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Comparison of the Direct Scoring Method and Multi-Criteria Decision Analysis for Dredged Material Management Decision Making

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PURPOSE: Decision making for complex environmental problems such as dredged material management can become overwhelming, especially when dealing with multiple conflicting objectives, alternatives, and stakeholders. A process is needed to organize the massive amount of information into a usable form. The purpose of this document is to show the disadvantages of using the direct scoring method for dredged material management decision making as it relates to dredged material placement and its role within the U.S. Army Corps of Engineers (USACE). Multi-criteria decision analysis (MCDA) is an approach that is readily available and is more suitable for dredging and other Corps projects. This will be discussed as a preferred alternative to the direct scoring method.

BACKGROUND: Historically, USACE has used the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (also called Principles and Guidelines) (USACE 1983), the National Economic Development, the Environmental Operating Principles (USACE 2003), and specifically the direct scoring method as approaches for planning and decision making (Kiker et al. 2005). Such approaches are single measure or criterion approaches (e.g., cost-benefit analysis) where decisions are based on a comparison of alternatives using one or two factors. These methods have inherent disadvantages because factors such as cost, impacts, and benefits are rarely accurately known; this leads to a decision process that is often unsatisfactory to stakeholders. There remains a call for a systematic strategy to implement new directional methods within specific USACE mission areas such as navigation (Kiker et al. 2005).

The direct scoring method was originally called the “Borda” method (Pomerol and Barba-Romero 2000). This decision method dates to the 18th century and is named for Chevalier Jean-Charles de Borda, a French scientist. It is widely used in ranking sports competitions (e.g., the Tour de France, World Motor Racing Championships, and football polls) and is also used in scoring track meets or selecting winners in music or television award shows. This method sums rankings collected by a given alternative relative to each criterion (Pomerol and Barba-Romero 2000).

When projects are multi-faceted and complex, a systematic process must be used to organize large amounts of information in a manner beneficial to pre- and post-phase decision makers. MCDA dates to the 1970’s and is described as a set of tools and techniques that describe objectives, alternatives, and uncertainties within a framework designed to guide complex decisions (Keeney and Raiffa 1976). The MCDA process has been widely used for management of environmental projects, which contain complex problems. Such complex problems are often referred

to as 'wicked' problems, problems having no right answers (Yoe 2002). Environmental projects such as those prioritizing dredged material disposal sites, ecosystem restoration sites, and lock and dam maintenance projects can all seem complex when multiple objectives, alternatives, and stakeholders collide. MCDA leads decisions and advances such projects. Other agencies, such as the U.S. Environmental Protection Agency and the U.S. Department of Energy have successfully used MCDA in a number of their projects (Kiker et al. 2005). MCDA works well in environments with multiple stakeholders balancing multiple alternatives for achieving numerous objectives. The MCDA process involves the following steps and is illustrated in Figure 1:

- Explicitly define problems and objectives.
- List and describe alternatives for achieving objectives.
- Define criteria (often called objectives, attributes, or performance indicators) to measure performance of alternatives.
- Design and execute studies to collect data to evaluate decision criteria.
- Populate a decision matrix of alternatives versus decision criteria.
- Elicit appropriate weightings for criteria.
- Synthesize criteria, assign weights to rank alternatives, communicate results with stakeholders.
- Decision-makers make decisions with stakeholder input and guided by MCDA results.

