УДК 574

MANAGEMENT OF CONTAMINATED AQUATIC ENVIRONMENT WITH IMPLEMENTATION OF MULTI CRITERIA DECISION ANALYSIS

B.I.Yatsalo*, I. Linkov, G. Kiker***, T.P. Seager****,A.N. Tkachuk***

***** Obninsk State Technical University of Nuclear Power Engineering, Russia***

***Cambridge Environmental Inc., Boston, USA*

**** University of Florida, USA*

***** University of New Hempshire, Durhem, USA*

Рассмотрены задачи применения методов многокритериального анализа (МКА) к управлению загрязненными водными территориями. Представлен краткий обзор методов МКА. Исследованы две практические задачи ранжирования предлагаемых мероприятий по управлению загрязненными донными отложениями с использованием различных методов МКА.

INTRODUCTION

Environmental decision-making strategies over the last several decades have evolved into increasingly more sophisticated, information-intensive, and complex approaches including expert judgment, cost-benefit analysis, toxicological risk assessment, comparative risk assessment, and a number of methods for incorporating public and stakeholder values. This evolution has led to an improved array of decision-making aides, including development of Multi Criteria Decision Analysis (MCDA) tools that offer a scientifically sound decision analytical framework. Even though a great deal of work has been done in justifying the theoretical foundation of these methods, their real life applications in Russia are still rare.

However, the barest necessity in implementation of decision support methods and tools for scientific substantiation of ranking/selecting alternatives is one of the requirements of up-to-date culture within the decision-making. And, in our opinion, interest and call in implementation of MCDA for practical needs will inevitably rise along with increase of various sophisticated computer tools for multiple criteria decision analysis.

Existence of different MCDA methods and availability of corresponding software are in itself rather promoting then repelling moment for practical implementation of these methods. Without any doubts, process of analyzing a “significant multicriteria problem” should be carried out under the guide of a facilitator, who assists the decision-maker in reaching a satisfactory decision and is well educated in MCDA.

This paper illustrates application of three different MCDA methods for the two case studies on protection of water ecosystems. These case studies are based on real sediment management problems.

COCHECO RIVER AND NEW YORK/NEW JERSEY HARBOR CASE STUDIES

Two case studies selected for this research are representative of sediment management challenges [1]. The Cocheco River is located in the southeastern part of New Hampshire and flows toward the Gulf of Maine and the Atlantic Ocean. A section of the river, from below the dam in the center of the city of Dover to the Cocheco's confluence with the Piscataqua River, was proposed for dredging. Plans to dredge have been in the works for a number of years (since approximately 1996). There are many motivations for the dredging, including the economic redevelopment of Dover and the overriding goal of maintaining a navigable channel for federal navigation.

There has been and still is much debate over the need to dredge and remove sediment from the bottom of the Cocheco River. Approximately 45,000-60,000 cubic yards of sediment, some of which are contaminated with polyaromatic hydrocarbons (PAHs) and heavy metals, are planned for removal [1]. The decision regarding what to do with the contaminated sediment is not an easy one.

Regulatory constraints required secure disposal of contaminated materials (i.e., prohibiting ocean dumping). Other commonly used options (CAD, landfill) were found to be not useful for the site. For example, the closest authorized landfill, the privately-owned Turnkey landfill in Rochester, NH, refused to accept dredged soils. The next nearest landfill (in Maine) was prohibitively expensive due to the transportation costs and tipping fees, causing secure landfill disposal to be judged infeasible. After extensive negotiations, cement manufacture, flowable fill, wetlands restoration, and upland disposal cell were identified as feasible alternatives for consideration, Table 1.

Table 1

Alternatives Under Study (Cocheco case study)

Technology	Process and Hypothesis
Wetland restoration	Surrounding contaminated sediment core with clean material in new wetland cell may restore hydrologic function and ecological habitat to areas diked and/or drained.
Cement manufacture	Blending with conventional raw materials and firing in rotary kiln for manufacture of cement may destroy organic contamination. Metals may be bound upon hydration of portland cement concrete in normal construction applications.
Upland brownfield disposal cell	Dewatering, compacting, and capping on site may prevent dispersion of contaminants to environment and allow construction of recreation space on top of cell.
Cement stabilization in flowable fill	Blending with pozzolanic material such as cement, fly ash, or blast furnace slag may bind contaminants upon hydration in normal structural applications such as trench backfilling or soil strengthening.

