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A Multiple-Objective Decision Analysis for Terrorism Protection: Potassium Iodide Distribution in Nuclear Incidents

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This paper presents a multiple-objective decision analysis approach to qualitatively and quantitatively evaluate different potassium iodide (KI) distribution plans for a hypothetical local region. We developed this approach for a U.S. National Research Council committee that was charged with figuring out the best means for protecting people against potential thyroid cancer resulting from the release of radioactive iodine from nuclear incidents occurring due to terrorism or accidents. We first identify an objectives hierarchy and then develop the single-attribute value functions and the weights for the objectives using a swing weight method. The identification of the largest value gaps between the status quo and the ideal situation helps to develop potential KI distribution plans. We then use an additive value function to assess the performance of these new alternatives, with the status quo as a benchmark, by computing their overall values. Finally, sensitivity analysis for the KI problem shows how this approach can create more key insights for the improvement of health and safety decision-making processes.

Key words: multiple-objective decision analysis; terrorism protection; emergency health and safety decisions; potassium iodide (KI); nuclear incident; sensitivity analysis; Excel sliders
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1. Introduction

The use of potassium iodide (KI) is an effective and safe measure to protect vulnerable populations from risks of thyroid cancer caused by exposure to radioactive iodine in the event of a nuclear incident caused by terrorism or an accident. In this paper, we use a multiple-objective decision analysis approach to evaluate different KI distribution plans for a hypothetical local region to effectively protect people against potential thyroid cancer due to the release of radioactive iodine.

1.1. Background

Several radiation incidents causing human morbidity and mortality occurred subsequent to the adoption of nuclear technologies to generate electricity in the second half of the last century. Radioiodine is one of the major threats to public health in the surrounding territory if it is released into the environment when a nuclear incident occurs. People exposed to radioiodine could have an increased risk of radiation injury of the thyroid, including thyroid cancer, primarily due to inhalation of contaminated air.

The most serious accident occurred at the Chernobyl nuclear power plant in the Ukraine on April 26, 1986, in which huge quantities of radioiodine were released into the environment, exposing a large population. Many subsequent studies of this disaster show that very young children have the highest sensitivity to the risk of thyroid cancer after exposure to radioiodine. UNSCEAR (2000) states that by the year 2000, about 2,000 cases of thyroid cancer attributed to exposure to the Chernobyl fallout had been reported in the area surrounding the nuclear power plant. The vast majority of the people who later developed thyroid cancer were four years old or younger (including fetuses) at the time of their exposure to the Chernobyl fallout, indicating an extremely low risk to adults.[1]

[1] The children near Chernobyl (now known as Chornobyl in the independent Ukraine) inhaled contaminated air and ingested contaminated milk and vegetables.

As an important protective measure specifically against radioactive iodine, stable potassium iodide (such as KI) has proved to be effective in mitigating radiation doses to the thyroid from radioiodine with the occurrence of an accidental or intentional nuclear fallout event. It is extremely important for the most vulnerable people, including children, infants, and pregnant and lactating women, to take KI within a few hours before or after exposure to radioiodine. This will block radioactive iodine from getting into the thyroid and thus will help protect the thyroid from cancer (FDA 2001). Furthermore, KI is generally safe, except for the relatively few people who have some preexisting thyroid conditions and iodine allergies.

Like Chernobyl, nuclear power plants in the United States also contain a source of radioactive iodine. In the event of a very rare serious accident, the radioiodine might create health risks from exposure to a contaminated environment in the vulnerable population and could cause thyroid cancer years later. Further, because terrorism has become a major threat to the homeland security of the United States, nuclear power plants are considered to be potential targets. Therefore, it has become increasingly important to plan how to protect people exposed to radioactive iodine in the event of a nuclear incident from later developing thyroid cancer. Because KI is effective in protecting against thyroid cancer, a KI distribution program has been considered by the U.S. government and associated agencies as part of a nuclear incident preparedness program. Potassium iodide distribution is a supplement to the primary protective measures of evacuation and sheltering, which protect against all nuclear incident risks, not just radioactive iodine.

The KI distribution planning process we participated in was initiated by Massachusetts Congressman Edward J. Markey's law (i.e., Public Law 107-188, §127). To satisfy the requirement of this law, the National Research Council (NRC) organized a committee to conduct a study, funded by the Centers for Disease Control and Prevention (CDC) on the best way to distribute and administer KI in the event of a nuclear incident. One of the authors of this paper (Keller) served as a decision analyst on the committee of experts from a variety of fields, including thyroid cancer physicians, radioactive safety experts, nuclear power plant safety professionals, and emergency management experts. The study began on March 27, 2003, and the committee met monthly until September 2003 at the National Academy of Sciences offices, primarily in Washington, D.C. (and once each at the University of California, Irvine and Woodshole, MA offices). During this period, the committee received oral or written public testimony from experts at several agencies and organizations, such as the U.S. Nuclear Regulatory Commission, U.S. Environmental Protection Agency (EPA), Federal Emergency Management Agency (FEMA), Food and Drug Administration (FDA), etc. In December 2003, the committee submitted their report for publication as the 2004 peer-reviewed book entitled *Distribution and Administration of Potassium Iodide In the Event of a Nuclear Incident*.

1.2. Research Focus from a Decision Analysis Perspective

While the ultimate task for the NRC committee was to find the best solution to the distribution and administration of KI in the event of a nuclear incident, the main purpose of this paper is to demonstrate how a decision analysis process can complement health risk assessment to improve terrorism protection and emergency health and safety decision making by using the KI decision problem as an example application. Based on the purpose of our study, we cover the following in this paper:

What role can decision analysis techniques play in terrorism protection and emergency health and safety assessment and management issues? When people are faced with such decision-making problems, it may be technically or politically difficult to assess associated risks, partly due to qualitative and nonnumerical outcomes. Even so, some systematic decision-structuring methods can be employed to formulate the decision problems and evaluate different alternatives. In particular, the multiple-objective decision analysis approach using a decision-under-certainty model was used in this paper to show the committee that a decision analysis process can help decision makers analyze the KI problem effectively.

What is the typical framework of a multiple-objective decision analysis approach that can be implemented for terrorism protection and emergency health and safety management problems? As a systematic decision-making methodology, the multiple-objective decision analysis approach has been widely used in various fields (see the literature review in §2). In §3, we provide a typical framework for the multiple-objective decision analysis approach to evaluate such decision problems in Figure 1. Then, the KI decision problem is used as an application of this framework.

What key insights can a multiple-objective decision analysis process provide decision makers for terrorism protection and emergency health and safety decisions? The multiple-objective decision analysis approach is shown to create key insights by providing the ability to tailor the analysis to specific contexts and enabling sensitivity analysis in the KI decision problem, as addressed in §4.

What lessons can decision analysts learn from the project? Section 5 contains a discussion of lessons we learned in this project.

2. Literature Review

This paper contributes to the growing literature on the multiple-objective decision analysis approach (Keeney and Raiffa 1976) and its applications. Von Winterfeldt (1987) provides an introduction to the use of an objectives hierarchy (which he calls value tree analysis). Keeney (1992) summarizes guidelines for constructing objectives. Kirkwood (1997) provides details for building multiple-objective decision models.