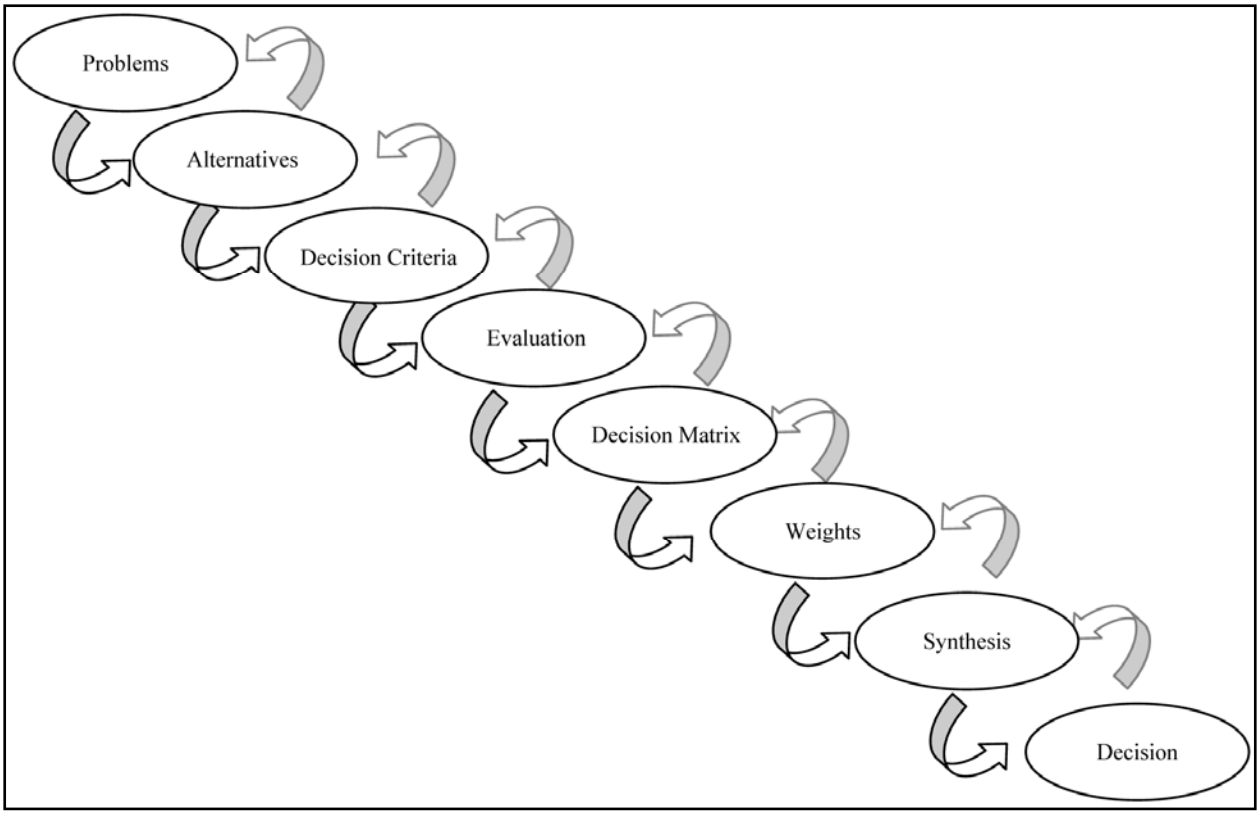

Figure 1. The iterative steps of MCDA (from Yoe (2002)).

DIRECT SCORING METHOD: The direct scoring method asks decision-makers to specify numerical values for the expected performance of decision alternatives measured against multiple objectives. A commonly used example of the direct scoring method includes point allocation used for scoring sporting events (Pomerol and Barba-Romero 2000). This method assigns the scores obtained by a given alternative with different maximum points available for each criterion. Then, all the points obtained for all the criteria for each of the alternatives are summed to produce a ranking of the alternatives. This method is frequently applied to evaluate environmental problems because it is the easiest and simplest method to use (Yoe 2002). Unfortunately, the method can yield biased and misleading results. Table 1 illustrates this point.

Table 1. Alternatives and Screening Criteria for a Hypothetical Dredging Project Using the Direct Scoring Method.

Upland Disposal Site	Capacity (1-5)	Proximity (1-5)	Real Estate (1-5)	Regulatory Issues (1-5)	Total Score
Site 1	2	1	4	3	10
Site 2	3	4	1	1	9
Site 3	1	5	3	3	12
Site 4	5	1	3	3	12
Site 5	4	2	3	1	10

A hypothetical yet realistic example is provided to illustrate the inherent weaknesses of the direct scoring method. The criteria in this example are to evaluate upland disposal sites for dredged material. There are five possible alternatives and five criteria (Table 1). Scores were assigned for each criterion ranging from 1 (best) to 5 (worst) and the scores from each criterion were summed to rank the alternatives (minimum possible score = 5). Each upland disposal site is evaluated for all five screening criteria. The optimal decision would be the lowest total scored alternative. Alternatives in the matrix are implied to have the same ranking if they have the same total score, even though the total scores may be derived in very different ways. The criteria are described in more detail below.