In both case studies (Cocheco one and sediment management for NY/NJ harbor, Tables 2,3) there are many stakeholders in this decision making process who have various concerns, some overlapping and others exclusive, about the management of contaminated sediments. MCDA methods and tools provide a sound approach to sediment management that integrates economic and technical considerations (such as cost, human health and environmental risks) with social factors (public acceptance, environmental justice, etc.).

MULTI CRITERIA DECISION ANALYSIS METHODS

Analysis of the theoretical foundations of multiple criteria approaches to decision analysis and discussion of an integrating framework for the use of MCDA methods has been presented, *e.g.*, in [2]. The common purpose of MCDA methods is to evaluate and choose among alternatives based on multiple criteria using systematic analysis that overcomes the limitations of unstructured individual or group decision-making. The following main categories of problems are considered on the basis of MCDA [2]:

• *sorting* alternatives into classes/categories (*e.g.*, «unacceptable», «possibly acceptable», «definitely acceptable», etc.);

• *screening* alternatives – a process of eliminating those alternatives that do not appear to warrant further attention, i.e., selecting a smaller set of alternatives that (very likely) contains the "best" alternative;

• *ranking* alternatives (from «the best» to «the worst» in accordance with an algorithm chosen);

• *choice* of the «best alternative» from a given set of alternatives;

• designing (searching, identifying, creating) new action/alternative to meet the goals and aspirations.

Some other categories of problems, *e.g.*, such as description/learning problematique (analysis of actions to gain grater understanding of what may or may not be achievable) and portfolio problematique (choice of a subset of alternatives, taking account not only individual characteristics of alternatives, but also their positive and negative interrelation) also may be considered with the use of MCDA approaches.

Two *key schools* within the MCDA methodologies are considered in this paper, each of them is based on the specific approaches to multiple criteria analysis and methods used:

• *value function* based methods; and

• *outranking* methods.

Approaches with the use of value functions form so called MAVT methods (multiattribute *value* theory). However, very often the acronym MAUT is used (multiattribute *utility* theory). Concerning interpretation of the differences between *value* and *utility* there exist several judgements. E.g., Winterfeldt and Edwards [3] do not find the principal differences between *value* and *utility functions* and consider utility as «a different set of elicitation methods intended to provide consistency checks on the construction of a value function». On the other hand, taking into account the Expected Utility Theory developed by von Neumann and Morgenstern [4], *utility theory* may be viewed as an extension/generalisation of value measurement, relating to the use of probabilities and expectations to deal with uncertainty [2]. Therefore, in most cases, when analysing applied MCDA problems, authors do not distinguish MAVT and MAUT, indicating implementation of MAVT/MAUT methods.

The objective of MAVT is to model and represent the decision maker's preferential system into a value function $V(\boldsymbol{a})$,

$$V(\boldsymbol{a}) = F(V_1(a_1),\ldots,V_m(a_m)); \tag{1}$$

where alternative $\boldsymbol{a}$ is presented as a vector of the evaluation criteria $\boldsymbol{a}=(a_1,\ldots,a_m)$, a_i is the assessment of alternative $\boldsymbol{a}$ according to criterion i, $V_i(a_i)$ is the *value score* of alternative reflecting its performance on criterion i (as a rule $0 \le V_i(a_i) \le 100$). The most widely used form of function $F(\ )$ is an additive model

$$V(\boldsymbol{a}) = w_1 V_1(a_1) +\ldots+ w_m V_m(a_m), \tag{2}$$

$$w_i > 0 , \Sigma w_i =1, \tag{3}$$

where w_i, $i = 1,\ldots,n$, are the weights reflecting the *relative impotency* of the criteria (or corresponding *scaling factors*). It should be stressed, however, that for justified implementation of additive model (2) some requirements/axioms of MAVT should be held (one of the key of them is *preferential independence* requirements, [2,3]).

MAVT relies on the assumptions that the decision-maker is rational (preferring more utility to less utility, for example), that the decision-maker has perfect knowledge, and that the decision-maker is consistent in his judgments. The goal of decision-makers in this process is to maximize the overall value $V(\boldsymbol{a})$ of alternative $\boldsymbol{a}$.

