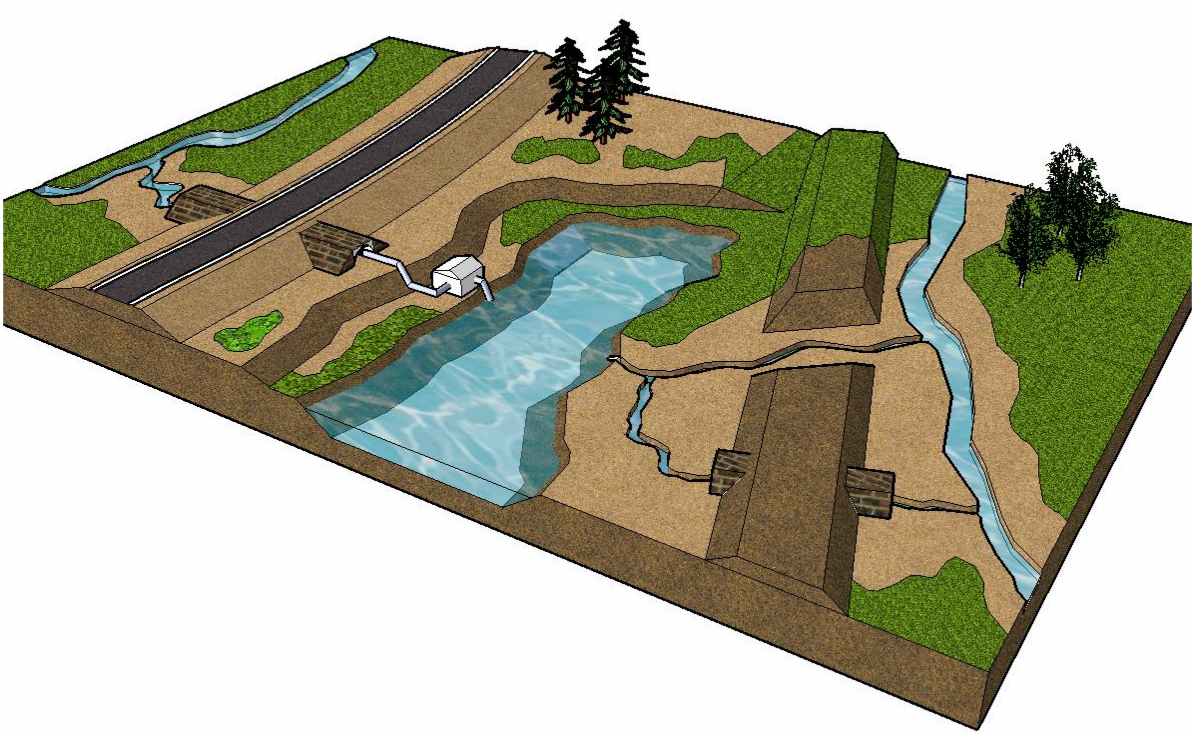

Figure 2 *Scheme of case study options: pump station (left) or free outflow (right), 1- mining lake, 2 – dam, 3a – open ditch, 3b – pipe installation, 4 – river, 5 – pump station, 6 – pipe installation, 7 - road*

Option 2

The water will be discharged partly into an open trench and partly into a pipeline. The different piping sections lead to the sub-options "open trench" and "piping" (Table 1).

- Investments: The earthwork, the vegetation work, the surveying and engineering services as well as the permitting costs will be taken into account as one-off investment costs (€ 524,500 or € 537,300, respectively). The pipelines and the trench construction will have to be renewed cyclically (every 40 years) at a cost of € 19,400 and € 264,800, respectively.
- Operating costs: Checks are necessary in the interest of public safety and to maintain the reliable function of the discharge installation (8 hours/week, € 10,000 p.a.).
- Risk: The water outflow to be constructed runs across an old dumpsite. As no hydrological assessment of the water level in the dumpsite has been prepared, no final statements as to the required construction of the water discharge installations can be made. These risks will also be reflected by an interest rate discounted by 0.5%.

The two options will be commercially evaluated based on the expense parameter AW as applied in equation (1). All necessary payments over the entire project duration will be taken into account, the cyclic investments as investment annuities. The project duration of both options is infinite.

The mathematical calculation of the investment costs assumes a real interest rate of 4% as well as a price and inflation adjustment.

The input data and the result of the mathematical/financial calculation of the expense parameter AW based on equation (1) are summarized in the table 1.

Table 1 The project costs broken down in accordance with the options considered

Elements of the project costs	**Option with a pump station** (10^3 €)	**Free outflow option**	
		Open trench (10^3 €)	**Pipeline** (10^3 €)
1. New investments	71.3	524.5	537.3
1.1 of which: one-off investments	10.2	505,1	272.5
1.2 of which: cyclic renewal, every 12 years	20,2	-	-
1.3 of which: cyclic renewal, every 40 years	40.9	19.4	264.8
2. Renewal of existing plants, every 40 years	21.6	-	-
3. Operating costs per year	18.6	10.2	10.2
Expense parameter AW	693.8	825.0	947.3

4.3 Results

A comparison of the options based on the above assumptions shows that the construction of the pump station ensures a relative advantage of about 18.9% over the option with a free open trench outflow. The option involving the free outflow with a pipeline is clearly much more unfavorable due to the high proportion of replacement investments. When looking at the effect the real interest rate has on the expenditure, the following statement can be made: Based on a real interest rate of 3% p.a., both options (with the pump station and with the free outflow) are commercially equivalent. If the real interest rate rises, the option with the pump station will become more advantageous. A relative advantage of 36.4% is already achieved with option 1 when the interest rate rises to 5% p.a., as compared with the other option. These statements underline and confirm how urgent it is to determine the interest rate exactly, i.e. to establish the real interest rate, the price modification rate, the inflation rate and the risk-related interest rate (Equation 3).

Conclusions

A major feature of mine closure activities is their long-term character and the special risk. This applies particularly to remediation in the field of water management, such as to objects for to objects for the collection, treatment and disposal of contaminated seepage water from mining slopes, dumpsites and disused industrial facilities, as well as to objects for controlling and limiting the rising ground water levels in old mining locations affected in this respect. Alternative technological and commercial options to solve the problems as well as specific technological and commercial risks are typical of these long-term objects, and they often seem to require an infinite duration to complete them.

In the current practice of mine closure, the general problem of the commercial valuation of long-term remediation objects is embedded mainly in two fields of the decision-taking process: First of all, as a pre-requisite for determining the most suitable option of technological and commercial behavioral alternatives. Secondly, the progress made with the remediation creates the prerequisite for transferring the object into the responsibility of a third party. The problem is to make an inter-temporal comparison of the expenditure involved, depending on the time when these amounts become due. The problem can only be solved by applying financial and mathematical valuation models. The approach is to establish the cumulative cash value of all financially assessed expenses required for the valuation projects over a limited or unlimited time horizon and in accordance with the required safety and remediation standards. These "mathematically calculated financial investment costs", referred as the expense parameter (AW), act as criteria when the commercial advantages of alternative options are compared and when a one-off payment is made to the future owner after the financial responsibility has been transferred.

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