Capacity. Each upland disposal site will be evaluated for capacity. It is estimated that at a maximum, 4 million yd^3 of material will require disposal at an upland disposal site. The likely need is approximately 2 million yd^3. One time use is estimated to require a minimum capacity of 200,000 yd^3. Most of the material is anticipated to be of sufficient quality to be placed in the upland disposal site. Descriptions are provided for scores of 1-5 as follows:

1. Site has capacity in excess of 4 million yd^3, sufficient for entire 20-year life of the project.
2. Site has capacity between 2 million and 4 million yd^3, likely sufficient for the entire 20-year life of the project.
3. Site has capacity between 500,000 and 2 million yd^3, sufficient for more than one use but likely insufficient capacity for the 20-year life of the project.
4. Site has between 200,000 and 500, 000 yd^3 capacity, sufficient for one-time use as a disposal site.

5. Site has less than 200,000 yd^3 capacity, insufficient for one-time use as a disposal site.

Proximity. This measure evaluates the proximity of the disposal site to the navigation channel. It also addresses rehandling requirements. The further the distance from the navigation channel to the disposal site, the higher the disposal cost. The rehandling of material may also double the cost of disposal and adds to environmental concerns. Descriptions are provided for scores 1-5 as follows:

1. Site is adjacent to the navigation channel and dredged material does not require rehandling.
2. Off-load site is within 2 miles of the navigation channel. Hopper dredge pump-out is feasible, but pipe-line dredging is not feasible.
3. Off-load site is within 10 miles of the navigation channel. Clamshell dredging is assumed and the rehandling site is also the final disposal location of dredged material.
4. Off-load site is within 10 miles of the navigation channel. Clamshell dredging is assumed, rehandling of dredged material is required, and the final disposal site is within the greater metropolitan area.
5. Off-load site is further than 10 miles from the navigation channel. Clamshell dredging is assumed, rehandling of dredged material is required, and the final disposal site is located outside the greater metropolitan area.

Real Estate. Real estate examines ownership issues related to the disposal site. The port is responsible for the upland disposal of dredged material and as such is responsible for procuring upland disposal sites. Descriptions are provided for scores of 1-5 as follows:

1. The port owns the disposal site.
2. The port does not own the site but has permission to use the site for the disposal of dredged material.
3. The port does not own the site, does not have permission to use the site for the disposal of dredged material, but is likely to obtain permission to use the site for the disposal of dredged material.
4. The port does not own the site, does not have permission to use the site for the disposal of dredged material, and obtaining permission to use the site for the disposal of dredged material is uncertain.
5. The site is privately held and the owner is unwilling to sell it to the port or allow the port to use it. Condemnation is required to obtain the site.

Regulatory Issues. This screening measure evaluates regulatory issues and permitting regarding the upland disposal site. Descriptions are provided for scores of 1-5 as follows:

1. No regulatory issues regarding upland disposal site; regulatory agencies are likely to support use of upland disposal site; site is already permitted for the disposal of dredged material.
2. Some regulatory issues regarding upland disposal site; regulatory agencies are likely to support use of upland disposal site; no permit for the site. Obtaining a permit for the disposal of dredged material is not likely to be an issue.

3. Some regulatory issues regarding upland disposal site; regulatory agencies are neutral on use of channel maintenance proposal; no permit for the site. Obtaining a permit for the disposal of dredged material may be an issue.
4. Some regulatory issues regarding channel maintenance proposal; regulatory agencies are opposed to use of upland disposal site: no permit for the site. Obtaining a permit for the disposal of dredged material will be difficult.
5. Significant regulatory issues regarding upland disposal site; regulatory agencies are strongly opposed to use of upland disposal site. Change of land use regulations is required.

There are three main concerns with this approach: lack of weighting, categorical scores, and subjectivity. An initial concern is that the scoring in this scenario implies that, for example, the capacity and proximity criteria are equally important by having the same weight for each of the two alternatives that received a score of 12 (i.e., sites 3 and 4). This is because the increase in satisfaction from swinging capacity from the worst score (site 3) to the best score (site 4) is equally as valued an improvement as swinging from worst (site 4) to best (site 3) in proximity. So by using the direct scoring method it is not possible to distinguish performance within a criterion from differences in relative importance among criteria. This demonstrates the inherent bias associated with using the direct scoring method. A second concern is that the decision maker loses information by using this approach. For example, the capacity criterion uses a discrete scale, resulting in loss of much needed information. Two alternatives with capacities of 3.9 M yd^3 and 4.1 M yd^3 would have different scores although there is no substantive difference in capacity between the two alternative sites. This is why continuous scales for criteria are preferred when making informed decisions. Furthermore, people have attitudes towards risk. Several case studies and empirical research have shown that the attitude of decision-makers is often risk averse because they want to achieve their objectives with more certainty (Eeckhoudt et al. 2000). Less variance is usually preferred to more. However, the direct scoring method cannot represent decision-maker's attitudes.

