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Optimising the Net Value of Water to the Mining Industry through an Adaptive and Risk-Based Framework

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ABSTRACT

Water remains a key limiting resource for the oil, gas and mining industries. Often the geological deposits are located in arid areas and mineral processing requires large quantities of water. In planning for extractive industries infrastructure projects, cost/benefit analyses play a critical role. However, with government subsidies being offered for water and energy in many cases, the true value of hydrological resources in terms of their social and ecological importance gets eclipsed. We provide a review of methods which can be applied to valuing water that are ecologically appropriate as well as frameworks for considering social value of water. Four key attributes of the valuation process are addressed in our analysis: *Benchmarking*: How to establish a baseline value of water (i.e. prior to the mine), especially in non-stationary, already perturbed environments; *Uncertainty*: How does variability in water availability affect the value placed on it; *Complexity*: Indirect and non-linear effects of mines on water, e.g. population and land use change, and *Formalisation*: Quantifying or otherwise formally describing the social value of water. Recognizing that water's social and ecological valuation might not be adequate policy drivers on project approval, a comparative framework provides a means for documenting the social and ecological risks of projects which move forward, given such a comprehensive evaluation process.

INTRODUCTION

Mining requires water for numerous uses including mineral processing, dust management, drilling, transport and human consumption. The absolute amounts of water used for mining might not be generally comparable to uses such as agriculture but the significance of mine water use in some mining areas is acute. Since geological presence of minerals limits mining sites for investment, and the marginal benefits of water can be very high, water availability is often "engineered" to provide for the mineral processing opportunity. Furthermore, the water demand of mine sites is dynamic on a scale of years compared to many water users, due to the life cycle of the mine and in response to production demands. This makes mining qualitatively different from other sectors in terms of water supply planning methodologies, which must contend with a complex and dynamic set of circumstances that are tightly coupled with technology and associated risks of contingencies.

At the same time, the ecological risks associated with water availability and quality impairment are also coupled with risk of social unrest (Adler et al., 2007, Bebbington and Williams, 2008). As demonstrated by mining projects in arid areas worldwide, there can be protracted conflicts associated with water availability and perceptions of environmental injustice around water rights and allocation (Martinez-Allier, 2001).

The high potential value and costs of water to the mining industry, in terms of productivity and managing 'license to operate', mean that mining companies have been forthcoming in reporting their water usage more so than most other industries. A report by KPMG (2012) of G250 companies found 100% of mining companies in that cohort reporting both mining water reduction and water treatment and reuse data. Only the pharmaceutical industry had comparable reporting statistics. Mining companies were also the only ones to report their "water footprint" consistently – in comparison only 20% of food and beverage companies did so despite the large water usage in their sector. In a separate study by CERES (2010), mining companies scored highest in disclosing risk associated with water scarcity. In the same study, out of a hundred companies across 8 industrial sectors only the oil, gas and mining sector disclosed direct consultation strategies with stakeholders on water impacts of siting or expanding operations. Based on these findings, the mining sector is well-positioned to play a leadership role in effective valuation of water and associated planning methodology that can be transferable to other sectors.

In this article, we present an approach for integrating valuation methodologies with concepts of risk and adaptability, aiming to provide a more comprehensive and prospective approach to sharing water. Our goal is to not only improve industrial metrics of water valuation but to provide a framework by which water can be used with greater long-term net benefit for multiple stakeholders in a region, including internalization by communities who are confronted with the spectre of mining development. The paper will now briefly review the challenge of valuing water and the role of risk and uncertainty in defining value; followed by a review of existing approaches to adaptive decision-making by water users and suppliers. The proposed planning framework will be presented and illustrated using a hypothetical case study; and the challenges and opportunities arising for the mining industry and its regulators discussed.

Water Values

It is now generally accepted that water cannot be valued economically across all its uses because the methods to do so are available do not provide adequate clarity within error margins. Instead, regulated allocations, based on a combination of historical legal rights, and consultation are a more effective approach. This can be undertaken by prioritise human health needs, followed by some trade-off between ecosystem needs, business needs, non-essential uses, such as recreation and aesthetics, and cultural and spiritual needs.

