NUMERICAL AND VERBAL DECISION ANALYSIS COMPARED IN PRACTICE

PART I: SIBERIAN AND ALASKAN TEST CASES.

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Abstract

Personal decision analysis can take one of two forms: numerical and verbal, typically associated with Western and Russian Schools, respectively. An empirical study, supported by NSF and the Russian Academy of Science, sought to compare the two, as useful aids for policy prescription. Both approaches were exercised in two live cases of Arctic natural resource development. One was a Russian government decision on where to located a major Siberian gas pipeline. The other was the design of a US regulatory procedure for approving industrial waterway projects, in the context of an Alaskan oil construction application. Part I reports on the case studies themselves. Part II attempts to draw some general conclusions on the practical strengths and weaknesses of each approach under different circumstances.

Introduction.

Issue

Anyone who has tried to apply decision analysis to a practical task knows from experience that success depends not only on the technique used, but also on the skill of the practitioner. Decision analysis is not the objective science of finding the best decision. It is a process for helping people to understand and ultimately to resolve a difficult problem, taking into account their personal values and wishes. The analyst or consultant providing the help must have mastery of decision science and decision skills. (Larichev, 1979; Raiffa, 1982).

A recent additional problem in the complex world of consulting is the proliferation of analytic techniques. It is difficult to select the appropriate decision method for a practical task, especially in an organizational context. One must take into account distinguishing features, not only of the decision method and the task, but also of organization and decision maker (decider). Nowadays there are many different decision analytical techniques developed by various schools (Keeney and Raiffa 1976, Howard et al. 1983, Brown et al. 1974, Saaty 1980, Roy 1985; Edwards and von Winterfeldt 1986, Watson and Buede 1987, Larichev 1987,1992). Together they comprise a toolbox for modern consultants helping a client to solve practical problems. But how to use this toolbox? How to select a tool appropriate to a given practical problem?

Scope of paper

We will compare here two decision analytic approaches of broad application: verbal and numerical, variants of which have been associated with Russian and Western schools represented by the authors. We now discuss how the two approaches compare, both in these cases and more generally, in terms of criteria relevant practically for complex institutional situations. We use three groups of criteria : methodological , institutional and personal.

In the present paper, the first of two parts, we describe the analytical techniques to be compared, with a brief literature review, and two case studies where both approaches were attempted, one a current decision in Western Siberia and one a retrospective case in Alaska. These case studies are presented more fully in Larichev et al. (1993), Brown et al. (1997) and Flanders et al. (1998). In a subsequent paper, we will compare the two approaches more generally.

In both cases, we limit somewhat the context for which comparison is to be made. We focus our attention to the problem of aiding a decider in *current* decision task, i.e. in a situation where the need for action has already arisen, such as a live choice between fuel transportation methods in a particular case. The related task of contingent decision aiding, i.e. of devising a decision procedure for situations not yet current, is discussed in Brown et al. (1997)

We have also focused attention on a particular area of application: natural resource development in the Arctic. Our observations relate specifically to that context, though they may generalize beyond it. There are, however, some distinctive features of typical Arctic decisions from a decision aiding point of view.

- There are few options, but many evaluation criteria .
- Several interest groups are involved (to different degrees) in the decision making process. They might be called *active parties.* Active parties may have different option evaluation criteria, and different preferences with respect to the options within criteria.
- There are large uncertainties surrounding the evaluation of options and the selection of the best one, which cannot be removed before making the decision. Human knowledge concerning many natural processes in Arctic is limited and may only be gradually expanded after many years of careful observation. Therefore the possibilities for reliable measurement of many important factors are limited.
- Consequences of options are long-term, as with many strategic decisions.

Research approach

There have been important, if not extensive, attempts to compare decision analysis tools in a laboratory setting (Timmermans,1991; Buede and Choisser,1992; Larichev et al.,1993; Olson, 1992). Essentially all involved a sample of subjects (typically students) solving the same hypothetical task using different decision tools. Laboratory studies are valuable in suggesting universal pros and cons of methods, especially psychological, which do not depend on context. But there is no assurance that these experiments give all information necessary to apply a decision method for a real decider in the real world, nor how performance is influenced by context specifics.