Various sophisticated methods for defining partial value functions $V_i(x)$ and assessing weights w_i have been developed both for quantitative and qualitative criteria. One of the most popular and simplest version of MAVT is SMART (Simple Multi-Attribute Rating Technique), suggested by Edwards [5]; at present several versions of SMART are used [3, 6].

Concerning weights eliciting within MAVT, some specialists point out that the weights assigned to criteria are rather scaling factors (which relate scores on a criterion to scores on all other criteria) then weights which simply reflect the relative importance of criteria [2, 3].

Because poor scores on criteria can be compensated for by high scores on other criteria, MAVT is part of a group of MCDA techniques known as «compensatory» methods.

Outranking approaches imply forming outranking relation on a given set of alternatives. At that, outranking methods are based on pairwise comparison of alternatives for each criterion under consideration with subsequent integration of obtained preferences according to the algorithm chosen. Among outranking approaches, the ELECTRE family of methods developed by Roy [7], and PROMETHEE method by Brans [8] are the most used ones.

PROMETHEE, based on the performance matrix $\{z_i(\boldsymbol{a})\}$ (where $z_i(\boldsymbol{a})$ is an evaluation of alternative $\boldsymbol{a}$ against criterion i) and a chosen preference function $f_i(x)$, $0 \le f_i(x) \le 1$, with specified indifference and preference thresholds, determines the intensity of preference for alternative $\boldsymbol{a}$ over alternative $\boldsymbol{b}$, $P_i(\boldsymbol{a}, \boldsymbol{b}) = f_i(z_i(\boldsymbol{a}) - z_i(\boldsymbol{b}))$, and preference index, $P(\boldsymbol{a}, \boldsymbol{b})$,

$$P(\boldsymbol{a}, \boldsymbol{b}) = \Sigma w_i\, P_i(\boldsymbol{a}, \boldsymbol{b}) \tag{4}$$

where weights w_i reflect the relative importance of criteria, and meet the requirements (3). According to the features of preference functions $f_i(x)$, if $P_i(\boldsymbol{a}, \boldsymbol{b}) > 0$, then $P_i(\boldsymbol{b}, \boldsymbol{a}) = 0$.

Preference indices are used for determination of *positive outranking flow* for $\boldsymbol{a}$:

$$Q^+(\boldsymbol{a}) = \Sigma_b\, P(\boldsymbol{a}, \boldsymbol{b}) \tag{5}$$

and *negative outranking flow* for $\boldsymbol{a}$:

$$Q^-(\boldsymbol{a}) = \Sigma_b\, P(\boldsymbol{b}, \boldsymbol{a}), \tag{6}$$

with summing for all alternatives $\boldsymbol{b} \neq \boldsymbol{a}$.

According to PROMETHEE 1 method, $\boldsymbol{a}$ outranks $\boldsymbol{b}$ if $Q^+(\boldsymbol{a}) \geq Q^+(\boldsymbol{b})$ and $Q^-(\boldsymbol{a}) \le Q^-(\boldsymbol{b})$; $\boldsymbol{a}$ is indifferent to $\boldsymbol{b}$ if $Q^+(\boldsymbol{a}) = Q^+(\boldsymbol{b})$ and $Q^-(\boldsymbol{a}) = Q^-(\boldsymbol{b})$; $\boldsymbol{a}$ and $\boldsymbol{b}$ are incomparable if $Q^+(\boldsymbol{a}) > Q^+(\boldsymbol{b})$ and $Q^-(\boldsymbol{b}) < Q^-(\boldsymbol{a})$, or $Q^+(\boldsymbol{b}) > Q^+(\boldsymbol{a})$ and $Q^-(\boldsymbol{a}) < Q^-(\boldsymbol{b})$.

Thus, PROMETHEE 1, as some other outranking methods, does not presuppose that a single best alternative can be identified as some alternatives may be incomparable.

PROMETHEE 2 method, which is based on the *net flow* criteria $Q(\boldsymbol{a})$:

$$Q(\boldsymbol{a}) = Q^+(\boldsymbol{a}) - Q^-(\boldsymbol{a}), \tag{7}$$

may be used for complete ranking of alternatives (and alternative $\boldsymbol{a}$ outranks $\boldsymbol{b}$ if $Q(\boldsymbol{a}) > Q(\boldsymbol{b})$), though this approach is considered as more disputable then PROMETHEE 1.