A further source of uncertainty and shifts in values arises from community perceptions of the value of water. Water is now increasingly perceived as an inherent human right beyond just the biological needs of individuals and has been noted as a distinct human right by organizations such as the Institute on Human Rights and Business (Kemp et al, 2010). However, the legal rights to water are often malleable with legislative changes in terms of government subsidies for subsurface extraction that can often take place with extractive industry projects. The argument in such cases is often made more in terms of collective national progress that underplays the community perception of value as idiosyncratic and highly subjective. Damigos (2006) noted this in his review of valuation methods for water in the mining industry where in one case the average estimates for the environmental assets were similar for both plaintiff and defendant in a legal struggle but the aggregated results estimated by the public trustee were 84 times the estimate of the defendant. In another case, conventional economic methods for valuation showed enormous variation: property value change methods differed from contingent valuation metrics by a factor of 35 (Ibid., p. 244). The stable valuation of water is further complicated when considering that perceptions of value may change as lifestyles are altered by the mining process itself. The high stakes, but fundamental difficulty of establishing an agreeable and stable value of water in such contexts motivates decision-making frameworks designed around monitoring, updating and risk.

In some cases mining projects can provide opportunities for making greater amounts of water available for community use -- for example, through the construction of water pipelines and reservoirs. This has particularly been the case in the Andes mines where desalinated water has been piped to mining communities at great infrastructure cost that have ranged from $100 million to $3 billion (Miranda and Sauer, 2010). While intuitively attractive from a regional water supply perspective, a company's perception of increasing supply through an engineered solution does not often translate into an automatic "social license to operate," and water may become more a corollary for operationalizing trust between the company and community. Water in this regard is a universal "currency" for configuring conflict in such areas and becomes a vital bargaining tool whose purpose extends beyond the specific value of the resource itself.

Another aspect of water valuation that mining operations may consider more directly is the framework of "ecological services." As defined by Bai et al (2011), in the context of mining, ecological services or 'eco-services' are different from 'ecosystem services' in terms of the dynamic interaction between nature and society that the former concept offers as compared to the latter. The traditional concept of ecosystem service as accepted by the Millennium Ecosystem Assessment divided value into four key areas a) supporting service: such as nutrient cycling b) provisioning service: such as food and water availability; c) regulating service: such as water purification and flood regulation and d) cultural services: educational and aesthetic appeal.

Furthermore, the valuation of water with mining projects is tied to the discounting of future benefits of conservation. As noted by Nyoka and Brent (2007) in their evaluation of environmental valuation approaches to decision-making in the metallurgical sector, "externality costs are very sensitive to the discount rate used for estimating the present value of future damage costs applying to a long-term perspective." However, for ecological systems, the benefits or conservation as well as the impacts of depletion or deterioration are often much further in the future. The choice of the discount rate in such contexts needs to be far more carefully examined and should usually be lower than the conventional discount rate used for net present value calculations for the economic productivity metrics of the mine.

Hence we argue that a quantitative approach to water valuation provides a tangible focus for communication, consultation and updating of how we value water. The aim is not to produce a definitive metrics of value or importance-weights, but to provide values-scores that can feed into an objective and transparent decision process. Differences of opinion and ambiguity, and variability in data needs expressed as uncertainty, which in turn can be used to derive risk metrics, so that decisions recognise the significance of these uncertainties.

Risk and Uncertainty

Risk as a concept accepts that significant costs (or loss of value) may be associated with infrequent and difficult-to-foresee events, for example production losses due to interruption to water supply or accidents that result in manifest changes to public opinion. Risk as a decision-making variable allows the expected costs of these events to be balanced with the cost of avoiding them. The use of risk as a decision criterion may seem obvious, however the consideration of such events will reduce potential profits (rather than long-term expected profits, which it is designed to protect) and hence risk has not been employed as much as it might. Also, the fact that risk aims to account for infrequent and difficult-to-foresee events means that the data required to calculate it are not generally at hand and usually require some investment. Numerous simple approaches are used to estimate risk to alleviate this burden, for example using best-estimate costs without significant attention to foresight about possible events. However, where risk is potentially high due to uncertain water supply and uncertain competing demands for water, more sophisticated approaches are recommended. Thus the two properties of an event that define risk – its cost and its probability of occurrence (or other expression of its uncertainty) – are central to a discussion of mine water management.