There have been a few limited efforts to match decision situations to decision aiding options, largely based on “expert judgment” (Brown and Ulvila 1977, Larichev 1979). Attempting to put findings on a firmer footing through any kind of controlled experimentation runs into almost insuperable limitations of cost and feasibility. A natural start would be to have a single decider use different analytic techniques on the same live problem. However, real deciders addressing important tasks, especially under exacting organizational pressures, don’t play games. They are understandable reluctant to depart much from the normal practice of using one currently favored approach, just once. In any case, the context changes, perhaps dramatically, after one approach has been tried on the problem; not to speak of the methodological nightmare of measuring what difference a decision aid might have made to the quality of decision, in a given instance (Brown, 1995).

We have tried to approach (though from afar) a controlled experiment ideal in a four year research project intended to compare qualitative and quantitative decision analysis in the context of Arctic natural resource decisions[1]. Given resource limitations, the difficult

[1] “Logical frameworks for making and justifying Arctic natural resource decisions: American and Russian approaches” National Science Foundation, Arctic Social Science Program, grant #DPP9213392.

research strategy trade-off was between getting firm findings and having them apply to more than a narrow class of problems. In any case, no more than a couple of case studies could be pursued with any thoroughness, which cannot be expected to do much more than suggest or confirm promising generalizations, or make them more concrete. The main source of our generalization hypotheses has been review of the somewhat sparse literature and the authors' substantial experience of applying their own favored techniques (see Part II)

Our research decision, in the event, was to take two very *similar* problems (land use for oil and gas production). On the basis of practical experience, we hoped that this similarity would define similar requirements for solving the problem, and therefore make it possible to observe real differences in the approaches, at least for this problem types. The chief proponent of each approach on the research team applied it to one problem, in a consulting role. To add insight to the comparison, the proponent of the *other* method applied it *off-line* (i.e. without working directly with the decider) to the same problem, as a kind of thought experiment. Even so, the comparison was potentially confounded by institutional difference (America versus Russia), the deciders' personal characteristics and whether the choice is live (one was a past decision).

Both cases involved aiding a current government choice on what to do about a potentially environmentally hazardous oil and gas construction project. One case was whether the Russian government should pipe gas from the Yamal Peninsular in Western Siberia over land or under sea. The two Russian team members applied their qualitative approach, working with the main participants. Then the American team considered how they *would have* applied their quantitative approach to the same material.

The other case was retrospective: whether American regulators, in a recent case, should have permitted an oil company to build a causeway to an oilfield in the Arctic Ocean. The American team reconstructed how they would have applied their approach, working with the very same people who had been involved. Then the Russian team briefly considered what their approach would have been.

Decision analysis techniques

Decision analysis is a broad paradigm for the systematic evaluation of alternative actions, based on all available information, as a basis for choice among them. Its purpose is normally to make decisions better and clearer. Personal decision analysis is a special case, where the choice is by an individual (rather than a collective), and the inputs are supplied by the decider (rather proposed by someone else, such as an expert). Those inputs refer to the decider's perception of the options, their consequences and their relative importance.

In one widespread decision analysis technique (Watson and Buede, 1987) the parameters describing a problem (or option evaluations according to criteria) are considered qualitatively initially. Then they are transformed into quantitative form by various means (through quantitative scales in Multiattribute Utility Analysis [Keeney and Raiffa,1976], or in the Analytic Hierarchy Process (AHP) [Saaty, 19xx], through membership function (Budescu and Wallsten,1995) and so on). Quantitative or numerical decision analysis (NDA) represents uncertainty and value in the form of numbers, and combines them in a quantitative model (derived from statistical decision theory).

Another variant of decision analysis uses only qualitative (verbal) variables, without any transformation into numbers. (Larichev, 1992, 1987, 1979). Qualitative or verbal decision analysis (VDA) relies on natural language and non-numerical categorization of the considerations in a choice. VDA has been associated with Russian decision analysis, and NDA with Western. They may draw out different aspects of the same problem. We tried in our study to compare those two quite different kinds of decision analysis..

Verbal decision analysis.

VDA tries to structure a problem by using the natural language commonly used by the decider, active parties participating in the decision process, and potential experts. The goal of structuring is to define the main factors or criteria which could be applied for the evaluation of decision options, initially considered. For each criterion a scale for the evaluation is constructed with a small number of quality grades. Some verbal expressions from the language are used to describe the quality grades located from best to worst. (For example, "No damage to the environment"; "moderate damage to the environment"; "great damage to the environment").

