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FIRST PRIORITY, AN EXPERT SYSTEM FOR PRIORITIZING (U)

by

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Abstract

Prioritizing lists of diverse entities such as projects, tasks, documents, recommendations or physical locations is a necessary part of business at DOE facilities. A key issue is whether or not this necessary and problematic activity of prioritizing is performed in a methodical, defensible and traceable manner, especially when the goals are hard to compare and measure. Sound methods of prioritizing are often not employed because of their complexity or difficulty in implementation. To overcome these problems, WSRC is developing an expert system, First Priority, which will provide individuals or committees a comprehensive process for prioritizing lists of any sort. A set of windows, editors, and pull-down menus guide the user in building and modifying an (inverted) weighted tree structure which represents the goals the prioritization is to advance. The process of building this structure is divided into four stages which are generally followed in order. These stages are:

- building the goal tree,
- ordering the goal tree nodes,
- weighting the goal tree nodes, and
- designing measurement methods for each leaf node.

Based on the resultant structure an evaluation module is generated to evaluate the items of the list. This list is then prioritized and grouped into user-defined categories, taking into account cost or other resources. Additional First Priority tools provide sensitivity analysis, graphical displays of data, and reporting.

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Introduction

Prioritizing lists of such diverse entities as projects, tasks, documents, recommendations or physical locations is a necessary part of business at DOE facilities. Planning, scheduling and resource allocation require prioritizing implicitly since everything cannot be done at once, and perhaps some things not at all. There are two key issues which need to be addressed in this necessary and problematic activity of prioritizing. First, is the prioritizing performed in a methodical, defensible and traceable manner, that is, are sound methods of prioritizing being employed? Because of the complexity and difficulty in implementation of many prioritization methods, this is not always the case. Second, there are a number of seemingly quick methods which are demonstrably unsound and should be avoided. To fill the need for suitable methods of prioritizing at the Savannah River Site (SRS) we are developing an expert system, First Priority. This system will provide a comprehensive process for prioritizing lists of any sort in terms of criteria or goals, even when the goals are difficult to compare and measure for.

Currently, a limited prototype of First Priority exists and is used for demonstration purposes. The body of this paper provides a description of the underlying methodology followed by a description of the full-featured implementation of First Priority as if it already existed.

A Description of the Methodology

First Priority is basically a Multi-Attribute Utility analysis (MAU) [1],[2], with certain key differences which make it more suitable for most (if not all) of the prioritization tasks at SRS. The goal is to make formal prioritizations at SRS easier to do and understand, and make the results of these prioritizations easier to trace and explain. The methodology follows the MAU format of taking into account several attributes or goals and breaking them down into measurables within a tree structure. It is mainly in the elicitation process for this goal ranking, the process of defining measures, and the specific technique in working with committees, that First Priority differs from the usual MAU systems.

The First Priority methodology involves four steps or functions. When committees are involved these are performed by up to four subgroups of the committee rather than an individual. These steps, which are briefly described below, build the prioritization structure which is used to rank the list of items. More detailed descriptions of committee interactions, as well as discussions of some related decision theory issues will be left to another publication. Our intent here is to give a brief description of the methodology followed by its implementation as a user-friendly, interactive system.

Step 1. Define the List.

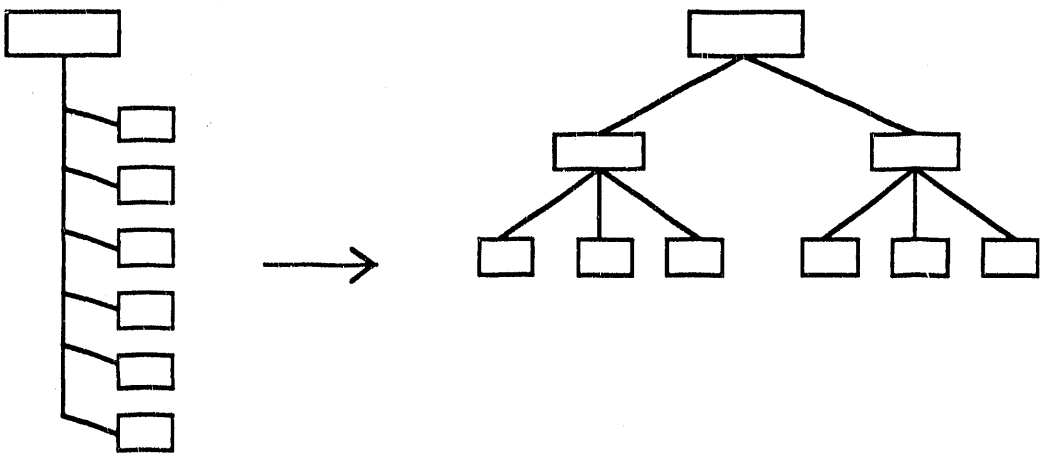
The list to be prioritized must be clearly defined, or at least the nature of the list understood. Defining the list of items, or at least understanding it is not always easy to do.

Step 2. Define the Goal Tree.