The use of risk as a water management decision variable is well established. However there are significant obstacles to its successful uptake by water managers and to objectivity in its calculation and communication. The general challenge of estimating risk in this context is to integrate the costs (loss of value) associated with shortage of water over the uncertainty about the frequency and severity of shortage. Irrespective of the problem of defining value (see previous discussion), at least four types of difficulty arise in the calculation of risk: The subjectivity and simplifications required to quantify uncertainty and thus potential lack of transparency of method; the difficulty of communicating risk to stakeholders; the need to reduce an infinite number of future water shortage scenarios to an evaluable set; the computational burden of including a risk calculation within an iterative decision-making procedure especially where mathematical optimisation is involved. The latter two issues relate to the evaluation effort justified for a particular problem and may be addressed by screening risks prior to detailed analysis. Of more interest to our proposed adaptive decision process are the other two issues - of transparency and communication.

The issues of transparency and communication relate to the conceptual and theoretical understanding of uncertainty and its translation to risk. There are various sources of uncertainty in water supply planning, which may be categorised into two types: 1. Random variability (aleatory uncertainty). This can include anything that appears to happen randomly, potentially including random components of climate variability and fluctuations in demand. So long as data exist to characterise this variability (including statistical dependence between variables), this type of uncertainty is quite easily translated into scenarios using an established sampling method. 2. Unknowns (epistemic uncertainty) including unknowns about future climate change, regulatory constraints on water allocations, infrastructure reliability and unknowns about historic hydrological yields due to lack of data. This second type of uncertainty can also be approached using statistical methods, but the formulation of the statistical distributions and their dependencies requires subjective judgement. Furthermore, the need to include conceptually different types of uncertainty and the mathematical integration with costs means that risk is inherently difficult to communicate to a lay-audience. These issues are potentially of major importance in the mining context, where the transparency of assumptions behind risks and the communication of risk may be critical in internally justifying investment and in seeking public confidence. The role of epistemic uncertainty and the need to minimise subjectivity that comes from lack of knowledge supports the move to more adaptive and engaging decision-making frameworks.

Adaptation and engagement in decision making

The need to update decisions periodically is ingrained into most water planning frameworks. Long-term planning decisions are typically reviewed every 5 years, while the gradual realisation that climate change will affect water supplies and the need for integrated catchment planning has gradually been introduced into planning strategies over many years. More operational matters are reviewed on a range of different time scales, for example allocations, demand management impositions and decisions to transfer water between regions may be reviewed monthly by water suppliers, based on reservoir or groundwater levels. Decisions by water users are more dynamic still, for example exchanges of water rights within regional trading schemes and users' abstraction rates will respond continually to individual values.

However, frameworks that allow adaption to the regional social and eco-service contexts are less well developed. The ambition to better represent social values and eco-service values in water management provides motivation for new frameworks to be developed and tested. While there has been much progress on quantitative hydro-ecology – the quantification of how ecological health varies with alterations to the hydrological regime – the expense of monitoring and the need to generalise measurements over large regions means there is still an evolving science base. Similarly, the lack of data on case-specific relationships between hydrological metrics and social values, as well as natural variability between individuals and between stakeholder groups, means that uncertainty is inevitably high, and any serious attempt to quantify social values would require developing a stakeholder engagement and data collection process. While it is common to collect some data prior to embarking on a water management plan, the on-going engagement is likely to be essential in order to build significant knowledge.

As well as permitting regular updating of value functions and risk estimates, there is also an intrinsic value to community engagement.

In addition to mitigation of eco-service impacts through adaptive water management, human interactions in highly engineered circumstances such as mining projects require us to also consider how human interactions might augment ecological services. This can be undertaken through water delivery mechanisms, constructed wetland systems, restoration of naturally degraded landscapes. In other words, the social values attached to water not only constrain mine water use but may be influenced positively by the broader mine water management plan. Figure 1 shows a schematic developed by Bai et al (2011) for how a conventional cost-benefit analysis could be tied in with eco-services valuation metrics and interfaced with socially acceptable compensation mechanisms for a mine site. We concur with this approach to handling complexity and inter-linkages between ecological and social valuation processes but would draw attention to the support polygons at the base of the diagram which are key to formalizing such processes.