In the framework of VDA, special methods for comparing options have been developed (Larichev and Moshkovich,1994,1995; Berkeley et al.,1991). In each method only verbal evaluations on the criteria are used at all stages of an analysis, without transformation into quantities. Only the logical consequences of qualitative relations between verbal evaluations are used in the analysis.

Some VDA methods are adapted to problems with few options and many criteria, which typify Arctic resource problems. In one of them, to be tested here, options are compared in a qualitative, pair-wise way, identifying their relative merits and deficiencies. One seeks a condition when the advantages of one option are dominated by the advantages of the other.

First, the decision maker ranks the advantages of two options separately. Then special reference options are created which are constructed from real ones in the following way: each has the best (or worst) evaluations of two options on all criteria except for one or two on which the real advantages are given. When comparing the two reference options the decider seeks some condition when some advantages of one option are better than the advantages of the other one. If it is possible to find such compensation for all advantages of one option, the problem is solved. While comparing the two reference options, the decision maker performs a psychologically “valid” operation--the comparison of two objects which differ only on two or three criteria (Larichev, 1992).

The answers of the decider are constantly checked for contradictions. Any contradictory answers are shown to the decider, to give him a chance to correct them. Any evaluations on criteria which are not really different between options are eliminated from the analysis, thereby simplifying the comparison. [2]

Pair-wise compensation compares two options in terms of a binary relation, which can be in one of three conditions : dominance, equivalence and incomparability. When the evaluations of options are very conflicting, the operations of comparison described above do not guarantee identifying the best. The options are incomparable. This problem may be resolved by creating a new, more promising option which is better than the two given initially. The method (Berkeley et al., 1991) helps the decider to find minimum changes in the evaluations of existing options needed to create a dominating, new option. Experts are involved in this creative process and in defining the condition for implementing the new option. At every stage of decision process VDA helps the decider to reduce the decision to a more manageable size.

The positions of different active parties, and the differences between them are analyzed similarly. Promising new options are developed in the process of searching for agreement between the active parties. Special software has been developed for this kind of problem (Larichev et al., 1995; Berkeley et al.,1991). The methodological basis of VDA and related decision methods are described in Larichev (1987,1992) and Larichev and Moshkovich (1995,1996).

Numerical decision analysis

The Numerical decision analysis (NDA) paradigm is familiar to Western audiences (Watson and Buede, 1987), and needs only a few observations here. NDA essentially translates judgment and knowledge relevant to evaluating some choice into a quantitative model. Normally, it calculates a numerical value for each option, so that the best is clear. For example, a probability and utility are attached to each possible consequence of an option, and the option with the highest probability-weighted (expected) utility is logically preferred. This type of model often suits a case where uncertainty is critical.

In many environmental management decisions, the critical issue is conflicting objectives, and a different common model often works well. The competing criteria are listed along with a numerical indication of the relative importance of each. The impact of each option is scored on each criterion, and the preferred option is (usually) the one with

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[2] It can be proven (Moshkovich,1987) that the operation of the compensation is mathematically sound in the condition of preference independence (Keeney and Raiffa, 1976). A check on preference independence is the coincidence of results of comparisons for two pairs of reference options which differ only in best or worst evaluations on all criteria except two or three (which show real disadvantages)

the highest importance-weighted impact. Thus, high impact in areas of little importance balances out small impact in areas of great importance. This linear additive model is a special, but commonly applicable, case of more universally appropriate multiattribute utility theory.

An NDA approach is normally comprehensive, in the sense that it purports to characterize *all considerations* relevant to a choice, i.e. values and assessments, possibly at a highly aggregated level. For example, an importance-weighted impact model does not attempt to reduce the number of criteria *per se*, though it may group them into a few *classes*. In calculating the utility, the decision-maker can distinguish between options that might have high impact but in areas of little importance, from those in areas of very great importance but where the impact is small.

The NDA may use qualitative assessments and natural language, preparatory to developing numerical values (which may not always prove necessary). The success of an approach depends on the technical variant used: in the cases demonstrated here a graphic sum-of-boxes implementation of a linear additive model is used.