PROMETHEE like other outranking methods are considered as attractive and transparent method, though both positive and negative flows depend on the complete set of alternatives under consideration [2].

Outranking techniques, according to (4)–(7), allow inferior performance on some criteria to be compensated for by superior performance on others. They do not necessarily, however, take into account the magnitude of relative underperformance in a criterion versus the magnitude of over-performance in another criterion. Therefore, outranking models are known as «partially compensatory».

The Analytic Hierarchy Process method, AHP, developed by Saaty [9], presents in fact an integration of additive model (2) with a peculiar approach to determination of matrix $V_{i,a}$ and criteria weights w_i. Within AHP approach, instead of defining value function $V_i(x)$, systematic pairwise comparison of alternatives with respect to each criterion is used based on the special ratio scale developed: for a given criterion alternative $\boldsymbol{i}$ is preferred to alternative $\boldsymbol{j}$ with strength of preference given by $a_{ij} = s$, $1 \le s \le 9$, correspondingly, $a_{ji} = 1/s$. Then, the same procedure is implemented for pairwise comparison of criteria in the same numerical ratio scale. The obtained matrices are processed (for extracting the eigenvector corresponding to the maximum eigenvalue of the pairwise comparison matrix) giving at the output values $V_{i,a}$ and weights w_i for subsequent aggregating with the use of model (2).

Thus, AHP may be considered as an approach with a specific eliciting a value function (*scoring*) and criteria weights (*weighting*). However, taking into account different assumption and approaches, AHP proponents insist that it is not a value function method [2].

Despite longstanding discussions on correctness of AHP for analysing and ranking alternatives (specific scoring and weighting, «rank reversal problem», etc.) [2, 10], this method is sufficiently popular due to its transparency and relatively simple judgements at the pairwise comparing alternatives and criteria.

The AHP technique relies on the supposition that humans are more capable of making relative judgments than absolute judgments. Consequently, the rationality assumption in AHP is more relaxed than in MAVT.

Although, in our opinion, simplicity in realisation of all the procedures does not lead to the depth of problem elaboration and justified inferences that is and should be taken into account by exacting experts and decision makers.

METHODOLOGY

To test sensitivity of the «optimal» management alternative to the specific MCDA method used, this work employs all three indicated above methods (MAVT, Outranking, AHP) and compares the resulting selection of a sediment management alternative for the two case studies.

The starting point for the analysis presented in this study are performance matrices developed for the Cocheco and NY/NJ case studies. The decision matrix for the Cocheco case study (Table 2) presents evaluation of four alternative policies using four criteria (cost, environmental quality, impact on ecological and human health habitats) [1]. One of them, *Environmental Quality*, is a qualitative criterion. For realization of this criterion 3-level qualitative scale is considered: low, medium, and high. Other criteria are quantitative («no change» in Table 2 means 0).

Table 2

Performance Table for the Cocheco Case Study [1]

Alternatives/*Criteria*	*Cost* (*$/cy*)	*Environmental Quality*	*Ecological Habitat* (*acres*)	*Human Habitat* (*acres*)
Wetlands Restoration	$75	High	10 addn.	No change
Cement Manufacture	$30	High	No change	No change
Upland Disposal Cell	$40	Medium	No change	4 addn.
Flowable Fill	$55	Medium	No change	No change

Table 3

Performance Table for the NY/NJ Case Study, [15]

Criteria/ Alternatives	CAD	Island CDF	Near-Shore CDF	Upland CDF	Landfill	No Action	Cement Lock Technology	Manufactured Soil Technology
Ecological Hazard Quotient	680,00	2100,00	900,00	900,00	0,00	5200,00	0,00	8,70
Complete Ecological Exposure Pathways	23,00	38,00	38,00	38,00	0,00	41,00	14,00	18,00
Complete Human Health Exposure Pathways	18,00	24,00	24,00	24,00	21,00	12,00	25,00	22,00
Maximum Cancer Probability (*Non-Barge Worker*)	0,03	0,09	0,04	0,04	0,30	0,20	0,02	1,00
Est. COC Conc in Fish / Risk-based Conc	28,00	92,00	38,00	38,00	0,00	220,00	0,00	0,00
Cost ($CY)	5,00	25,00	15,00	20,00	70,00	2,00	75,00	60,00
Ratio of Impacted Area to Facility Capacity (acres/MCY)	4400,00	980,00	6500,00	6500,00	0,00	0,00	0,00	750,00

The performance matrix for the NY/NJ case study (Table 3) presents evaluation of 8 alternative policies using 7 quantitative criteria [15].