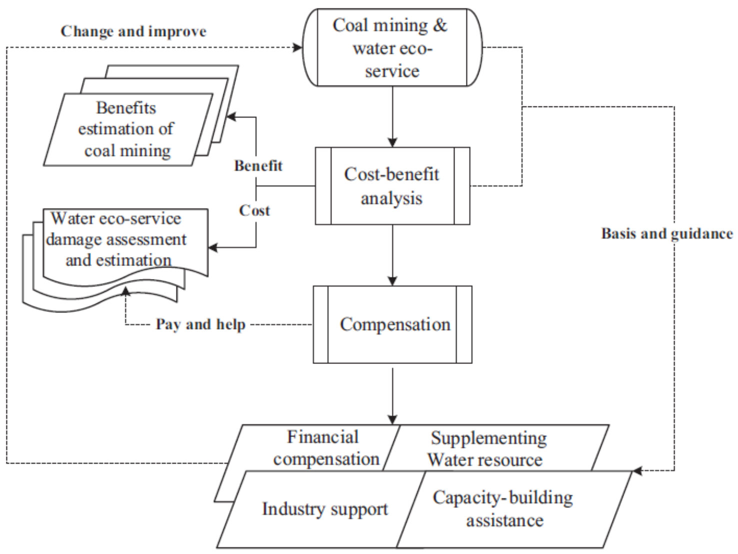

Figure 1: Eco-service framework for water valuation in a mining case (Bai et al 2011)

Proposed framework

A dynamic approach to understanding water value requires us to consider a more cyclical approach to information flow. Figure 2 shows a framework for evaluating water benefits. At the top of the diagram, the benefits derived from a water dependent system will depend on how the water is allocated. A change to the allocation of water drives a change in the quantity and potentially the quality of water (the right part of the diagram). The magnitude of these changes are estimated (at given spatial locations and times) using conventional scientific approaches (a combination of monitoring and modelling). When the quantity and/ or quality of water changes the benefits derived from that water may change (bottom of the framework diagram). This requires methods to measure the relationship between the magnitude of a benefit and the quantity and quality of water. Finally, we must have an agreed method for assessing whether there is net more or less benefit following a change in water use. This can be achieved by constructing views of the benefits which reflect the positions, opinions, aspirations and cultural attributes of those involved in deciding whether a water allocation change would be triggered.