Russian Case: the Yamal Pipeline

In the early nineties, a senior Russian official had a choice between a sea and a land route for a gas pipeline on the Yamal Peninsula in the Russian Arctic. Russian decision analysts, including one author of this paper, were working with them in a consulting capacity. Below is the essence of the problem. The case and its analysis are discussed in greater detail in Larichev et al. (1993)

Background

According to expert estimations, gas extraction in Russia will decrease in several years. To compensate for this reduction and maintain gas supply to Europe, the Government of Russia has pushed the exploration of new gas fields. The most outstanding gas fields, with reserves of more than 20 trillion cubic meters (comparable to the oil reserves of Saudi Arabia), are situated on the Yamal Peninsula with severe climatic conditions and a vast expanse of permafrost soils.

The development of the Yamal gas fields had become a matter of national importance. This development has, however, many unresolved problems. An essential one is the choice between two routes connecting the gas fields to the existing gas pipeline system. During the development of the project, the idea of straightening of the pipeline, by crossing Baidaratskaya Bay, received strong support (sea route). A second, land route crosses the Yamal Peninsula to the east of the bay (land route). The decision and the start of pipeline construction had recently been postponed, partly because of the complexity of this choice.

Thus, the task was one of decision-making with two options. As we shall see this problem concerns the interests of different groups influencing the choice, unknown natural conditions, and contradictory appraisals of the alternatives on various criteria, as well as other things. For a more detailed description of this case, see Andre'eva et. al. (1995).

Options

The two options are: a sea route crossing the bay and a land route. The following characteristics distinguishing options were initially included in analysis: (1) length of the route; (2) terms of construction; (3) time for construction; (4) cost of construction; (5) impact on the environment; (6) risk of pipeline rupture accidents; (7) consequences of a pipeline rupture accidents; (8) time needed to recover from an accident; and (9) uncertain and unknown factors. Under (6), the sea route option involves unique features that could cause an accident: (a) the instability of the shore because of permafrost processes and sea ice impact; (b) the rupture of or damage to the pipeline through ice scouring; and (c) ice conditions: according to experts, iceberg sections in the Kara Sea are capable of reaching Baidaratskaya Bay.

Active parties

Before comparing the two options we must analyze who will make the choice and how. It is not likely that the choice of option will be made by a single decision-maker, because of the high cost of this project. On the contrary, several institutions and organizations, which we shall call "active parties", are taking part directly or indirectly in the decision.

They are the following: (1) a Russian joint stock company, Gasprom, which ordered the development of the project, evaluates and confirms it; (2) two project research institutes that developed the two options (each supports a different one); (3) Nadymgasprom, the operational division of Gasprom in the North Siberia region, which is responsible for the construction and exploitation of the gas pipeline system; (4) the Ministry of the Economy, which evaluates the economic considerations and economic efficiency of the future project and approves a design; (5) the Ministry for Protection of the Environment and Natural Resources, which evaluates the ecological impact and ecological security of the project and gives permit for construction; (6) the local authorities in the Yamal region, who must give their agreement to one option of the pipeline; and (7) local communities, or representatives of native peoples, whose territory and resources will be affected by the construction of a very large pipeline system.

The active parties have different motivations for their choice of an option, different orientations and contradictory opinions on the criteria. As one might expect, the groups support different options.

The application of Russian VDA to the Yamal case

Evaluating the options

The research team looked at the options through a "fog of uncertainty" that derived partly from the difficulty in measuring the options in terms of the criteria. How does one evaluate cost in a time of inflation? How does one evaluate the probability of an accident in the absence of information, reliable models, or long-term observational data? The VDA approach to problems with major measurement difficulties is to use relative, rather than absolute evaluations of the options (B. Huber, O. Huber, 1987; Yu. Oseredko et al., 1982).

The Yamal options were to cross the Baidaratskaya Bay (sea option) or to construct an additional 160 km. of pipeline (land option). We took into account only the criteria where we could find an essential difference between the options in terms of those criteria. For example, preliminary estimates were that the required construction time would be 5-7 years for both options. The unstable national economic situation can impact the starting time. Because this problem exists for both options, the analysis can ignore the problem because it is not relevant to a choice between the two.