In some situations, decision problems involve multiple stakeholder groups with different objectives. Winn and Keller (1999, 2001) present a multiobjective, multistakeholder decision-modeling methodology to represent decision problems systematically and capture the complex and dynamic nature of evolving decisions. They apply this approach to Starkist's dolphin-safe decision and MacMillan Bloedel's no-clear-cutting forestry decision. Keeney et al. (1987) characterize an objectives hierarchy for the former West Germany's energy supply decision problem by combining the divergent views of multiple stakeholders together into one hierarchy.

In a multiple-objective decision analysis process, decision makers may need to quantify the performance of each alternative on the objectives. Keeney and Raiffa (1976) show that an additive or multiplicative decomposition can provide an appropriate value function for evaluating alternatives of a multiattribute decision problem. Edwards and Barron (1994) propose an additive value function to model a multiple-objective decision analysis process (see Kirkwood 1997, Chapter 4). Dyer and Sarin (1979) provide conditions under which single-attribute value functions may be separately assessed (and then combined with weights) for an additive multiattribute value function. Keller and Kirkwood (1999) use an additive value function to evaluate different plans for the merger of two professional societies in operations research and management science. This paper uses an additive value function to calculate the overall values for each planned option because it is relatively straightforward to decision makers.

Four weighting methods used in decision analysis are discussed in Borcherding et al. (1991): the ratio method, the swing weight method, the tradeoff method, and the pricing-out method. We use the swing weight method in this paper because it allows us to emphasize the need for explicit consideration of the range of possible performance on an objective by embedding sliders in a Microsoft Excel spreadsheet, which "swing" the weight. See Clemen (1996) and von Winterfeldt and Edwards (1986) for more discussion on the swing weight method.

The multiple-objective decision analysis approach has become a widely applied decision analysis tool to support decision makers in a variety of decision-making settings, e.g., terrorism protection planning, environmental issues, and nuclear power plant site choices (Ford et al. 1979). There is a large body of literature on decision analysis applications.[2] Many of these decision problems are complicated because they involve health and safety outcomes, and the implementations of alternatives usually are constrained by legal, political, or resource requirements. Rosoff and von Winterfeldt (2006) analyze possible terrorist attacks on the California ports of Los Angeles and Long Beach using a radiological dispersal device (a "dirty bomb") to shut down port operations, thus causing substantial economic and psychological impacts. Their multiple-objective analysis considers human health effects and economic consequences. Keeney and Ozernoy (1982) and von Winterfeldt

[2] See Corner and Kirkwood (1991) and Keefer et al. (2004) for surveys.

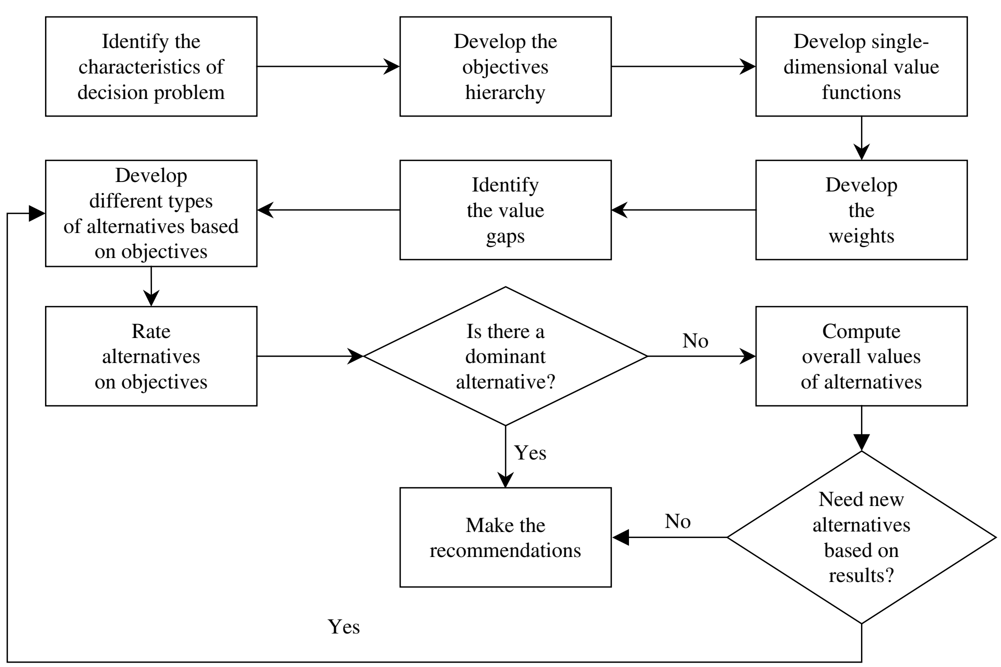
(1982) use decision analysis to set standards for different types of pollution, ambient carbon monoxide and offshore oil discharges, respectively. Keeney and Sicherman (1983) present a decision analysis model to study technology alternatives to generate electricity (e.g., coal versus nuclear) when several important evaluation criteria are considered, including economic, environmental, health, safety, and social factors. More recently, von Winterfeldt et al. (2002) employ a decision analysis process to assess and manage potential health risks from electric powerlines to the public. Flüeler (2005) proposes an empirically based and technically sound approach to dynamically manage radioactive waste over the long run.

Sensitivity analysis has been widely used in decisions under risk with the aid of decision tree software; however, there are only a few papers discussing sensitivity analysis in decisions under certainty in the literature. Merrick et al. (2005) use a multiple-objective decision analysis process to help develop potential plans to improve the quality of the Upham Brook watershed by identifying the largest value gaps between the status quo and the ideal situation, and then perform sensitivity analysis on the value gaps to test the robustness of the analysis to the changes in the weight of one specific objective. Our paper shows how to conduct a more extensive sensitivity analysis by allowing adjustments of the weights on two objectives simultaneously using sliders created in the spreadsheet program Microsoft Excel (Excel hereafter) to examine how the performance of different alternatives changes with the variations in the weights of either one or two objectives, which is a useful contribution to sensitivity analysis in decisions under certainty.

3. A Multiple-Objective Decision Analysis Process

In general, KI is considered to be an effective and safe protective measure against thyroid cancer. Given its efficacy and safety, a number of key stakeholders have called for a study of how to distribute and administer KI effectively in the event of a nuclear incident. A multiple-objective decision analysis approach is presented in this section to analyze the KI decision problem. A typical decision analysis procedure that is appropriate for evaluating the KI decision problem is illustrated in Figure 1.

Figure 1 **An Illustration of a Multiple-Objective Decision Analysis Approach**



3.1. Identifying the Characteristics of the Decision Problem

Stakeholders. The stakeholders for the KI decision problem are mainly government agencies and organizations, including the federal level (e.g., EPA, FEMA, and FDA), state and local authorities, and the general public. This characteristic makes health and safety decision issues different from most business and not-for-profit decision-making problems, in which governmental authorities are only a part of the multiple stakeholders, and they may not have a prominent impact on decision making. In contrast, for many health and safety decisions, governmental authorities usually represent the majority of the stakeholders and have relatively dominant power in the decision-making process.