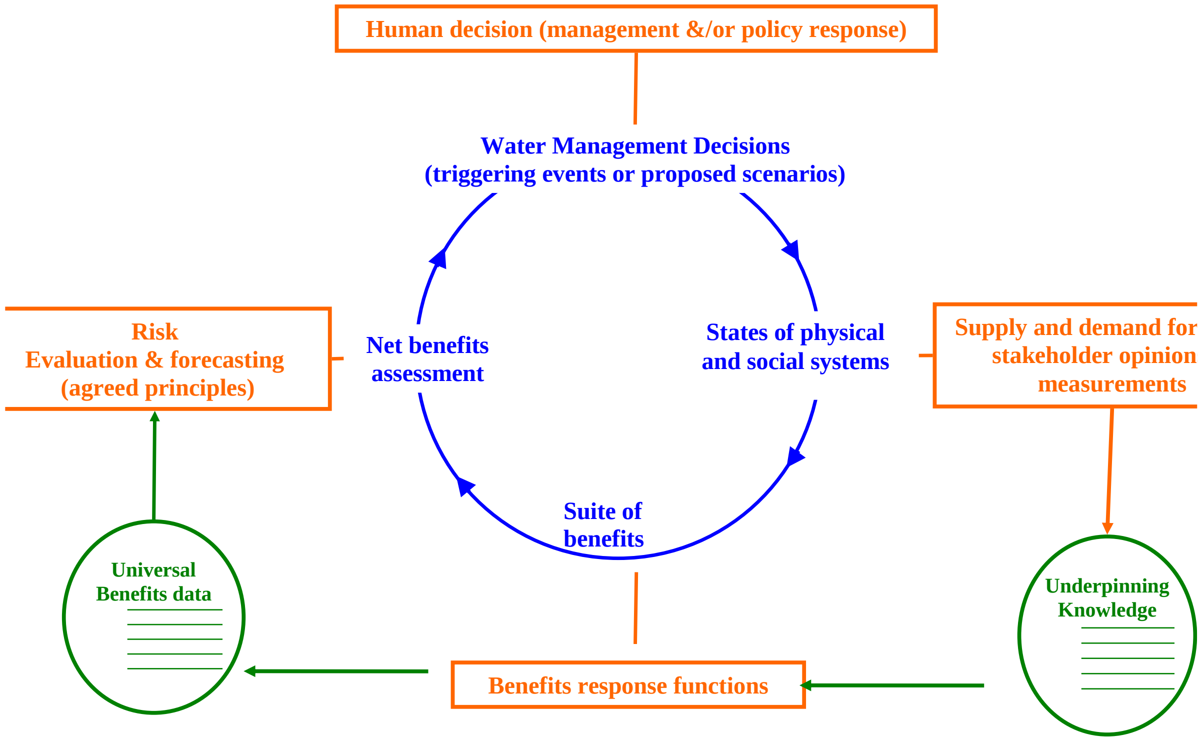

Figure 2: A Framework for Evaluating Water Benefits

Focusing on the example of the mining industry, Figure 3 presents a hypothetical example of output from a net benefits assessment and the relation with risk evaluation. For simplicity we are considering only two water uses – mine water use and social use – and the respective proportional water allocations add up to 1. An arbitrary common value score is used assuming that some weighting scheme has been defined (although this could be an uncertainty). At time t (left hand figure) uncertainty in the social valuation is high, reflecting differing opinions about the value function, as well as hydrological variability. This provides a basis for communicating risk in terms of the distribution of values for a given allocation, and the implications of being risk averse (i.e. high confidence in achieving a desired minimum value) in terms of loss of net benefits, and the potential net benefits of better precision in social valuation. The high uncertainty in social values also indicates the need for the mine to have a contingency under potential future social pressure. The right hand plot illustrates the case where opinion about social values has converged over time, reflecting an agreement that more water needs to be allocated to social uses than was previously expected, acting to reduce allocations to the mine and also to reduce net benefits. In this case the subsequent decision by the mine management may be to either positively influence the social value curve by negotiation, an offsetting investment, or to look into changing its own curve by drawing on its contingency plans or by planning new mine water management options. However, comparison of the marginal benefits illustrates the relatively large social gains to be made at small loss of value to the mine, so the company may accept a local hit for the purpose of its global outlook.

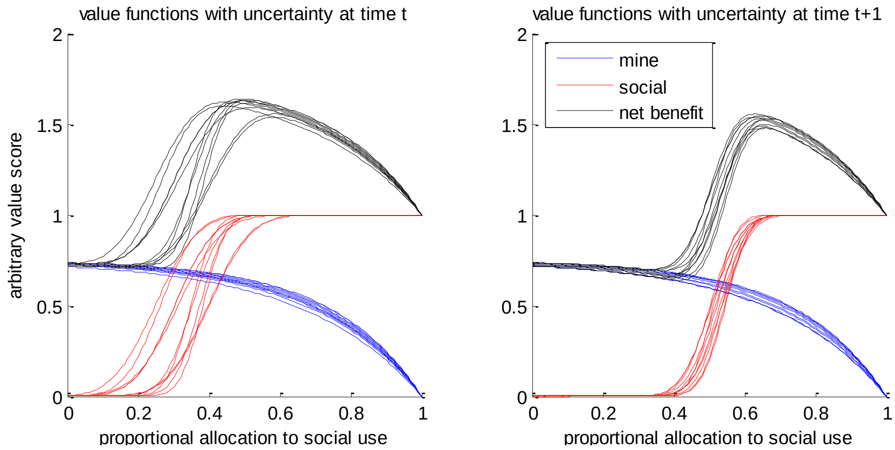

Figure 3: Hypothetical value functions showing uncertainty, trade-off and updating as part of the cyclic framework

Formalization

The final stage of operationalizing water value that encompasses the aforementioned complexity of the system necessitates a formal quantification of value. Feasibility of a dynamic method for water valuation has been evaluated through a pilot study with a small number of scientists was analysed and the results presented in a variety of ways during a project carried out by the Commonwealth Scientific Industrial Research Organization (CSIRO) in Australia by co-author of this working paper Chris Moran. These respondents identified a wide range of expected economic, environmental and social benefits, as including potential institutional and scientific benefits (see Pahl-Wostl, 2002). A consolidated list of benefit types was developed and categorized as follows:

(i) Demographic outcome
(ii) Social services
(iii) Commercial
(iv) Biodiversity
(v) Material and energy use
(vi) Aesthetics and spirituality
(vii) Land surface
(viii) Industrial
(ix) Lifestyle
(x) Tourism
(xi) Institutional functioning
(xii) Agricultural
(xiii) Scientific
(xiv) Water and aquatic
(xv) Public health
(xvi) Policy and decision making