[PUT TABLE 1 HERE]

The relevant criteria and their evaluations shown in Table 1 are:

1. Cost. The cost of crossing Baidaratskaya Bay is determined by a foreign firm which is prepared to construct this part of the pipeline. The initial approximate estimations show that it is a little bigger than the land route cost.

2. Ecological impact. Both options have a negative impact on the environment. Though the sea option contains some uncertainty, this influence is much larger for the land option: It occupies a lot of land and crosses many rivers.

3. Probability of accident. Because of unstable shores and the possibility of ice scouring the probability of an accident for the sea option is larger.

4. Consequences of the accident. An accident is usually connected with an explosion and destruction of the environment for the land option. In the case of the sea option, there would not be an explosion. The gas would rise through the water and cracks in the ice. The land option is clearly worse.

5. Reliability of gas supply. The repair of the pipeline after an accident requires much more time under the sea option, particularly since the bay is ice free for only 60-70 days per year. The sea option is clearly worse.

6. Uncertain and unknown factors. Many uncertain and unknown factors are connected with the realization of the unique project of crossing Baidaratskaya Bay. The sea option is clearly worse.

These comparative, qualitative evaluations are all we can measure practically, with any confidence: others are more difficult. How does one draw conclusions with such weak measurements?

The comparison of options.

Below is the analysis corresponding to the interests of Gasprom. As noted, VDA methods do not guarantee that pair-wise comparisons of the disadvantages of two alternatives will always lead to a clear preference; and this was the case here. The greater uncertainty and lesser reliability of gas supply for the sea option were more serious than the ecological impact from the land option. But the negative consequences of an accident under the land option B were more serious than the larger probability of an accident under the sea option. The research team, working with the decision-makers and experts, undertook the development of a new, more promising option out of the existing ones.

Developing a new variant

In this case, as in many others, the practical value of decision analysis consists not only in the comparison of existing options, but in the creative invention of new ones. A method for aiding strategic choice, ASTRIDA (Berkeley et al., 1991), permits, not only the comparison of several options, but a definition of the requirements for a new, desirable and potentially best option. In the case of incomparability, ASTRIDA proposes the modification of one existing option. That is, the method asks the question: what needs to be changed in one option to make it equal to or better than the other option? Thus, ASTRIDA defines the characteristics of a potentially best option that was not initially on the list of preferred alternatives.

A new sea route option resulted from a search for ways to change these characteristics. Discussions with experts suggested ways in which the negative aspects of the sea option could be removed:

- To eliminate the influence of seashore instability, special shafts could be constructed at a safe distance from the sea and the pipeline put through them. This construction would incur additional costs.
- To avoid damage to the pipeline from ice scouring, the pipeline can be laid in special trenches 1.5 - 2 meters deep. They would be deeper than the project plan calls for, so there will be additional costs.
- Icebergs are a very rare but dangerous event in the bay. A special observation service and a special ship to drag the iceberg away would eliminate this problem, and incur further cost of the service and ship.

Adding these features to the old sea alternative creates a new option with an element of uncertainty approximately equal (according to experts) to the traditional land option. With the development of a special repair service for the underwater tubes, the reliability of the gas supply could be made equal. Thus, no significant differences would exist between the sea and land routes, except cost and ecological impact. The cost of the new sea option, including the three extra costs, would clearly be more expensive. The land option will still create greater environmental destruction. But, now the comparison can be considered as one between higher costs and lower environmental protection. The comparison between these two factors presents the real, crucial choice to be made.

The influence on decision process

An analogous analysis was made from the positions of active parties. The development of new option was useful in this case too. With regard to the two initial options, only the positions of the local authorities and local population were clear: They supported the sea option. The new sea option was more attractive to four organizations from six. The positions of Gasprom and Ministry of the Economy, in the final, crucial choice presented above was influenced by the financial situation in Russia. The final choice has not yet been made at the time of this writing.

Due largely to difficulties in the organizational decision a final choice had not yet been made. At the start of our project, the original sea option was more attractive to the majority of Gasprom managers, with whom the final decision lay and they intended firmly to begin construction of the pipeline without delay. They had expected that our report would support this option. Instead, the report created doubts about the acceptability of this option.