MCDA: Due to the inherent shortcomings of the direct scoring method, it becomes clear that a more transparent and reproducible approach should be used to help determine the most appropriate upland disposal site alternatives in the hypothetical example. Criteria such as human impacts, ecological impacts, and social preferences should also be added because these criteria also can significantly affect the dredging operation decision and are important to stakeholders. Cost and other scores should be continuous, rather than discrete, values. Weights (relative importance) affect the decision outcome; therefore, weights should be elicited in an appropriate manner. A discussion of how these tasks can be accomplished using MCDA follows.

A hypothetical example for MCDA: The steps of the MCDA process relevant to this discussion are to (1) identify the fundamental objectives and alternatives; (2) quantify the impact of the alternatives on the stated fundamental objectives to be achieved; (3) examine trade-offs; and (4) elicit and apply the value judgments that result in a ranking of alternatives. A detailed procedure for MCDA is described in Kim and Bridges (2006). While these elements are presented in the form of a sequential list, iterations of these steps may be necessary. As a part of this process it is critical to determine who the stakeholders and participants in the decision process are, since the MCDA process depends on an assessment of their beliefs and preferences in order to

establish the objectives to be achieved, the alternatives to be examined, and the weights that reflect the participants' priorities among these objectives (Kiker et al. 2005). Unlike the direct scoring method, MCDA separates judgments of scaling (i.e., relative performance, $u_i(x_i^a)$ of alternatives x_i within a criterion i, which often are legitimately made by scientists or experts) from judgments of weighting/tradeoffs w_i, which should be made by policy makers, stakeholders, or the public. The direct scoring method confounds the two judgments, making their separation difficult. Ideally, x_i is quantitative, but doesn't have to be. But it has to be unambiguous for proper valuation (Keeney and Raiffa 1976). Some examples of measurable indices (along with definitions) are provided as they may fit into the hypothetical upland disposal site selection for dredged material example below.

Three main criteria were identified: cost, environmental, and social (Figure 2). Each main criterion is divided into sub-criteria. The cost criterion is divided into construction, capacity to meet the 20-year demand, and access distance. The environmental criterion considers two sub-criteria to minimize human health and ecological impact. Including an environmental criterion is a very useful component of the decision matrix in such hypothetical dredging projects and will strengthen the result. A measurable index for this criterion would strengthen the result further because this might be one of the most important criteria from the stakeholders' perspective. The social and legal criterion is represented by one sub-criterion: regulatory issues. Most, but not all, of the proposed sub-criteria are represented by a measurable index (Table 2). The proposed criteria are described in more detail below.