Figure 4 shows the reported existing benefits achieved and perceived potential benefits from research conducted by the *CSIRO Water for a Healthy Community (WFHC)* research project, taking account of the differential weightings given by the respondents. The visual impression can be somewhat misleading because the variable plotted on the inside is allocated less area than those on the outside. The diagram shows the difference between the respondent's estimates of benefits achieved and potential benefits for each domain. This figures indicates that the technicians involved in the study rate the potential in policy, aquatic ecology, science, agriculture and biodiversity to be relatively high compared to public health, lifestyle etc. It is perhaps unsurprising that this group rate the potential benefits from science to be high and in a larger group sampling their opinions may be somewhat moderated both by themselves and by normalizing across a broader group. Interestingly, these technicians recognize the importance of policy – so they are not totally fixated on their own importance in achieving Water Benefits.

A follow-on use of information such as this would be to consider where an institution has skills to best make an impact. There is no reason to expect that the cost of a unit decrease in the axis would not be the same for all Domains. This cost would need to be considered before deciding where to invest resources for the best return in terms of increasing benefits achieved.

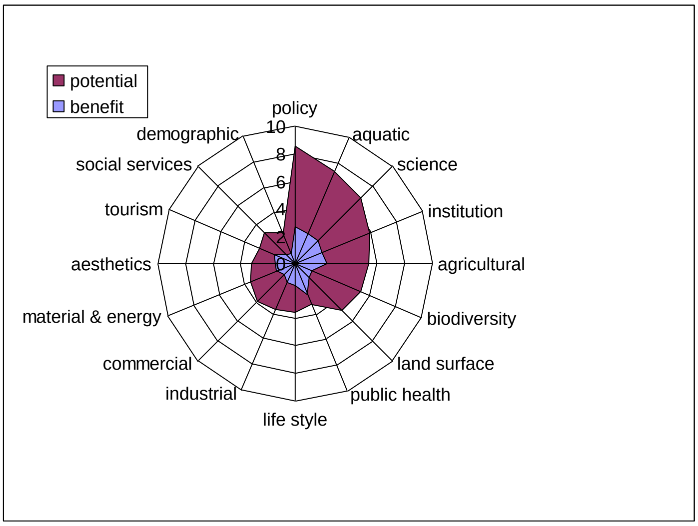

Figure 4: Spider diagram example output of reported benefits achieved

Two issues require elaboration at this point. The first is that of the reliability of the Analytical Hierarchy Process (AHP) type of approach for these purposes. If the measures vary randomly in repeated administrations the approach will be unhelpful. Fortunately we have some data on repeat measure reliability from a similar study related to the mining industry. This showed that there were stable community responses over a five year period (Nancarrow *et al.,* 1997). Nevertheless, a subset of respondents is currently undertaking a series of repeat measures over time to assess the stability of response. It must be emphasized in this regard that the measurement technique also has to be sensitive enough to register changes. It is these changes especially in the early stages of program development that may reveal not only the delivery of benefits but also the learning processes about benefits that are occurring among scientists and other stakeholders. The second issue is that of whether the number of Domains and Benefit Types are appropriate. To assess this as data is gathered some multidimensional analysis of the relationship between each of the Types will be undertaken to see if they can be reduced and thus simpler questionnaire instruments derived.

There are numerous other measurement and methodological issues that can also be examined. These include whether such benefit scales can be regarded as linear and whether gains in really low performing benefits are held in greater value than those that already have a "pass' mark and so on. In the methodology area we can ask are more sophisticated methods such as conjoint analysis appropriate?

How can satisfaction scores be included in trade-off analyses? What are the limitations of trade-off approaches in benefits analysis?

The general usefulness of any method will of course be dependent on the sample frame which is employed. Apart from the interaction with scientists initially it may be sufficient to concentrate on obtaining a stakeholder sample representing opinions of differing stakeholder and industry groups to enhance understanding of similarities and differences and to promote overall inclusiveness in terms of delivery of benefits. Such an approach could in fact make the AHP led approach applicable at a national level where peak bodies (which are particularly active in the extractive industries) examine their needs within a holistic benefits framework (Figure 5).