In spite of the government's desire to take practical steps toward pipeline construction, several reasons appeared to postpone this decision, and it was. One was the uncertain and unknown factors shown by the report. During the delay, new investigations, prompted by the report, were undertaken on the problem of seashore instability, which demonstrated the report’s influence.

Recently the beginning of Yamal pipeline construction was postponed again for several reasons, then most important of which appears to be the uncertainty surrounding the conditions of construction. Unfortunately, this uncertainty cannot be completely removed. The next decision, even though it will be based on new data, will still have to be under conditions of uncertainty.

NDA approach to Yamal case

We gave brief consideration to how the same problem could be addressed with NDA, instead of VDA, without involving any of the active parties. Larichev et al. (1993), for example, present a hypothetical “importance-weighted impact” model based on the same set of criteria--cost, ecology, accident risk, etc.

The evaluation scales for each criterion were from 0 to -100, where 0 is no impact of any kind, and -100 is the worst plausible impact. Each criterion impact was weighted by its evaluated importance. On one illustrative set of impact and importance inputs, proposed by a Russian research team member, the importance-weighted impact of the land route -20 and of the sea route -15. Thus, that evaluator would appear to favor the sea route. (This was largely because she considered ecology by far the most important criteria, and assessed the land route to have a significantly larger ecological impact.)

The effect of alternative inputs by the same or other evaluators could be readily calculated. The impact and importance inputs might be supplied separately; for example, impacts from relevant technical experts, and importance from any responsible citizen or government official. VDA, at least as applied here, appears to be tied more tightly to the specific active parties involved.

American case: Niakuk Causeway

Background

In the late 80s, the oil company BP sought permission from government regulators to develop an oil-field on Niakuk Island 1.25 miles off the Arctic Beauport Sea shore, with a gravel causeway to pipe the oil ashore. It represented several environmental hazards, including disruption of fish habitat (and consequently local fisheries), and degradation of water quality. Other means of transporting the oil were available to BP, notably slant drilling (directional drilling from the shore, which did not affect the sea directly). However, they were more expensive, and might make the development of the oilfield unprofitable. If it were abandoned by BP, a significant source of domestic oil would be lost to the US, with implications for its energy independence, a national policy objective.

The major disadvantages to the causeway over slant drilling were in impacts on anadromous fish, ecosystem quality and pro-wilderness public sentiment. It had advantages in construction employment and a precedent effect for the oil industry. The precedent effect means that causeways would continue to be an available option for the industry in oil field development.

The regulatory regime to which the permitting decision was to conform consisted of numerous sprawling, uncoordinated state and federal statutes, administered, largely in isolation, by different government agencies. They required that a permissible project must not exceed certain levels of different kinds of environmental damage, and also that it should "serve the public interest". There were three salient permitting options: no oil field, one with and one without a causeway -- i.e., using slant drilling.

As required, BP submitted a detailed permit application in a loosely structured format of its own choosing, consisting mainly of qualitative arguments. As lead regulatory agency, the Alaska District of the Corps of Engineers (CoE) issued a permit to develop the oil-field, but without the causeway (on the grounds that it failed a statutory fish habitat standard). After some national controversy, following a BP appeal to the Republican Administration, Corps headquarters in Washington rescinded the findings, pending additional data. Democratic Congress conducted hearings on possible improper political influence on that rescission. BP eventually opted to develop the field using slant drilling. It proved profitable (although a, major BP had argument had been that slant drilling would make the project uneconomic, and an energy resource important to national security would be lost).

Application of American NDA in Niakuk case

The research team met with the CoE regulatory team in Alaska, four years after the events described, to develop an NDA-oriented aid that *could have* been used to support the initial local permitting decision, or the subsequent challenges to it. We worked with the same government and industrial institutions, and the key specific individuals within them, who had been originally involved. Each party was presented with an NDA-type analysis, to be treated *as if* BP had submitted it in support of their application. The analysis was intended to faithfully reflect whatever knowledge and thinking was available at the time (without attempting to improve them). The sought-for contribution was to find the best way to *communicate* the likely consequences of each option and also to determine if those consequences were acceptable.

We considered three alternative formats within a "multiattribute utility" NDA paradigm: qualitative, graphic and numerical. In each case all consequences--economic, environmental, strategic, etc.--were considered, no matter how intangible. The impacts on the criteria were based only on knowledge available at the time. Option evaluation was based both on acceptable thresholds for each impact and compensation among them.