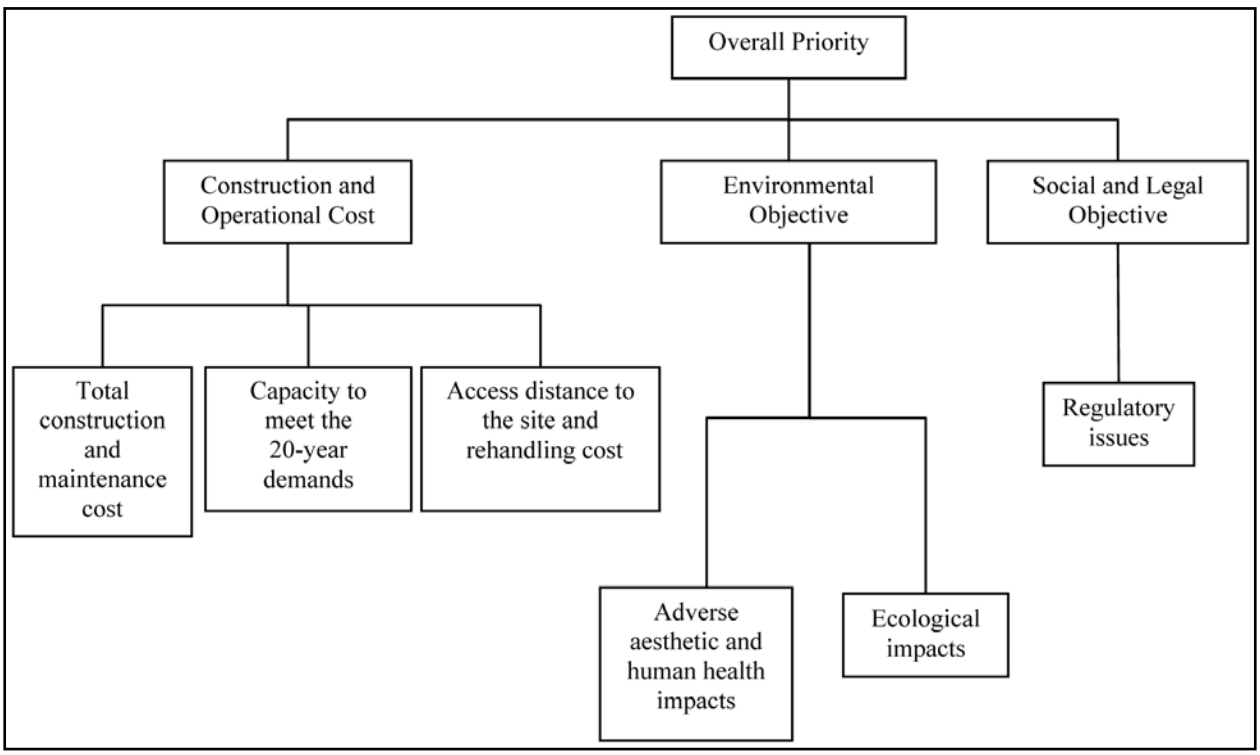

Figure 2. Hierarchical objectives for alternative disposal site.

Table 2. Proposed criteria matrix for the hypothetical disposal site.

Criterion	Measurable Index (Units)	Range	
		Best	Worst
Minimize total construction and maintenance cost	Total cost in millions ($)	2	15
Provide adequate capacity to meet the 20-year demands	Capacity in cubic yards (million yd^3)	4	0.2
Proximity: minimize the access distance to the site and rehandling cost	Transportation cost and rehandling cost depending on dredging methods (i.e., hopper and pipe, and clam shell) ($/$yd^3$)	15	35
Minimize adverse aesthetic impact	Total distance with ¼ mile from the site to highway times the number of cars at the site per day	500	2000
Minimize ecological impacts	Subjective scale [0-5]	0	5
Minimize regulatory issues	Subjective scale [1-5]	1	5

Descriptions of the proposed criteria are as follows:

1. Minimize total construction and maintenance cost. This cost includes the total construction and maintenance cost for the entire 20-year planning window.

2. Provide adequate capacity to meet the 20-year demands. This criterion measures site capacity adequacy. The primary difference here is this criterion is now measured on a continuous rather than discrete scale. It is estimated that at a maximum, 4 million yd^3 of material will require disposal at the upland disposal site. The likely need is approximately 2 million yd^3. One-time use is estimated to require a minimum capacity of 200,000 yd^3.

3. Proximity. This criterion measures the cost associated with transportation and rehandling due to proximity from dredging site to disposal site.[1] This criterion can be measured in units of dollars per cubic yard.

4. Minimize adverse aesthetic impact. This criterion measures adverse aesthetic impacts measured by total distance with ¼ mile from the site to highway times the number of cars at the site per day.

5. Minimize ecological impact of the site. This criterion measures the ecological impact, measured by subjective judgment on a scale of 0 to 5, with 5 being worst.

   - 0 – No damage to species of plants or wildlife that are desirable, unique, and biologically sensitive.

[1] The selection of disposal site depends on which dredging methods are used. Thus, the optimal decision is affected by temporal and spatial boundaries. This example assumes any alternative for each site is already linked with an appropriate dredging method. For example, if the disposal site is within 2 miles of the navigation channel, hopper dredge pump-out method is selected and pipe-line dredging is considered not feasible.

- 1– Damage to individuals of a desirable species or habitat, but they are common throughout the region.
- 2 – Damage to individuals of biological sensitive species, but this does not threaten their regional abundance.
- 3 – Damage to individuals of threatened endangered species (TES), but does not threaten their regional abundance.
- 4 – Damage to individual of TES of their habitats, but it does not threaten their regional abundance.
- 5 – Damage to individual of TES and threatens their regional abundance.