"Scientific" Perspective. The study of the KI decision problem was initiated by government officials and agencies, but these political authorities called for a scientific perspective from the committee to analyze the distribution and administration of KI. The NRC committee members were experts on radiation, thyroid cancer, nuclear power plants, emergency management, and decision analysis, rather than policy experts. This underscores that a scientific viewpoint should play a significant role in terrorism protection and emergency decision issues. Further, stakeholders need the information from scientific reports to improve decision making or to justify their desired action plans.

KI Focus. We focus on KI as mandated by Markey's law. Perhaps because public opinion has framed KI as a "sure thing" in terms of protection from radioiodine, Congress mandated a sole focus on KI. In most cases, a terrorism protection or emergency planning problem involves a number of important issues to be discussed. However, sometimes decision makers are forced to focus on one or two issues, while other issues are ruled out of the analysis. While the NRC committee was charged to just consider KI plans, they broadened the discussion by considering the objective of minimizing harm from other aspects of a nuclear incident.

No Consideration of Cost. Minimizing overall costs is usually one key objective in most business decision problems, as well as in a number of municipal, societal, and environmental decision-making issues. However, for those decision-making situations involving serious health risks to the public, monetary cost often is not considered to be an important evaluation factor. In the KI problem, some government agencies and officials might refuse to allow cost to be considered in the evaluation process because, in their opinion or because of their agency's mandate, KI costs could almost be ignored compared to the potential severe outcomes to the radiation-affected population.

3.2. Developing the Objectives Hierarchy

As discussed above, the key decision makers are mainly government agencies and organizations, at both federal and local levels. Because the KI problem involves health and safety risks to the public, those governmental stakeholders tend to have some mutual interests and some agreement upon objectives, which turns out to be a positive factor and helps mitigate the conflicts among them. The overall goal is to "minimize radiation health risks to the public."

An objectives hierarchy can help key decision makers fully understand the characteristics of decision problems and better evaluate the advantages and disadvantages of different alternatives. According to the guidelines of constructing objectives for evaluating decision alternatives in Keeney (1992), objectives are designed to specify the preferred direction for performance improvement. Moreover, several papers also discuss methods to characterize and generate the objectives for a decision problem structure (see Buede 1986; von Winterfeldt 1987; Winn and Keller 1999, 2001). Based on these guidelines, an objectives hierarchy of the KI decision problem was developed for a hypothetical local region,[3] as shown in Figure 2.

This objectives hierarchy contains two top-level categories, three levels of objectives and subobjectives, and 16 objectives at the lowest level. From Figure 2, the general objective is to "minimize radiation health risks to the public," which is followed by two top-level subobjectives, i.e., to "minimize radioactive iodine risk to thyroid" and "minimize harm from other aspects of incident." This objectives hierarchy can help government officials quickly grasp the

[3] This is based on Table 7.2 in the book *Distribution and Administration of Potassium Iodine In the Event of a Nuclear Incident* (2004, p. 147).

Figure 2 Objectives Hierarchy of the KI Decision Problem for a Hypothetical Local Region

essence of the KI problem. Note that this is a sample objectives hierarchy for officials in a hypothetical local area surrounding a nuclear power plant. For example, as mentioned earlier, the developed hierarchy did not explicitly consider costs (because one committee member very strongly believed that costs should not be considered). However, costs are implicitly covered in the objective "KI procedures' resource use not excessive." The objectives hierarchy may vary from one region to another due to specific situations of each local area. Thus, local areas may need to augment or decrease the number of objectives, modify some objectives, etc. For example, in a specific region where evacuation could be completed within 24 hours in all scenarios, ensuring multiple-day supplies of KI in homes would probably not be a planning objective. Instead, the objectives might explicitly include "minimize mortality and morbidity due to radioiodine exposures to thyroids." Therefore, throughout the rest of this paper, we use a hypothetical local region surrounding a nuclear power plant to demonstrate the multiple-objective decision analysis approach for the KI problem.

3.3. Developing Single-Attribute Value Functions

In a multiple-objective decision analysis approach, the widely used additive value function is an appropriate method, assuming reasonable independence conditions hold,[4] to help further evaluate the KI decision problem quantitatively. Combining weights on the objectives and single-attribute value functions, the additive measurable value function can be written as

$$v(x_1, x_2, \ldots, x_n) = \sum_{i=1}^{n} w_i v_i(x_i), \tag{1}$$

where $v(x_1, x_2, \ldots, x_n)$ is the overall value for an alternative, x_i is an alternative's performance on the

[4] Such an additive value function assumes mutual preferential independence, difference consistency, and difference independence of one objective from the others. See Theorem 9.23 in Kirkwood (1997) based on the original Theorem 1 in Dyer and Sarin (1979).

Table 1 Sample Rating Scales for Evaluating the KI Decision Problem on the Subobjective of "Maximize KI Availability"

	Maximize KI availability		
	x_1: Max. availability for children and pregnant women residents	x_2: Max. availability for other residents	x_3: Max. availability for mobile population
Selected points on 0–10 rating scale			
$v_i(x_i)$			
0	1 dose/person in stockpile	0 doses/person in stockpile	1 dose/child in stockpile
5	50% have extra dose at home now	10% have extra dose at home now	1 dose/person in stockpile
10	85% have extra dose at home now	25% have extra dose at home now	25% have extra dose at mobile location now

*i*th objective, w_i is the weight assigned to the *i*th objective, and $v_i(x_i)$ is the single-attribute value function for the *i*th objective. (See Edwards and Barron 1994, Kirkwood 1997, Chapter 4, and Keller and Kirkwood 1999 for a review of the additive value function in decision analysis.)

To construct the additive value function, it is necessary to assess the single-attribute value functions that represent the attainment of different levels on an *evaluation measure* (i.e., the subjective ratings of one alternative's performance with respect to an objective). One method is to create rating scales to specify single-attribute value functions. Table 1 presents a sample of rating scales in the KI decision problem for the subobjective of "maximize KI availability."[5] In particular, each single-attribute value function can be scaled to place the values on a 0 to 10 scale, where 0 is minimally acceptable and 10 is best, depending on the degree of the attainment of the specific objective. Note that the end points of the rating scale need not be absolute ratings of the best and worst conceivable levels. Instead, they can be set to be the best and worst levels attainable with a reasonable set of options. For example, on the subobjective of "maximize availability for children and pregnant women residents," "1 dose per person in stockpile" may receive the lowest-level rating of 0 and "85% have extra dose at home now" may become the highest-level rating of 10, if this is the range for the set of options being considered.

3.4. Developing the Weights

We use the swing weight method in the KI decision problem, which is a theoretically correct way to assess and interpret the weights (Clemen 1996, Kirkwood 1997, von Winterfeldt and Edwards 1986). By convention, weights are normalized to sum to 100%.[6] The appendix displays an example with weights for each objective in the KI decision problem for a hypothetical local region using the swing weight method. For example, the subobjective of "maximize KI availability for children and pregnant women residents" has the largest normalized weight of 20%. Members of the NRC committee developed the weights as an illustrative example.