We assumed that the industry applicant would make whatever case he normally would, but within this format; and the regulator would second-guess the applicant, again as he/she normally would. The intent was that this format could lead to a sounder or more easily reviewed decision.

Qualitative representation

Although expressed without numbers, the initial organization of available knowledge and judgment had an implicitly quantitative structure, with little adaptation needed for NDA. This was an attempt to bypass the common resistance to numerical representations of assessment and value, which was a central motivation for VDA (illustrated above). The NDA was presented first to the deciding CoE group, with the plausible expectation it would communicate all that was needed to organize their thinking about the problem and make a choice, without any explicit quantification.

[FIGURE 1 - QUAL FORMAT]

The first two columns of figure 3 list consequences, grouped by who is mainly affected. Columns 3 and 4 predict what the consequences of each option will be. They show that some impacts are better with slant drilling (very low impact on fish population) and some are better with causeway (water quality). Column 5 clarifies the meaning of the levels of impact by defining “very high impact”. Column 6 indicates what level is “unacceptable” (according to some regulatory statute). If those limits were the controlling principle, the causeway would be unacceptable on the grounds of fish population impact alone.

On the other hand, if compensation among impacts were allowed (contrary to literal interpretation of current regulation), the preferred option depends on which impact is more important, shown in the last column. In practice a regulator may stretch interpretation of thresholds to take trade-offs into account. This qualitative format may help him make the necessary evaluation informally. The CoE regulators found that it did help, but the implied permitting decision did not “jump out” at them, and it did not provide a readily communicated justification to present to critics and other third parties. (A more effective variant of the qualitative format might have worked better, of course).

Graphic format

[FIGURE 2: GRAPHIC FORMAT]

We proceeded to explicit quantification, but in a graphic form, again intended to avoid common “numerophobia”. Figure 2 expresses essentially all the same judgments as Figure 1, but quantitatively, in a graphic format, and more precisely, in the form of rectangles. Level of impact is represented by the width of the box, corresponding to the net effect of an option on a given criterion.. For example, in the first row, "fish population", "hi" impact is replaced by a bar about 3/4 of the width of that cell. That corresponds to a "very high" impact, interpreted above as "10 years to restore". (Equivalently, that impact could be given a numerical score on a scale from 0-100, correspondingly defined).

The height of the box represents importance. Thus the most important environmental dimensions (regardless of the impact of any particular option) are animal population, endangered species and water quality.

The two dimensions of importance of a criterion, and impact of an option on it, are combined in a box whose area is the product of impact and importance. This area gives an indication of the net effect of an option's impact on that criterion. Thus, the causeway has a significant effect via fish population (a shown by a large box) because the size of the impact is large and the importance is substantial (but not as high as some others.)
By comparing the total area of boxes favoring causeway (shown black) with those favoring slant drilling (gray), we have an indication of which option is preferred. Since the causeway area is clearly (by eye) much larger than the slant drilling area, it should be preferred—at least if the impact and importance inputs are accepted (and if the “sums-of-products’ evaluation is an acceptable approximation to more rigorous MUA, which it

usually is).

One can see, also by eye, that the greater area favoring causeway is due largely to the high impact and high importance attached to the three measures of industry profitability. This what one might accept if this were a submission from the oil company applicant. The regulator does not have to accept that, of course, and he can substitute his own assessments, when coming to a decision.

Numerical format

Although the same assessments can be communicated by numbers, these graphic representations can be better for communication. Whereas the numbers themselves may be difficult for a lay person to understand, the relative shape and size of the different boxes can convey the important differences. An overall look at the boxes can give a fairly good picture of which option is preferred. Finally, the boxes may avoid conveying a false precision. Whereas the decision-maker may not intend an implied precision of say an impact of 35 (as opposed to 34 or 36), the box diagram does not necessary convey anything but a fairly rough estimate.

On the other hand, discussion of the sides of the boxes, in order to second-guess the judgmental inputs or test the sensitivity of conclusions to them, often involved converting them into some kind of numerical form. (E.g. " I think fish habitat is about ¾ as important as water quality"). In the final recapitulation of the decision deliberations focused on the graphic format , with a corresponding table of numbers held available for inspection as needed for clarification and refinement.