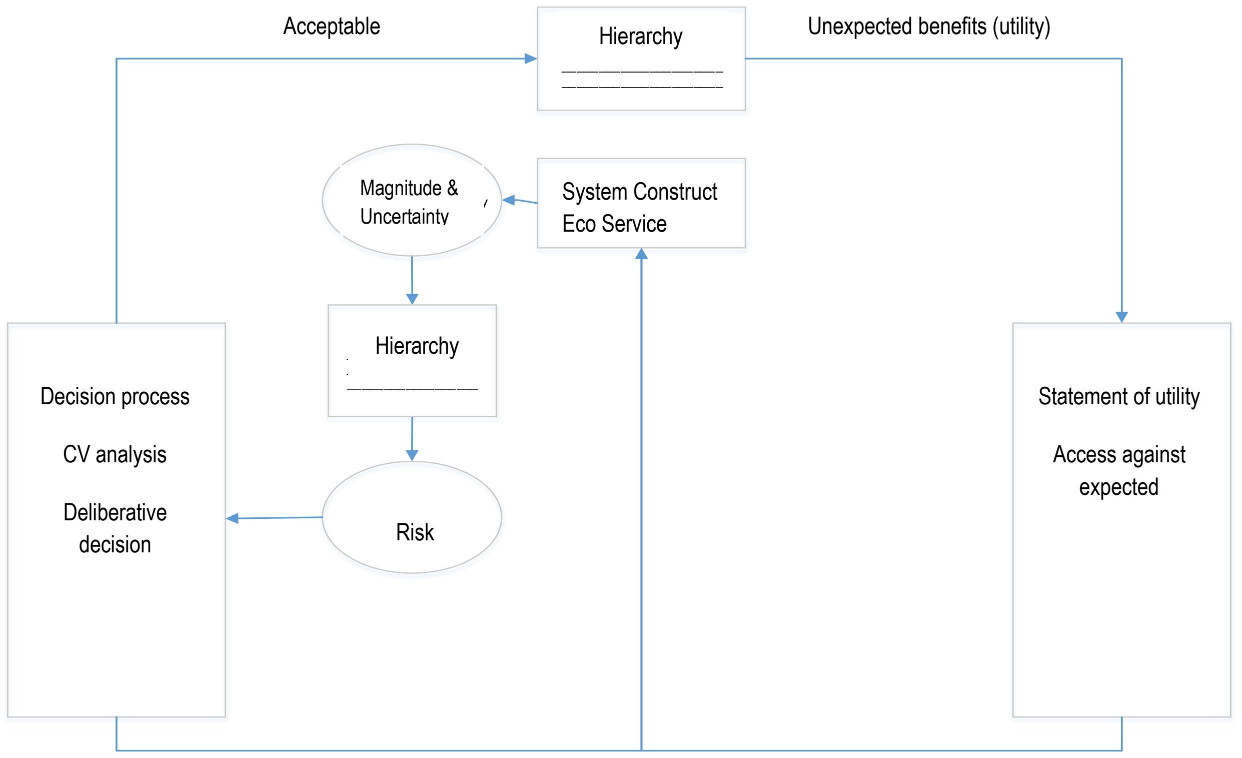

Figure 5: Synthesis framework for a dynamic approach to water valuation for mining projects.

We recognize that this is a conceptual frame which requires greater case analysis for verification and are providing this material within the context of a working paper that can spur further conversations with the scholarly community.

Conclusion

Water usage in the extractive industries is a major source of conflict since it is framed as a zero sum game where communities are pitted against companies for a finite resource. However, a dynamic and adaptive planning process that focuses on the relative marginal value of water and ways in which technology can overcome relative scarcity needs to be adopted. Given the large capital investment of mining projects, technical solutions that can account for such concerns such as designing mineral processing machinery to use untreated seawater for process deserve greater attention. Operationalizing risk within the context of mining projects that use large amounts of water and are thus highly susceptible to climatic variation needs to be accounted for more accurately on the business accounting side but also in the context of social risk of conflict. Although community perception methods can provide a valuable means of gauging public discontent, they cannot be effectively used as valuation methods for water given a high degree of variability and bias in the responses. Using a hybrid approach that incorporates eco-service valuation techniques and "water benefits" to the public through effective public communication may assist in resolving some of the social conflicts that arise from a perception of acute water scarcity. Further research is needed on how different stakeholders might view and treat multi-objective techniques for communicating water as having shared value.

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