3.5. Identifying the Value Gaps

In this section, we identify the value gaps between the status quo and the perfect situation for the KI decision problem, which helps to develop potential alternatives for improvement (see Merrick et al. 2005 for more details on value gap analysis; Kirkwood 1997 for an example of a networking strategy decision using the status quo as one alternative). The status quo in the KI decision problem can be considered to be the situation in which there is no distribution (ND) of

[5] A complete table with sample rating scales for evaluating the KI decision problem on all the objectives is given in the Excel spreadsheet, which is available as an online supplement on the *Decision Analysis* website at http://da.pubs.informs.org/online-supp.html. The members of the NRC committee developed the rating scales as an example. Each local area would develop its own scales. Here we choose one subobjective as an example to illustrate the method of developing the rating scales.

[6] For example, suppose in the KI distribution problem that decision makers think the objective of "maximize KI availability for children and pregnant women residents" has the greatest weight, and all the remaining 15 objectives have the same size weight, which is 20% as great a weight as this objective. Then, using the swing weight method, the weight for this specific objective is $100/(100 + 0.2 * 100 * 15) = 0.25$ and the weight for each of the other 15 objectives is $0.2 * 100/(100 + 0.2 * 100 * 15) = 0.05$.

Table 2 A Sample Analysis of the Value Gaps in the KI Decision Problem

Objectives hierarchy	Weights (%)	No KI distribution	Value gaps	Ranking of value gaps
Minimize radiation health risks to public				
Minimize radioactive iodine risk to thyroid (51%)				
Maximize KI availability (26%)				
For children and pregnant women residents	20	0	2.0	1
For other residents	2	0	0.2	9
For mobile population	4	0	0.4	6
Optimize ability to take KI on time (16%)				
Number of people who know where KI is	5	0	0.5	3
Optimal time if no evacuation	5	0	0.5	3
Optimal time if evacuation	3	0	0.3	7
Storage to ensure stability	3	0	0.3	7
Minimize harm from inappropriate KI administration (9%)				
Correct dose given (and taken) for age	5	0	0.5	3
First dose not taken too late	3	10	0	11
Adverse side effects (nonthyroid cancer) minimized	1	10	0	11
Minimize harm from other aspects of incident (49%)				
Minimize harm pre-incident (11%)				
Avoid excessive resources use in KI procedures	1	10	0	11
Educate public to respond to nuclear incident	10	0	1	2
Minimize harm during incident (38%)				
KI procedures do not impede evacuation	10	10	0	11
Avert mortality and morbidity from radiation or accidents	18	10	0	11
Minimize panic and anxiety due to KI procedures	2	5	0.1	10
Simplify KI procedures before and during incident	8	10	0	11

KI.[7] In contrast, Utopia is defined to be an ideal situation for the KI decision problem that achieves each objective completely. As a result, each single-attribute value in Utopia reaches the highest rating of 10, and thus Utopia serves as an ideal reference point. Table 2 presents a sample analysis of the value gaps on each objective in the KI problem for a hypothetical local region.[8]

From Table 2, the performance of the status quo (i.e., no distribution of KI) is weak in terms of some objectives, such as "maximize KI availability" and "optimize ability to take KI on time," but excellent in terms of the upper-level objective of "minimize harm from other aspects of the incident." Using Utopia as the reference point, the value gaps can be identified by computing the difference of the weighted values between the status quo and Utopia for each objective, which is useful for development of effective plan options that can improve the attainment of the objectives with large value gaps. The value gaps for each objective and the ranking of the value gaps are included in Table 2 as well. The ranking of the value gaps is determined by the potential improvement in each objective, weighted by the normalized swing weight of the objective. For example, the largest value gap (ranked first) is on the subobjective of "maximize KI availability for children and pregnant women residents," followed by "educate the public to respond to nuclear incident." Two of the next-largest value gaps relate to optimizing the ability to take KI on time.

[7] Some U.S. regions do have KI distribution programs in existence. The choice of the no-distribution option as the status quo is for a hypothetical-region example. Similarly, the example bounds shown in the rating scales in Table 1 were chosen to be realistically achievable levels for a hypothetical region. The reasoning for specific "ideal" levels of the objectives should be thought out well by the local region. For example, 100% coverage may not be a realistic ideal, just as the ideal level of employment may be 95%, rather than 100%.

[8] The value gaps are computed by multiplying the weight on an objective (e.g., the objective of "maximize KI availability for children and pregnant women residents") with the difference in the ratings between the Utopia and the status quo (i.e., no distribution of KI) on that objective. Therefore, the value gap for the "Availability" objective is $20\% * (10 - 0) = 2.0$.

It is worth mentioning that the status quo performs perfectly on several lower-level objectives in the category of "minimize harm from other aspects of the incident," which implies that the value gap is zero for each of these subobjectives. This is due to a specific characteristic of the KI problem: No action can completely achieve all of the above subobjectives, e.g., maximizing KI availability will not minimize KI procedures' resource use. Therefore, for potential alternative KI plans suggested by the value gap analysis, which will be discussed in §3.6, some of them may score worse on these subobjectives than the status quo. In other words, the improvements for one new alternative on some other subobjectives relative to the status quo are achieved at the expense of the losses in these subobjectives. As a result, when evaluating the new KI plan options, we need to assess the trade-offs between the decrements they suffer on these subobjectives and the improvements they achieve on others compared to the status quo.

Note that Merrick et al. (2005) present the value gap analysis to identify future plans for the improvement of watershed quality; however, they do not further discuss what the potential programs will be and how to evaluate these alternatives. In this paper, we intend to enhance their technique by proposing a method to evaluate potential alternatives for a decision using the status quo as a benchmark, in which alternatives are created by referring to a value gap analysis. In particular, after using a value gap analysis to identify some potential alternatives, we compare the relative performances of the alternatives compared to the status quo. We will use this method to evaluate different KI alternatives in §3.7. Decision analysis applications rarely evaluate a status quo alternative when making recommendations. In the KI distribution context proposed alternatives may score worse than the status quo on some objectives. This feature is not unique to the KI distribution problem, so it may be that the status quo is inappropriately ignored in some other decision analysis applications. Thus, our work highlights the importance of considering the status quo, not only for a value gap analysis, but also when evaluating alternatives.

The feasible alternatives will likely be constrained by the resources needed (cost, personnel, etc.). For decision models that disregard costs due to political or other constraints, decision makers may want to conduct a subsequent cost-benefit analysis to determine the allocation of the resources on the improvements in the objectives based on the budget constraints because the same amount of resources may lead to different levels of improvements in each objective. In the KI problem, some of the NRC committee members believed the costs of KI distribution alternatives could almost be ignored as discussed earlier, due to the potential critical morbidity and mortality outcomes. However, local authorities will most likely need to consider them in the decision-making process.

3.6. Developing Different Types of Alternatives Based on Objectives

After identifying the value gaps, the next step is to develop effective options that focus on the improvement of those objectives with the largest value gaps. For the hypothetical local region, the committee seeks potential alternatives with large improvements in these objectives, including "maximize KI availability for children and pregnant women residents," "educate the public to respond to nuclear incident," etc. Meanwhile, according to the NRC Committee (2004) report, the best timeline to administer KI to the potentially affected population near nuclear facilities is just before, concurrently with, or within a few hours after exposure to radioactive iodine. To be responsive to the possible radioiodine releases of a nuclear incident and target the large value gaps, the committee developed three different sample alternatives for a hypothetical local region shown in Table 3.