6. Regulatory Issues. This screening measure evaluates regulatory issues and permitting regarding the upland disposal site. Descriptions are provided for scores of 1-5 as follows:

- 1 – No regulatory issues regarding upland disposal site; regulatory agencies are likely to support use of upland disposal site; site is already permitted for the disposal of dredged material.
- 2 – Some regulatory issues regarding upland disposal site; regulatory agencies are likely to support use of upland disposal site; no permit for the site. Obtaining a permit for the disposal of dredged material is not likely to be an issue.
- 3 – Some regulatory issues regarding upland disposal site; regulatory agencies are neutral on use of channel maintenance proposal; no permit for the site. Obtaining a permit for the disposal of dredged material may be an issue.
- 4 – Some regulatory issues regarding channel maintenance proposal; regulatory agencies are opposed to use of upland disposal site: no permit for the site. Obtaining a permit for the disposal of dredged material will be difficult.
- 5 – Significant regulatory issues regarding upland disposal site; regulatory agencies are strongly opposed to use of upland disposal site. Change of land use regulations is required.

Once objectives are defined, the performance of each alternative in meeting each criterion is characterized along with the uncertainties associated with that performance. The quantification of impact should represent the performance of each alternative in respect to each criterion. The quantification can be predicted by historical data, expert judgment, or a mathematical model, which can be represented by either qualitative or quantitative information. When such information is not available, a mathematical model can be used to predict the possible effects on each of the criteria. Table 3 shows the hypothetical effectiveness for each criterion given any alternative. Unlike the direct scoring method, most of the proposed criteria are represented by a continuous scale (in millions of dollars), not on a discrete scale (1-5). A priori estimates or predictions of performance of each alternative are then made relative to the selected decision criteria (the criteria of each alternative).

Once the weight showing the performance of each alternative is developed, the relative importance for each criterion needs to be considered. MCDA makes use of both criteria scores and weights to develop a ranking of alternatives. Each alternative is scored for each decision criterion in a manner similar to the direct scoring method. In the case of MCDA, utility functions are used in the scoring process to reflect how degrees of satisfaction change as the score for a particular

criterion changes. This allows the decision maker and stakeholders to translate non-monetary and monetary values into a single index, which allows measurement of the effectiveness of an alternative so that each alternative can be ranked. The functions translate the physical criterion into a measure of value, and are scaled between 0 and 1, representing the worst and best values, respectively. As an example, a decision maker would develop a value function for turbidity by answering the question, "What aesthetic level is halfway between 300 (i.e., most desirable value with 1 in the function) and 2000 (i.e., worst value, 0 in the function)?" Each value function can take various shapes: linear, nonlinear, or stepwise. Several methods such as the certainty-equivalent technique and the probability-equivalent technique can be applied to develop utility functions (Keeney and Raiffa 1976; Clemen 1996). Through the use of utility/value functions, diverse criteria are converted into one common dimensionless scale (usually 0-1) of utility or value. The overall goal of decision makers in this process is to maximize utility/value (Kiker et al. 2005).

Table 3. Effectiveness of each alternative for all criteria.

Site	Minimize total construction and maintenance cost	Provide adequate capacity to meet 20-year demands	Proximity: minimize the access distance to the site and rehandling cost	Minimize adverse aesthetic impact	Ecological impact	Regulatory issues
Site 1	3	3.3	15	300	1	3
Site 2	8	4	28	350	4	1
Site 3	7	0.4	35	1200	3	3
Site 4	15	5	16	2000	2	3
Site 5	8	3.8	20	700	5	1

A weighting structure is also developed for decision criteria, which reflects differences in the degree of importance or value assigned to each criterion in the decision criteria set. Essentially, the weights assigned to each criterion represent the rate at which people are willing to trade off portions of the criterion range between the objectives. Therefore, the relative importance of objectives and weights should be determined by considering the full range of possible performance of each alternative in terms of each criterion. Several methods are used to elicit people's weight judgment, including the swing method, the tradeoff method, and the more widely used Analytical Hierarchy Process (AHP).[1] Developed in the 1970's by Dr. Thomas Saaty, AHP was originally designed to mimic human thinking (Saaty 1980). The hierarchical AHP decision structure begins with a problem or an overall goal, followed by criteria (often called objectives) and sub-criteria and then to selection of alternatives. An AHP technique that requires the decision-maker to consider each single criterion against every other criterion in pairs is called a pair-wise comparison (Yoe 2002). Pair-wise comparison judgments are then made throughout the

[1] The weights assigned to each criterion represent the rate at which people are willing to trade off portions of the criteria range between the objectives. Therefore, the relative importance of objectives and weights should be determined by considering the full range of possible performance of each alternative in terms of each criterion (Kim et al. 2003). Although AHP is the most widely used method of assigning weights, it does not consider the range of possible performance of each alternative.