Indicated in tables 2 and 3 performance matrices were transformed to fit input data formats for different software packages.

The following packages have been used within this work:

• *Decision Lab*, which realizes PROMETHEE method;

• *Expert Choice* with AHP method;

• *Criterium Decision Plus* with implementation of MAVT (SMART approach).

All the indicated packages are possessed of wide performance capabilities, including realization of sensitivity analysis, presentation of various output table and graphic forms on the basis of user-friendly interface.

Experts and stakeholders were involved in *structuring MCDA problems* mentioned above as the Cocheco and NY/NJ case studies, developing the performance tables and criteria waiting. At that, for MCDA analysis of Cocheco case study software package *Decision Lab* was originally used, and analysis of NY/NJ case study was originally based on *Criterium Decision Plus* package. Implementation of other software packages for cross analysis of indicated case studies was based on performance tables 2 and 3 and corresponding weights of criteria.

Definitely, if two different groups of experts analyses a given task using the same method (*e.g.*, outranking), we cannot state that the output ranking alternatives will completely coincide (*e.g.*, when groups suggest different criteria weights and/or ranking is sensitive to the preference functions or indifference/preference thresholds). However, if groups are large and qualified and/or intersecting, we may hope ranking orders will be close (or almost the same). However, if two expert groups make their judgments under two facilitators who use different methods (*e.g.*, MAVT and outranking), we cannot state ranking order should be the same even these groups are almost coinciding.

In fact, if within a MAVT approach the criteria weights were elaborated as *swing weights*, i.e., are the *scaling factors* (which relate scores on one criterion to scores on other criteria), then these weights may differ from weights elicited within an outranking approach based, *e.g*., on a notion of relative importance of the criteria. In addition, implementation of developed by expert groups value functions $V_i(x)$ and intensity of preference functions $P_i(\boldsymbol{a}, \boldsymbol{b})$ may also lead to an increase of differences in ranking order for alternatives, which are based on overall value function $V(\boldsymbol{a})$ and outranking flows $Q^+(\boldsymbol{a})$ and $Q^-(\boldsymbol{a})$.

Specific differences in ranking order are also occurred if one of the expert groups make their judgments working with a facilitator within AHP method, and another group does that within MAVT/outranking. Moreover, in this situation there is no well-defined and unique rules for transforming both quantitative (though partly) and qualitative criteria performances from a set of data developed under MAVT/outranking into the AHP scale. Although, pairwise comparison of alternatives against a quantitative criterion is effective, but an automatic transformation of pairwise ratios, *e.g.*, from interval (0, 100) into the standard AHP value scale ($1 \le s \le 9$ and $1/9 \le 1/s \le 1$) may differ from corresponding expert judgments made by experts under AHP method.

Comments made above were taken into account for comparison of ranking orders for indicated case studies and software packages. In all the scenarios linear value functions within MAVT, and linear preference functions within PROMETHEE (with 1% and 5% for indifference and 10% for preference thresholds) were used.

RESULTS

We discuss below only ranking order for alternatives for the two case studies under consideration. However, we would like to stress that ranking alternatives is not the final step but only one of the steps within the implementation of MCDA for analysis of applied problems [2, 3].

Table 4 presents an alternative ranking for the Cocheco site using different software packages. The decision matrix presented in table 2 was used in the all indicated software packages. Two criteria weighting scenarios were considered for the following stakeholder groups:

- The Environmentalist stakeholder group includes those concerned largely with plant, animal, and fish health, as well as the status of the environment particularly in terms of air and water quality.
- The Public Health stakeholder group saw human health and well-being as the most important consideration and as an indicator of environmental well-being.

Three MCDA software packages used within this work predict that *flowable fill* is the least attractive alternative for both stakeholder preference scenarios. *Wetland restoration* was ranked as the most attractive option by all methods for the two indicated groups of stakeholders. *Cement manufacture* and *upland capped* have ranks 2 or 3 depending on the method used, see table 5.