Both the first and second options recommend the predistribution of KI to all or segments of the potentially affected population as part of the preparation for responding to a nuclear incident. In particular, the first plan ("MM") involves direct distribution to individuals or groups by mail or door to door, while

Table 3 Three Sample Alternative Plans of the KI Decision Problem

Plans	Description
MM	Predistribute KI tablets inserted in mass mailing to households in KI planning zone (KIPZ); additional stockpiles at reception centers
VP	Predistribute to individuals in KIPZ via voluntary pickup; additional stockpiles at evacuation reception centers outside KIPZ
RC	Stockpile at evacuation reception centers outside KIPZ

the second one ("VP") institutes voluntary programs for people to pick up KI at several locations, such as government agencies, county health offices, and local pharmacies. It is obvious that predistribution can make KI immediately available to people exposed to radioiodine at the time of a nuclear incident and help educate people about how to respond. This implies that these two options can improve the performance on the objectives with the large value gaps. However, predistribution also has some disadvantages. Based on the coverage statistics of KI predistribution programs in the committee report, significantly less than 50% of the potentially affected people have participated in past voluntary pickup programs. Another technical difficulty is how to determine the size or location of the geographic area, which is necessary for KI predistribution. In addition, those who receive KI from predistribution need instructions in its purpose, proper storage, and use. Finally, at the time of an incident, those who received predistributed KI might not be able to find it or may have grown older and no longer be in a sensitive age group.

Another primary option ("RC") is stockpiling KI at evacuation reception centers outside the KI planning zone (KIPZ), from which it is dispensed to the potentially affected populace before, concurrently with, or immediately after a radioactive iodine incident. This option not only increases the availability of KI to the affected population, but also leads to better control of KI administration and better recordkeeping. However, stockpiling does not perform well in the relatively rare instances in which evacuation would be impractical, undesirable, or delayed. There are some other relevant issues as well, such as the location of the stockpiles.

3.7. Evaluating the Alternatives and Making the Recommendations

With new alternatives developed, we provided the NRC committee with a template to evaluate different KI distribution plans using the status quo as a benchmark, as shown[9] in Figure 3. To be consistent with the prior abbreviations of the alternatives, we continue to use ND to represent the status quo in the KI problem, i.e., no KI distribution, for the rest of the paper.

We explained to the NRC committee how to use the template to evaluate different alternatives in the KI problem. The first step is to rate how well each option does on each objective by using the value-rating scales in Table 1. For instance, the MM option receives 10 for the objective of "maximize the availability of KI for children and pregnant women residents" because it would provide an extra dose of KI to at least 85% of the households and thus completely meet this objective. Second, it is important to check whether one option is dominant or dominated compared to other options over all objectives. This option has the first priority to be considered for implementation if it is a dominant alternative, or it should be seriously considered to be eliminated from the set of choices if it is a dominated plan. However, in most cases there is no dominating or dominated option due to the inherent conflict in satisfying the objectives. Therefore, the next step is to compute the overall value of an option by multiplying the weight of an objective with the rating of the plan's performance on the objective, then summing these products over all objectives via (1). As a result, the alternative with the highest overall value would be the one recommended by using a multiple-objective decision analysis approach.

Figure 4 displays the sample overall values of different alternative plans in the KI problem,[10] with five subcategories plotted as a stacked bar graph. We can see that for this hypothetical region, the overall values of the MM option (6.10) and the VP option (4.58) are both higher than that of the ND option (4.20), i.e., the status quo. However, it is interesting to find that the RC option (3.77) performs even worse than the ND option.[11] As discussed in §3.5, it is because the improvements of the RC option over the ND option on some objectives (i.e., "optimize ability to take KI on time," etc.) are offset by even larger decrements on some other objectives (i.e., "avert mortality and morbidity from radiation or accidents," etc.). This further

[9] The sliders in Figure 3 are not needed for evaluating different alternative plans in this section. We will discuss the use of sliders in §4.2 to demonstrate sensitivity analysis in the KI decision problem.

[10] The sample data used to compute the overall values of different alternatives are provided in the appendix. The spreadsheet given to the NRC committee was set up to automatically graph the overall values once weights and value ratings were entered.

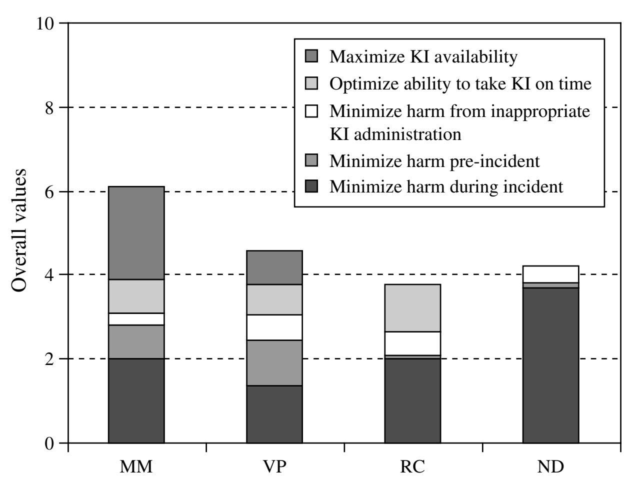
[11] Note that obviously, for a different local region, new alternatives may all perform better than the status quo.

Figure 3 **A Template for Evaluating the Alternative Plans in the KI Decision Problem**

Objectives	Calculated normalized weights (sum=100%)	Sliders to determine raw swing weights (0–100)	Raw swing weights (maximum=100, minimum = 0)	How well each plan meets each objective (Rate from 0 to 10 = best)			
				MM	VP	RC	ND
Minimize radiation health risks to public							
Minimize radioactive iodine risk to thyroid							
Maximize KI availability							
For children and pregnant women residents							
For other residents							
For mobile population							
Optimize ability to take KI on time							
Number of people who know where KI is							
Optimal time if no evacuation							
Optimal time if evacuation							
Storage to ensure stability							
Minimize harm from inappropriate KI administration							
Correct dose given (and taken) for age							
First dose not taken too late							
Adverse side effects (nonthyroid cancer) minimized							
Minimize harm from other aspects of incident							
Minimize harm pre-incident							
Avoid excessive resources use in KI procedures							
Educate public to respond to nuclear incident							
Minimize panic and anxiety due to KI procedures							
KI procedures do not impede evacuation							
Avert mortality and morbidity from radiation or accidents							
Minimize panic and anxiety due to KI procedures							
Simplify KI procedures before and during incident							
Overall value (Sum product of weights times ratings)							

underscores that it is critical to consider the status quo in decision problems. Therefore, for the hypothetical region considered in this analysis, KI predistribution in mass mailings would be recommended to decision makers for implementation. The MM option is most preferred because it improves the two objectives of "maximize the availability of KI to children and pregnant women residents" and "educate the public to respond to nuclear incidents" compared to the status quo by 10 and 8, respectively.