branch-like structure determining prioritized alternative courses of action. AHP can be used in many scenarios; for instance, resource allocation, outcome prediction, group facilitation, and cost/benefit comparison. The primary benefit of using AHP is decision-makers are able to pin down objectives that can ultimately achieve their goal and are completely cognizant of how and why the decision was made yielding results that are meaningful and easy to communicate. But each weighting method can result in a different weight; to alleviate this concern, it is recommended that decision makers consider using more than one method to check consistency of the weight. Table 4 shows the hypothetical utility value, assuming linear relationships for all criteria, ranging from 0 to 1. Table 5 shows the hypothetical weight values for each criterion. The weight is highest (0.3) for minimizing adverse aesthetic impacts and the lowest for minimizing costs (0.05). Eliciting people's weight judgments does not need to be a complicated process; commercial software products are widely available that can help obtain weight judgments systematically and easily.

Table 4. Utility values for each criterion.

Site	Minimize total construction and maintenance cost	Provide adequate capacity to meet the 20-year demands	Proximity: minimize the access distance to the site and re-handling cost	Minimize adverse aesthetic impact	Ecological impact	Regulatory issues
Site 1	1.00	0.63	1.00	1.00	1.00	0.50
Site 2	0.58	0.78	0.35	0.97	0.25	1.00
Site 3	0.67	0.00	0.00	0.47	0.50	0.50
Site 4	0.00	1.00	0.95	0.00	0.75	0.50
Site 5	0.58	0.74	0.75	0.76	0.00	1.00

Table 5. Hypothetical weights for each criterion.

Criterion	Minimize total construction and maintenance cost	Provide adequate capacity to meet the 20-year demands	Proximity: minimize the access distance to the site and rehandling cost	Minimize adverse aesthetic impact	Ecological impact	Regulatory issues
Weight	0.05	0.25	0.1	0.3	0.15	0.15

Finally, the criteria are aggregated to make an overall comparison. If the condition of additive independence[1] holds (Keeney and Raiffa 1976), then:

$$U\left(\underline{X}^{a}\right) = \Sigma_i w_i u_i\left(x_i^a\right) \tag{1}$$

[1] The major assumption underlying the additive independence is that preferences between two distinct alternatives depend only on the marginal probability distributions of the x_i within an alternative, and not their joint distribution (Keeney and Raiffa 1976).

where

w_i = weight for criterion i ($\Sigma_i w_i = 1$)
$u_i(x_i^a)$ = the single criterion utility
$U(\underline{X}^a)$ = the overall utility of alternative a

An overall ranking of the alternatives being considered by a decision is then developed by combining scores for the decision criteria with the weighting structure developed. Through this process of combining scores with weights, MCDA allows the alternatives to be ranked in a manner that reflects the objectives and values of the decision-makers. It should be noted that the purpose of decision analysis is not to calculate the right answer. Rather, it is the means to achieving an increased stakeholder understanding of the nature of the value conflicts and tradeoffs among criteria so that recommendations and valuations can be made with confidence.

Table 6 shows the total utility value using the results from Tables 4 and 5. The most preferred site using MCDA is site 1, compared to Table 1 in which the most preferred site using direct scoring is site 3 or 4. Therefore, the optimal site depends on the approach used. This difference in ranking exists for several reasons. The inclusion of the environmental criterion may have resulted in different ranking among the sites. Another likely cause is that performance results and weights were considered separately and explicit weights can lead to different rankings. Yet, it may be difficult to reach consensus for weights. While stakeholders and decision-makers may have different and irreconcilable views on which objectives are most important, the use of MCDA in quantifying and communicating stakeholder values can provide important insights as shown in the hypothetical example.

Table 6. Total utility and ranking from MCDA.

Site Number	Site 1	Site 2	Site 3	Site 4	Site 5
Total utility	0.83	0.74	0.32	0.53	0.67
Ranking	1	2	5	4	3

The key benefits of MCDA over direct scoring methods are its emphasis on the importance of the values of decision-makers and stakeholders in the course of establishing criteria, the explicit incorporation of these values into the decision-making process, and the ability to evaluate the contribution of specific values and criteria to overall ranks or decisions through a form of sensitivity analysis (Kim et al. 2003). Thus, MCDA supports several aspects of the decision-making process (Hobbs and Meier 2000) by:

1. Systematically structuring the decision process. MCDA helps decision-makers think systematically about the problem by providing a logical framework for defining options and comparing performance based on pre-established criteria.