Table 4

Alternative Ranking for Cocheco Sites using Different MCDA Software. Two Criteria Weighing Scenarios Were Used: Environmentalists / Public Health

Software & Method	Alternatives			
	Wetlands Restoration	*Cement Manufacture*	*Upland Capped*	*Flowable Fill*
ExpertChoice, AHP;	1/1	2/2	3/3	4/4
DecisionLab, PROMETHEE	1/1	2/2	3/3	4/4
CritDecPlus, MAVT	1/1	3/3	2/2	4/4

Table 5

Alternative Ranking for NY/NJ Sites using Different MCDA Software

Software & Method	Alternatives							
	CAD	*Island CDF*	*Near-Shore CDF*	*Upland CDF*	Landfill	*Cement Lock*	*Manufactured Soil*	*No Action*
ExpertChoice, AHP	5	8	6	7	2	1	3	4
DecisionLab, PROMETHEE 1,2	2	8	5	6	3	1	4	7
CritDecPlus, MAVT	2	7	4	5	1	3	6	8

According to sensitivity analysis, using PROMETHEE and Human Health scenario, increase of the weight for Human Habitat criterion from 30 to 35% changes ranking orders of *cement manufacture* and *upland capped* alternatives; whereas double increase of the weight of cost criterion (from 10 to 20%) changes ranks of *Wetland restoration* and *Cement manufacture* alternatives. Realization of AHP method for the Cocheco case study, Human Health scenario, demonstrates negligible difference between *cement manufacture* and *upland capped* alternatives, see Fig. 1.

Thus, we may state that alternative ranking for the Cocheco case study are practically the same independently from the method/software used.

For NY/NJ case study, *cement lock* and *landfill* and *CAD* were ranked as top choices by all three software tools, Table 5. And, according to sensitivity analysis (on the basis of MAVT/CDplus), differences between these three alternatives are negligible, see Fig.2, and change of some criteria weights up to 2–5% can change ranking order of these three alternatives. Other alternatives received lower scores. For *CAD* rank 5 within AHP method

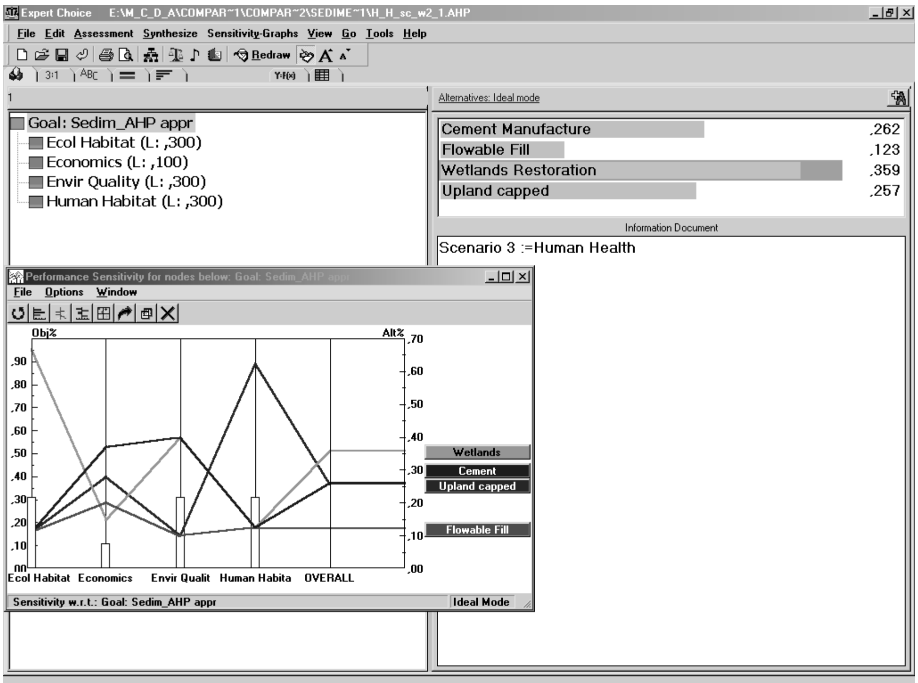

Fig.1. Case study 1: alternative ranking and sensitivity analysis, AHP/Expert Choice