Figure 4 **Sample Evaluation of Different Alternative Plans in the KI Decision Problem—Base Case**



It is important to emphasize that this is a sample result for a hypothetical local region. After the model's recommendation is determined, it is good to consider whether additional alternatives can be constructed to improve on the existing alternatives. Note in particular that the three options considered above, along with the status quo, are not a complete list of feasible plans for a local area surrounding a nuclear power plant. For example, a combination of some mechanisms above may form another practical plan for KI distribution, such as mass mailing plus voluntary pick-up. For the sake of clarity, we concentrated on these three basic and generic options.

Furthermore, a local area may develop its own specific alternative actions for a KI distribution program based on the characteristics of that area, such as geography, population density, meteorological conditions, and other characteristics related to nuclear power plants. The final recommendations will probably be different if there are changes in the characteristics of the KI decision problem, such as distinctive regional characteristics, a different objectives hierarchy, a different allocation of weights, or a different list of improvement options. Thus, decision makers need to use the multiple-objective decision analysis approach carefully to assess decision alternatives based on the specific characteristics of the decision problem.

4. Key Insights from a Decision Analysis Perspective

Throughout §3, the KI decision problem has been analyzed and evaluated by using a multiple-objective decision analysis approach. Some key insights from the constructed model may help decision makers understand the decision situation more clearly and completely.

4.1. Create Ability to Tailor Analysis to Specific Contexts

One advantage of multiple-objective decision analysis is that the general approach can be applied to a set of similar decision contexts. While some adjustments and customization may be required for specific implementations, many terrorism protection and emergency health and safety decision-making problems share objectives with KI distribution. For example, "educating the public" is likely to be an objective of virtually all government programs.

In addition, decision analysis offers flexibility in accommodating different stakeholder views in a single model in a consistent way. The KI decision problem is a good example for addressing the ability to tailor a multiple-objective decision analysis approach to a specific context. Because there were strong and divergent opinions among stakeholders in the KI problem about what action plan would be best, the NRC committee members felt that they needed to allow flexibility so that local decision makers could be free to choose their best option. The committee decided *not* to recommend a single one-size-fits-all KI distribution plan. Instead, they decided to present in the appendix of their book the decision analysis template described here for local decision makers to use. For example, the analysis in §3 is assumed to be implemented in a hypothetical local region, surrounded by its KI Planning Zone (KIPZ). In practice, this local region could be like any of the following three stylized local areas surrounding nuclear power plants: urban sites, suburban sites, and rural sites. In particular, these three types of local regions differ from each other in the following aspects: population concentration and structure, transportation system, climate, school and medical system, and other features related to evaluating KI plans. For example, an urban KIPZ has a large, highly concentrated, permanent population that increases during the week from the influx of large numbers of workers and families from the surrounding area. In contrast, a suburban KIPZ usually contains a few rapidly developing counties that are on the outer fringes of a major metropolitan area, and it is populated primarily by a mixture of young families, while a rural KIPZ might have mainly agricultural uses with a thinly distributed and generally middle-aged population.

Therefore, KI plans in these three distinctive local areas are three different decision problems due to the tremendous regional differences; however, they can be considered to be a generic type of decision problem because the main issue for all of them is to assess KI plans in a specific local region. The multiple-objective decision analysis approach can be readily used in any evaluation process of these three local regions with the same modeling framework. No doubt the alternatives, the objectives hierarchy, or the rating scales may be different for different geographical areas, and different regional characteristics may affect the performance of the same KI plan. However, this approach is considered to be effective partly in that decision makers can use the same analysis process to assess generic types of decision problems by involving revised alternatives, objectives, and rating scales for each specific scenario.

4.2. Create Ability to Ask "What If?" Questions

Most terrorism protection and emergency decision problems involve health risks to different groups, and political disagreements—thus, it is unlikely that there is a unanimously agreed-upon desirable alternative to implement. Accordingly, decision makers need the ability to ask "what if?" questions to understand potential trade-offs and interactions among the alternatives on the objectives and choose the option that can best satisfy the interests of diverse stakeholders.

In the KI problem, at first some NRC committee members thought that a single plan would be recommended based on our initial analysis. After conducting extensive sensitivity analyses with the spreadsheet template displayed in Figure 3, the NRC found that no single plan would be sufficient for all regions. In particular, the weights would be unique for different regions, leading to different recommended distribution plans. The committee concluded that providing the template to the local regions' stakeholders would provide the required flexibility to adapt to unique circumstances.

4.2.1. One-Way Sensitivity Analysis. Corresponding to the more familiar sensitivity analysis in single-objective decisions under risk, we now conduct a one-way sensitivity analysis for this multiple-objective decision by varying the weight of one objective. It is well known that sensitivity analysis is a useful tool in single-objective decisions. However, there is not much discussion of sensitivity analysis in multiple-objective decisions[12] in the literature. In this section, we discuss the creation of sliders in Excel[13] that help people perform dynamic sensitivity analysis in decisions under certainty by moving the sliders to adjust raw swing weights on the objectives.

As mentioned before, Figure 3 presents a sample template with sliders that can be used to conduct sensitivity analysis in the KI problem. We prepared this Excel spreadsheet for the NRC committee members so they could examine the effects of changing weights on the model's recommended actions while they were preparing their recommendations. They were able to visually observe changes in the heights of the bars in the bar graph showing the overall values of each option as they moved sliders for the weights on the objectives. This real-time sensitivity analysis during the committee meetings allowed the committee to ask "what if?" questions as they deliberated on their recommendations.

In Figure 3, a slider with the scale 0 to 100 is created for adjusting a subobjective's raw swing weight without having to directly type in a new raw swing weight number. The sensitivity analysis assumes that as the decision maker changes the raw swing weight on an objective, the other raw swing weights remain constant. These changes lead to new normalized objective weights that get reflected in real time in a graph of alternative scores. The sliders allow stakeholders to see how variations in one of the objective weights impact preference among the options. We believe that using the raw swing weights with sliders helps emphasize the need for weights to depend on the possible range of performance on the objective.

We will use the following two objectives with the first- and second-largest value gaps to demonstrate our methods for one-way sensitivity analysis for the KI problem: "maximize KI availability for children and pregnant women residents," and "educate the public to respond to a nuclear incident." For brevity, we refer to these two objectives as the "Availability" objective and the "Education" objective throughout the rest of this section.

We first conduct a one-way sensitivity analysis for the KI decision problem to see how the overall values of the alternatives (i.e., mass mailing, voluntary pickup, stockpile at the evacuation reception center, and no distribution of KI) change with variations in the weight of one specific objective. For example, suppose decision analysts want to perform a one-way sensitivity analysis on the Availability objective. The sample data in the appendix serve as the base case for the sensitivity analysis in Figure 5.

We can dynamically graph the one-way sensitivity analysis results in the KI decision problem in Excel by moving the slider to adjust the raw swing weight.[14]

[12] There are fewer choices of proper software to perform sensitivity analysis on the weights in multiple-objective decisions, unlike the situation for single-objective decisions under risk with more software available (e.g., Treeage Pro 2006 and Precision Tree). Logical Decisions for Windows (LDW) is the only software we are aware of that is explicitly designed to allow people to perform two-way sensitivity analysis in multiple-objective decisions under certainty.

[13] In contrast to the special purpose LDW software, Excel is available on most people's computers and many use it on a daily basis. Therefore, it is desirable to be able to do sensitivity analysis in Excel. Other controls in Excel, such as spin buttons, could be used in place of scroll bars (sliders).