2. Documenting how decisions are made and facilitating negotiation. By detailing how each of the steps of the decision-making process has been conducted, decision-makers can communicate and defend the basis of their decisions to stakeholders and other interested parties.

3. Helping the decision-maker and stakeholders reflect upon, articulate, and apply explicit value judgments concerning conflicting criteria and uses. During the course of a decision process, attitudes will evolve in response to new information, interactions with others, and viewing the problem from different perspectives; MCDA offers the means to document this evolution and explain the resulting ranks.

4. Helping people make more consistent and rational evaluations of risks and uncertainties. Behavioral and social sciences research has shown that people are inconsistent and challenged when making decisions involving risk. MCDA accounts for decision-makers' and stakeholders' attitudes towards risk.

5. Displaying tradeoffs among performance criteria so that managers and stakeholders can understand the relative advantages and disadvantages of management options. The "value path" approach (Bishop 1974) shown in Figure 3, displays the horizontal axis representing different metrics and the vertical axis representing the rescaled performance for each attribute. In this example, Option B is equal to or better than Option C for every metric. Therefore, Option B dominates Option C. In this case, Option C may be screened from further analysis, including the elicitation of value judgments.

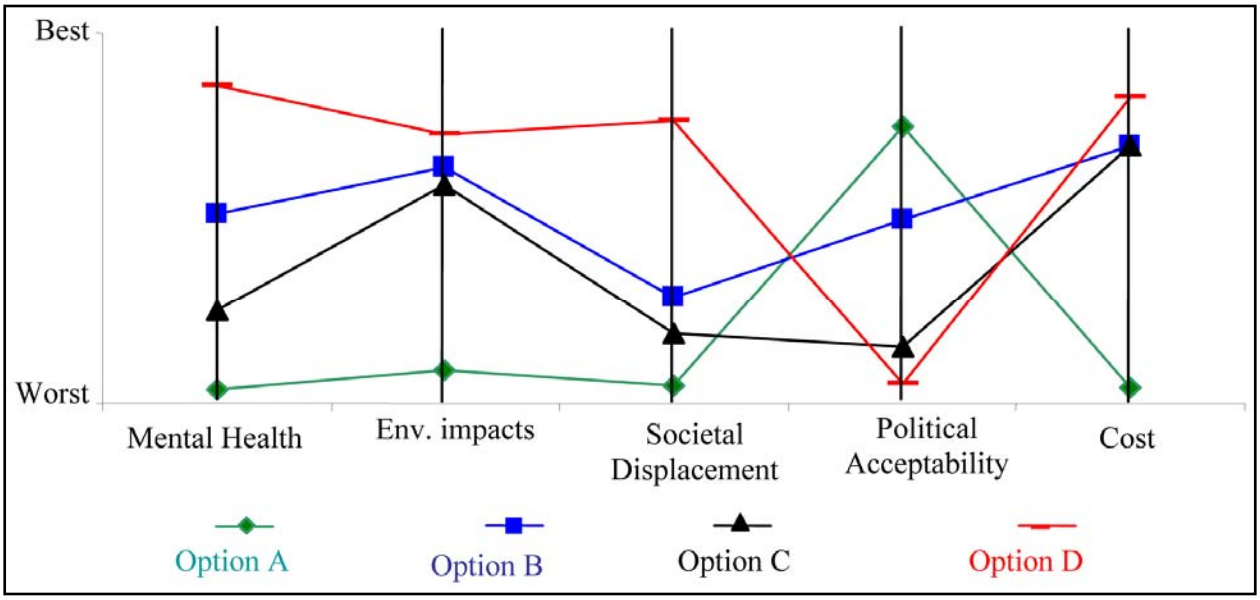

Figure 3. A value path diagram example.

CONCLUSION: The direct scoring method is one alternative to making decisions within the dredged material management realm. The direct scoring method has inherent disadvantages because factors such as cost, impacts, and benefits are rarely accurately recorded, leading to a decision process that is often unsatisfactory to stakeholders. There are other decision-making processes that provide more optimal results. For example, MCDA displays benefits when utilized for dredged material management decision-making and thus its use is highly encouraged. Ultimately, the expected benefit of using MCDA is better decisions, i.e., decisions that can be quantitatively and transparently supported by data and stakeholder values. It also aids in decision-making that considers both the technical information and stakeholder values that can

only be accomplished through the structure and discipline provided by MCDA. Such approaches enable decision makers to credibly distinguish and prioritize alternatives among low and high risks and to systematically evaluate and compare alternatives.

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