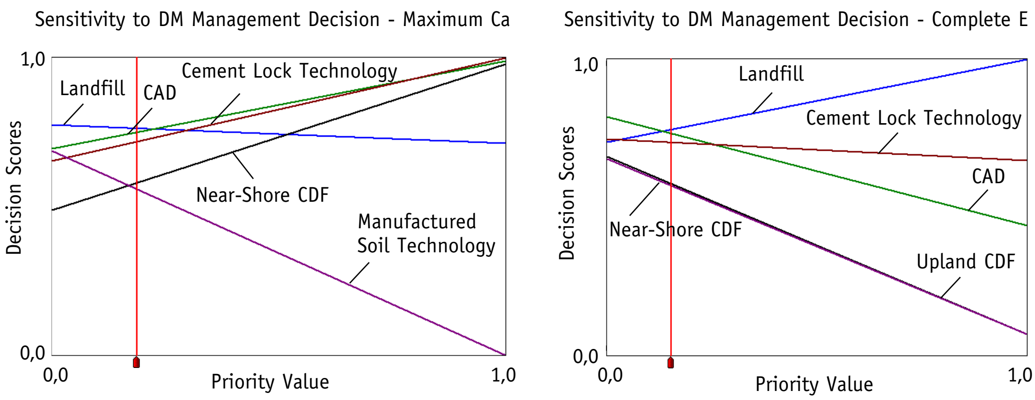

Fig.2. Case study 2: alternative ranking and sensitivity analysis, MAUT/CDplus ;

is a result of uncertainty influences when transforming data from performance table (table 4) into AHP scale (differences between rank 5 and 3 may be considered, within the sensitivity analysis, as negligible). In addition, «rank reversal» effect [ ] for AHP method was also observed when decreasing the number of alternatives from 8 to 5 (e.g., rank ordering of *CAD* and *manufactured soil* is changed).

Thus, despite some relative increase of discrepancies in rank ordering for NY/NJ case study (Table 5) in comparison with Cocheco case study (Table 4), the results of such an analysis lead to the finding that three indicated alternatives can be considered for further analysis as the most justified within MCDA methodology used.

CONCLUSION

Our analysis shows that even though each MCDA method and associated tools may use a unique theoretical background and calculation algorithms, they may be consistent in analysis alternatives available for environmental managers within the case studies under consideration. For example, the Cocheco case study shows that the flowable fill alternative is clearly least appropriate and can be safely removed from consideration. Three other alternatives are difficult to prioritize since their ranking is sensitive to stakeholder preference judgments. In the NY/NJ case, the top three alternatives clearly outperform the remaining four. The overall utility of this consideration is the ability to focus on the top few alternatives and eliminate underperforming alternatives from consideration.

Though ranking order of alternatives may change when using different MCDA methods, cross-platform analysis of a multicriteria problem may play an effective role for interactive and iterative process of problem understanding and eliciting key parameters and functions within methods under implementation as well as for subsequent decision making.

Comparative analysis of results on the basis of different MCDA methods (MAVT, outranking, AHP) demonstrates a proximity of ranking order for alternatives within the two case studies considered. At the same time, results obtained with the use of AHP method, though it is relatively simple and suitable for practical implementation, can get some doubts about their validity and robustness. Although, there is no such thing as the «right answer» within MCDA approaches [2], however, decision-makers need of justified methods, which could be verified based on some other approaches.

Therefore, a cross-platform analysis presented in this paper, may be useful both for screening purposes [14] and for the final choice of ranking order for alternatives taking into account a wide range of both parameter and model uncertainties.

Moreover, to our way of thinking, critical attitude of representatives of different MCDA schools to alternative MCDA approaches may and should be constructively used for elicitation of strengths and weaknesses of each method when solving a specific problem.

The findings of this paper emphasize not the difficulties in implementation of different MCDA methods/software when analyzing multicriteria objectives, but the necessity of bringing MCDA specialists in solving the specific practical multicriteria problems.

References

1. *Rogers S.H., Seager T.P. and Gardner K.H.* (2004). Combining expert judgement and stakeholder values with Promethee: a case study in contaminated sediments management. In: Comparative Risk Assessment and Environmental Decision Making. I. Linkov and A. Bakr Ramadan eds. Kluwer Academic Publishers, p. 305-322.