[14] For the Excel file, see Footnote 5.

Figure 5 One-Way Sensitivity Analysis on Raw Swing Weight of "Availability" Objective

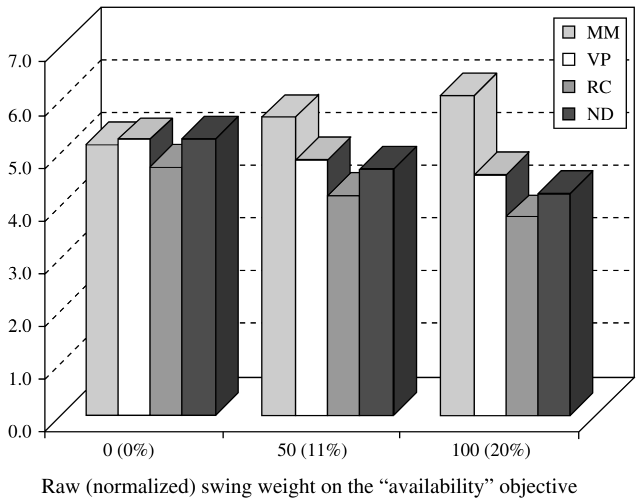
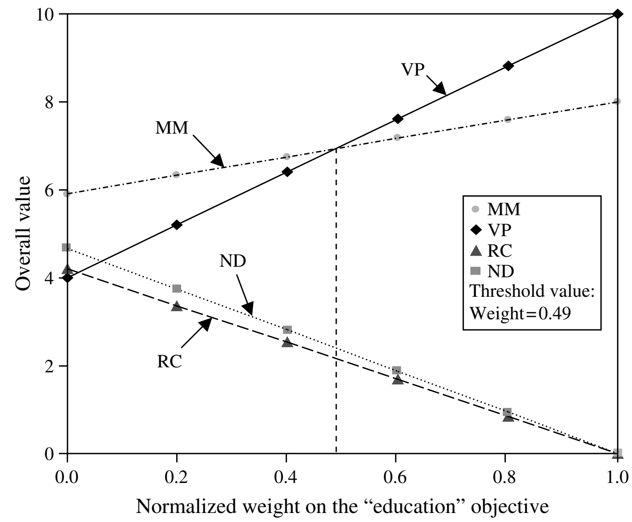


Figure 6 One-Way Sensitivity Analysis on Normalized Weight of "Education" Objective



As an example of the insights from sensitivity analysis, we present the results of varying the raw swing weight on Availability in Figure 5. The raw (normalized) swing weight for this objective is set at 0 (0%), 50 (11%), and 100 (20%) moving left to right across the figure, and the other raw swing weights remain at their base-case values (see the appendix). As the weight of Availability increases, MM becomes the most preferred option; the other options perform less well as the weight on Availability increases.

This result is not surprising because predistributing KI in mass mailings can greatly help improve KI availability for children and pregnant women residents, with a value rating of 10 compared to what the other three options can receive (e.g., the VP, RC, and ND options receive 2, 2, and 0 on the Availability objective, respectively). More interestingly, we find that no KI distribution (i.e., the status quo) is actually preferred when the Availability objective is considered to be least important with a zero for the raw swing weight. In addition, when the raw swing weight is 100, it coincides with the base case shown in Figure 4.

Clearly, in Figure 5, the *normalized* weight of the Availability objective does not vary from 0 to 1.0 (i.e., the range is indeed from 0 to 0.20). Sometimes sensitivity analysis on the normalized weight of one specific objective varying from 0 to 1.0 would provide more insights. Suppose we want to examine how the variation of the normalized weight on the Education objective affects the performances of different alternatives in the KI problem. Figure 6 presents a one-way sensitivity analysis on the normalized weight of the Education objective varying from 0 to 1.0. All the remaining objectives still retain their original proportions based on their raw swing weights in the appendix, so all weights add up to 1.0.[15]

From Figure 6, it is clear that the preference among different alternatives changes as the normalized weight of the Education objective varies. In particular, if the weight increases, the overall value increases for the MM option and the VP option, while the overall value decreases for the RC option and the ND option. Furthermore, both the RC option and the ND option are never the best, and the VP option becomes more and more preferable over the MM option when the weight is greater than 0.49. This is mainly because KI predistribution via voluntary pickup is a more effective way to educate people to respond to nuclear incidents than the other three alternatives (e.g., the VP option receives a rating value of 10 on the Education objective). Note that the base-case evaluation result in Figure 4 is consistent with the one-way sensitivity analysis here: In the base case

[15] For example, suppose the normalized weight on the Education objective is 0.50. Then the normalized weight on the Availability objective would be $(1 - 0.50) * 100/450 = 0.111$.

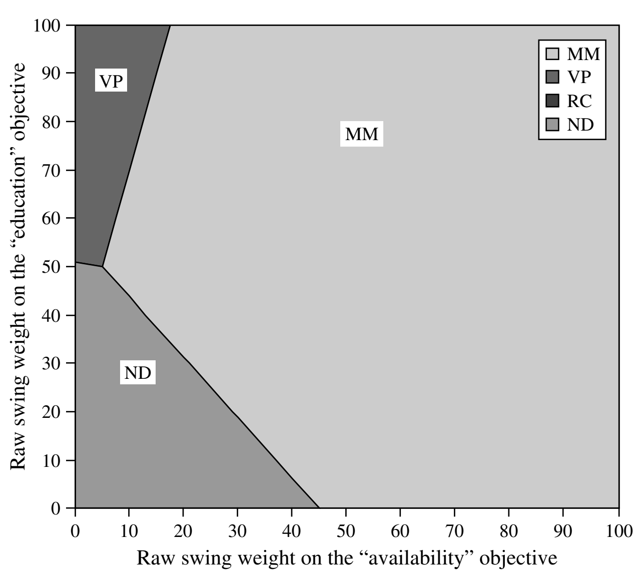
the weight on the Education objective is 0.10 and the MM option is the best.

4.2.2. Two-Way Sensitivity Analysis. Two-way sensitivity analysis in multiple-objective decisions can test how the performances of different alternatives change as the weights of two objectives vary. Suppose we want to perform a two-way sensitivity analysis on the Availability objective and the Education objective. Again, we use the sample data in the appendix as the base case. To conduct two-way sensitivity analysis, we vary the raw swing weights of both objectives from 0 to 100 and keep the raw swing weights of the remaining objectives fixed. Figure 7 presents a two-way sensitivity analysis on both the Availability objective and the Education objective.

We gain several interesting findings from Figure 7 regarding this specific hypothetical local region. First, the MM option (i.e., KI predistribution in mass mailings) performs well on both the Availability objective and the Education objective, and is the recommended choice when the weight on the Availability objective is high (no matter what the weight is on the Education objective).

Second, suppose the weight on the Availability objective is low. Then, when the weight on the Education objective is also low, no KI distribution (i.e., the status quo ND) becomes the recommended choice.