Re-analysis with authoritative input.

The above model, in its three alternative formats, was based on the analysts' preliminary perception of considerations considered by the regulatory staff at the Corps of Engineers in Alaska, who had been responsible for the original decision. It was refined to conform more exactly to their thinking by reviewing the structure and content in detail with the same people.

The final analysis included some redefinition of attributes, and numbers for predicted impacts and importance weights which reflected their recollection of the knowledge and judgments they used at the time. This analysis did, in fact, confirm the decision they had made: to permit development of the Niakuk oil-field, but on condition that an alternative to a causeway be used to transport the oil (e.g. slant drilling).

These more authoritative inputs are sensitive, in view of the controversial circumstances of the case (which has still not entirely died down!). They have not been released for publication, but do not affect the demonstration of the approach, nor its main practical implications in this case.

Potential technical improvements in NDA decision methodology

Comparison of NDA and VDA approaches must take into account the form each will take when mature, i.e. after improvements have been adopted. A number were suggested by this NDA exercise. For example, we would no longer try to include the "statutory threshold" in the same presentation, but would restrict ourselves to addressing only the "public interest" issue there.

A major issue, NOT captured explicitly by any of the formats, and surfacing repeatedly in decision deliberations based on them, is uncertainty. This was the greatest stumbling block to getting the regulators to comprehend all the critical considerations in the decision, from looking at a single chart. The impact predictions are all represented by a single qualitative or quantitative entry, regardless of how suspect the assessment may be. In theory, those "point" estimates are adjusted to account for uncertainty. Decider can always discount the value of very uncertain impacts, by making the estimate conservative. However, it may be helpful to register the uncertainty explicitly, to make clear to any observer where the "net" impact estimate came from. One way to handle this would be to shade the boxes darker for more certain estimates, possibly with some attempt to the implied uncertainty in the summed areas. Implementation would be by no means trivial and we have not yet put that idea into practice.

Influence on decision process

After several iterations at constructing a sum-of-boxes chart, to reflect most closely the key decider's judgments at the time the permitting decision had been made, he expressed satisfaction that it did indeed capture the considerations he had in mind at the time, and provided a convenient vehicle for communicating and, if necessary reconsidering, his ruling on the permit.

We can only surmise what the impact of such an analysis would have had on the politically charged sequence of events that in fact occurred. This is a major drawback of a retrospective case. However, a measure of the reaction of the intended primary beneficiaries – the CoE regulators – is that they are using the same approach (with our guidance) on a comparable current permitting decision: whether BP should be allowed to bury an oil pipeline, including at river crossings. The outcome of that exercise is not yet known.

VDA approach to Niakuk case

The Russian team gave a little thought to how VDA qualitative analysis of the Niakuk decision might have proceeded. Their analysis singled out 8 critical criterion variables.(Table 2). One more option was taken having the evaluations of CoE : a sub-sea pipeline below the ice scour level of the ocean's floor, was included. Of the criteria, one is considered to show no difference among the options: social consequences. Qualitative analysis does not attempt to draw out every single point of difference in detail. It seeks only the "broad brush strokes."

[TABLE 2]

Because of the threshold for anadromous fish, incorporated into the impact on the environment, the causeway is considered unacceptable. It is eliminated as an option. The question then arises, is there another option that could be used as a better alternative to slant drilling? The major differences between the two remaining options are found in the cost of construction, the number of uncertain factors and the reliability of the pipeline. The buried pipeline has disadvantages in its extra cost and its reliability. Slant drilling is disadvantageous in its many uncertain factors, which may block its effective realization. According to BP evaluations given at the moment of choice, slant drilling could not give enough profit.

At this point, the qualitative analysis would need to know whether the disadvantages of the buried pipeline could be made at least equal to slant drilling. The buried pipeline, according to the analysis has a number of advantages over the alternative. Reducing the cost of construction or increasing the reliability to the level of slant drilling, might make a buried pipeline a better alternative. In any case, the analysis can aid the problem analysis by showing where the major differences lie.

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In Part II of this series, we generalize from and beyond these two cases to review major differences between verbal and numerical decision analysis, and the circumstances under which each is favored.

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[REFS INCOMPLETE]