2. *Belton V. and Steward T.* (2002). Multiple Criteria Decision Analysis: An Integrated Approach. Kluwer Academic Publishers: Boston, MA.

3. *von Winterfeldt D. and Edwards W.* (1986). Decision Analysis and Behavioral Research. Cambridge University Press, Cambridge.

4. *von Neumann J. and Morgenstern O.* (1947) Theory of games and economic behavior. Princeton, NJ: Princeton University Press.

5. *Edwards W.* (1971). Social utilities. Engineering Economist, Summer Symposium Series, 6, 119-129.

6. *Edwards W. and Barron F.H.* (1994). SMART and SMARTER: Improved simple methods for multiattribute utility measurement. Organizational Behavior and Human Decision Process, 60:306-325.

7. *Roy B.* (1996). Multicriteria Methodology for Decision Aiding. Kluwer Academic Publishers, Dordreht.

8. *Brans J.P. and Vinckle P.* (1985). A preference ranking organization method: the PROMETHEE method for multiple criteria decision-making. Management Science, 31:647-656.

9. *Saaty T.L.* (1980). The Analytic Hierarchy Process. McGraw-Hill, New York.

10. *Dyer J.S.* (1990). Remarks on the Analytic Hierarchy Process. Management Science, 36:249-258.

11. *Charnes A. and Cooper W.W.* (1961). Management Models and Industrial Applications of Linear Programming. John Wiley & Sons, New York.

12. Office of the Deputy Prime Minister (ODPM) (2004). DLTR Multi-Criteria Decision Analysis Manual. Available at http://www.odpm.gov.uk/stellent/groups/odpm_about/documents/page/odpm_about_608524-02.hcsp

13. *Larichev O.I. and Olson D.L.* (2001). Multiple Criteria Analysis in Strategic Siting Problems. Boston: Kluwer Academic Publishers.

14. *Hobbs B.F. and Meier P.* (2000) Energy decisions and the environment:a guide to the use of multicriteria methods. Boston: Kluwer Academic Publishers.

15. *Kane Driscoll S.B., Wickwire W.T., Cura J.J., Vorhees D.J., Butler C., Moore D.M. and Bridges T.* 2002. A Comparative Screening-Level Ecological and Human Health Risk Assessment for Dredged Material Management Alternatives in New York/New Jersey Harbor. Human and Ecological Risk Assessment 8:3: 603-626.

Поступила в редакцию 12.10.2005

УДК 621.039: 61

Quality Control of Sickness Rate Registration of the Chernobil Accident Liquidators into a Different Radiation Dose Groups \ A.P. Birukov, V.K. Ivanov, V.F. Ukraintsev, M.A. Bolkhonenkova, H.V. Kochergina, Z.G. Kruglova, N.S. Zelenskaya; Editorial board of journal «Izvestia visshikh uchebnikh zavedeniy. Yadernaya energetica» (Communications of High Schools. Nuclear Power Engineering). – Obninsk, 2005. – 6 pages, 6 illustrations. – References, 9 titles.

Investigation of radiation dose factor impact on the quality of registration of Chernobil liquidators health were cariied out. A source material of the investigation was data of the National radiation-epidemiology register: structure and values of standartiezed sickness rate at two radiation dose groups (1-st with a dose 0-10 centiGray; 2-nd higher than 20 centiGray).

It is proved, that dispancerisation efficiency and monitoring intensity into a different radiation dose group are the same (they are determines by legislation acts, which are actual at the Russian Federation) and do not influence on the results of radiation- epidemiology analysis conducting.

УДК 574

Management of Contaminated Aquatic Environment with Implementation of Multi Criteria Decision Analysis \B.I. Yatsalo, I. Linkov, G. Kiker, T.P. Seager, A.N. Tkachuk; Editorial board of journal «Izvestia visshikh uchebnikh zavedeniy. Yadernaya energetica» (Communications of High Schools. Nuclear Power Engineering). – Obninsk, 2005. – 11 pages, 5 tables, 2 illustrations. – References, 15 titles.

Implementation of Multi Criteria Decision Analysis (MCDA) to the problems of contaminated aquatic environment management is presented. Different MCDA methods (MAVT, AHP, and outranking) are briefly discussed. Analysis of the two case studies on ranking alternatives for contaminated sediment management using different MCDA methods is considered.