Figure 7 **Two-Way Sensitivity Analysis on the "Availability" Objective and the "Education" Objective in the KI Decision Problem**



In contrast, the VP option (i.e., KI predistribution via voluntary pickup) is the recommended choice when the weight on the Education objective is high. The VP option has a benefit on the Education objective because communications would go to households, but it does not perform well on the Availability objective, because people tend not to pick up their allocated doses when distribution is voluntary and people have to pick it up themselves.

Third, the RC option (i.e., stockpile at evacuation reception centers) is never the best for this specific hypothetical example. However, it may be the recommended choice for a different local region.

We have demonstrated sensitivity analysis by varying weights. Jiménez et al. (2003) developed a software system for multiattribute utility evaluation based on imprecise weight assignments, to be used to evaluate how much the entire set of assessed weights could change within a constraint of maintaining the assessed rank order of the weights and still have the same top-ranked plan remain top ranked.[16] Such a system will provide even greater insights on the suitability of apparently top-ranked plans.

5. Lessons Learned for Decision Analysts

We learned a number of lessons for decision analysts while working with the NRC committee. First, we found that there are substantial advantages of using sliders in Excel for real-time dynamic sensitivity analysis with the clients. The committee members particularly liked being able to dynamically change the bar graph in Figure 4 by moving the sliders on the raw swing weights on the objectives. We believe that it was important for the committee members to have the ability to visualize that specific regions could tailor their analysis to their situation with this flexible decision template.

Second, it is important to maintain flexibility in the analysis approach you will use to meet the client's

[16] We thank an anonymous referee for pointing this out and demonstrating via a simulation using the Jiménez et al. (2003) system that assuming the rank orders of the swing weights in our example and the sample data in the appendix, the mass mailing option is preferred for most of the possible sets of weights that satisfy the rank ordering of the weights. We emphasize that the specific weights and data would vary for each actual local region.

needs. At first blush, this project appeared to be well suited to assessment of probabilities about key uncertainties and computation of costs of different KI plans for use in a decision-under-risk problem solved with decision trees. Although a few of the committee members were well acquainted with risk analysis methods and were eager to carry out such an analysis, such an approach was unacceptable to some committee members, who rejected any detailed analysis of costs or uncertainties. Therefore, a multiple-objective decision-under-certainty model was proposed and found to be a useful aid.

Finally, even if the client does not support the use of a technique, it could be used in a subsequent analysis not sponsored by the client. In particular, a follow-up decision under risk analysis (Clemen 1996) could be conducted by local KI planning regions or by decision analysts acting on behalf of the public at large. A decision tree could be constructed to combine sequences of uncertain events to determine the probability of an entire path, from nuclear incident to radioactive iodine exposure to health and cost outcomes. Such an analysis would be similar to that done on the terrorism protection issue of the evaluation of countermeasures to Man-Portable Air Defense Systems by von Winterfeldt and O'Sullivan (2006) and in nuclear power plant probabilistic risk assessments (Kazarians et al. 1985). Consequences could be evaluated in terms of both health outcomes and monetary costs, such as the cost of production or purchase of KI,[17] the size of the population to be provided with KI, and the number of doses to be provided per person. Health and safety impacts would include averted thyroid cancer morbidity and mortality, averted or indirectly caused morbidity or mortality due to accidents, and adverse health effects of KI use. There are different means for placing a value on such health and safety impacts, including direct assessment of single-attribute value functions or "pricing out" the health outcomes in equivalent monetary amounts. Local officials could begin such a pricing-out procedure by starting with a benchmark of the amount that U.S. government decision makers have been willing to spend in the past to save a statistical life-year; see Tengs et al. (1995).

[17] If KI were to be produced by the government without profit, it would cost under $0.50 per dose. KI is available to the public for around $1/adult dose for one day's protection, based on the June 2006 price from the website http://www.nukepills.com. Children take half of an adult dose or less, depending on their size.

6. Conclusion

A decision analysis process can help stakeholders to better understand characteristics of a decision problem and to evaluate potential alternatives. Throughout the discussion of the KI decision problem, a multiple-objective decision analysis approach was used to assist NRC committee members in analyzing different alternatives. In addition, sensitivity analysis using sliders in Excel created a way for committee members and local decision makers to ask "what if?" questions to analyze the decision problems more completely, and thus provided them with some key insights to improve decision making. Some committee members liked the spreadsheet-enabled decision analysis approach so much that they kept the file to use in their own work. The KI problem shows how decision analysis can complement risk assessment and evaluation to improve terrorism protection and emergency health and safety decision making.

The reactions to the NRC report from local stakeholders were also positive. For example, a state Radiological Emergency Preparedness Coordinator wrote (e-mail message to author):

> The report is perhaps the most balanced and accurate summation of the issues associated with KI distribution that I've seen in more than a decade of involvement with the subject . . . it is gratifying to see that the report . . . addresses the technical and medical aspects as well as the practical and social considerations involved . . . the report will prove to be a valuable tool in helping public policy makers confront the questions and concerns of many on both sides of this debate.

Finally, many terrorism protection and emergency decision-making problems involve governmental authorities representing key stakeholders. Our multiple-objective decision analysis of the KI problem demonstrates one way that decision analysts can play a significant role in structuring consideration of such major political issues.

An online supplement to this paper is available on the *Decision Analysis* website (http://da.pubs.informs.org/online-supp.html).

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Appendix. Sample Data to Evaluate Different Alternatives for a Hypothetical Local Region

Objectives	Normalized weights (sum = 100%) (%)	Raw weights (100 = max, 0 = min)	Description of how well each plan meets each objective (Rate from 0 to 10 = best) MM	VP	RC	ND
Minimize radiation health risks to public						
Minimize radioactive iodine risk to thyroid (51%)						
Maximize KI availability (26%)						
For children and pregnant women residents	20	100	10	2	0	0
For other residents	2	10	10	1	0	0
For mobile population	4	20	0	10	0	0
Optimize ability to take KI on time (14%)						
Number of people who know where KI is	5	25	0	5	10	0
Optimal time if no evacuation	3	25	10	3	0	0
Optimal time if evacuation	3	15	10	10	10	0
Storage to ensure stability	3	15	0	0	10	0
Minimize harm from inappropriate KI administration (9%)						
Correct dose given (and taken) for age	5	25	0	5	10	0
First dose not taken too late*	3	15	10	10	0	10
Adverse side effects (nonthyroid cancer) minimized	1	5	0	8	10	10
Minimize harm from other aspects of incident (49%)						
Minimize harm pre-incident (11%)						
Avoid excessive resources use in KI procedures	1	5	0	5	7	10
Educate public to respond to nuclear incident	10	50	8	10	0	0
Minimize harm during incident (38%)						
KI procedures do not impede evacuation	10	50	0	5	10	10
Avert mortality and morbidity from radiation or accidents	18	90	10	3	0	10
Minimize panic and anxiety due to KI procedures	2	10	10	5	10	5
Simplify KI procedures before and during incident	8	40	0	3	10	10
Sum of weights	100	500				
Overall value (Sum product of weights times ratings)			6.10	4.58	3.77	4.20

*The value rating of 10 for the "first dose not taken too late" under the status quo of "no distribution" is debatable. No one gets it too late, so a person would not be likely to protest later that the government should have gotten the KI to the public more quickly, because it had decided it was worthwhile to make it available. Each local area is advised to use its own approach to determining the value function scales.

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