The Goal Tree can be represented by an inverted tree structure with the most general or highest level goals at the top broken down into more "concrete" subgoals immediately below, and finally terminating in measurable subgoals, (i.e., leaf nodes). These subgoals are headings under which one can construct measures by which the items of the list can be evaluated. The requirements on this tree are that it codify in terms of goals, all the major

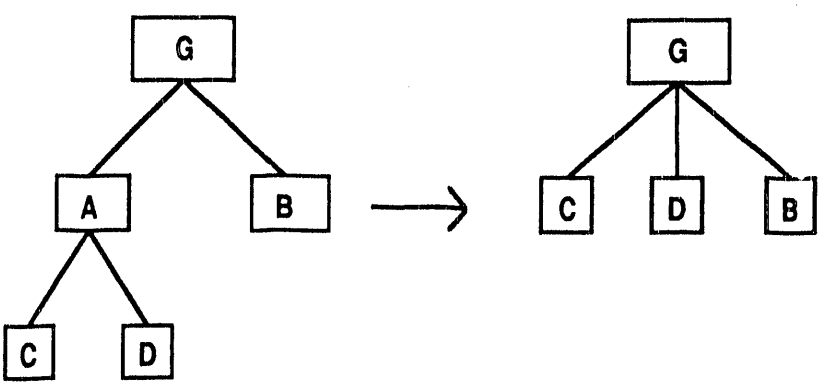
issues in a concise structure, with no redundancies. The idea is to establish clear goals and perform a prioritization of the list which best advances these goals.

The number of goals at each level should not exceed more than five or six. First Priority will check for this at each level. If the number of subgoals is initially larger, First Priority will ask the user to check them for redundancy and interdependence. Hopefully, one or more may be dropped or combined with no essential loss. If no such reduction is possible, First Priority will suggest that these subgoals be divided into two or more distinct subclasses with the concepts defining these subclasses translated into new intermediate parent goals.



These new intermediate subgoals often, in effect, point out categorical distinctions that could make the relative weighting stage easier. This process can be referred to as "structural elaboration".

On the other hand, structural simplifications can occur as follows. It may be that a pair of subgoals, A and B, under the same parent goal G are superfluous. An indication of this possibility occurs when one of these subgoals, say B, has no offspring subgoals, while the other, A, does. In this case the subtree might be clarified by the simplification resulting from combining B with the offspring of A (provided they are not too numerous) and removing A.



First Priority will look for and alert the user about these and other structural forms and redundancies that might detract from having an optimally efficient structure.
It is not advisable to have a committee as a whole attempt this goal tree,which at first would be only a *candidate* goal tree. Instead, a small subroup would have this task, and would bring the structure, which First Priority helps them build, to the committee for approval in terms of accuracy and completeness.

Step 3. Weighting the Goals.

Before relative weights can be assigned to the goals within a sibling group (i.e., a group of related goals which define some higher level goal.), the order of the goals within the group must be established. This is a simple non-quantitative ordering; it must not extend across sibling groups. First Priority will assist the user in the process by allowing only one group of siblings to be considered at a time .

After the order of the goals has been established for all the sibling groups, First Priority will help the user assign the numerical weights. The numerical weights are arrived at by using a scale adapted from Thomas Saaty [3] which "...has been validated for effectiveness, not only in many applications by a number of people, but also through theoretical comparisons with a large number of other scales" [4]. This scale is part of his system which one could use to try to rank up to about seven items. For prioritizations with a large number of items, it becomes impractical since it ultimately calls for n(n+1)/2 comparisons with n items. However, the number of goals in each sibling group is small (usually less than six). This manageable number allows us to take advantage of this reasonable scale. The scale is applied as follows:

- Given a ordered set of goals {A,...,E,F,G}, select the goal G that was judged to be the least important and assign G the value of 10.

- Assign a relative value to the next more important goal, F, according to the choice of the most applicable statement below, with appropriate interpolations when needed.

Value (F) = 3 * G if experience and judgment slightly favors F over G.

= 5 * G if experience and judgment strongly favors F over G.

= 7 * G if F s strongly favored over G and its dominance is demonstrated in practice.

= 9 * G if the evidence favoring F over G is of the highest possible order of affirmation.

The goal F now takes the place of G as the less important goal and the next more important goal, E, is compared to it in the same manner. The process continues up through the most important goal.

Assigning relative weights to the goals should involve the highest authorities that can be called upon who understand the issues and the nature of the list, and who can be expected to be reasonably objective in this task. These weights may or may not be sensitive and confidential and must be handled accordingly.

Step 4. Define the Methods of Measure.

Now that all the important concerns and goals have been organized in a relatively weighted structure, there needs to be a system of measures devised in order to evaluate each list item in terms of this structure. First Priority assists in every aspect of this task. Recall that the leaf node subgoals represent the most concrete and measurable definition of the top level goals, so we want measures built for each of these leaf nodes. Some measurable subgoal formulations, may have a simple multiple choice "choose the statement that best applies" type of format as their measure design or " scale ". In this case, relative values (or weights) must be associated with each such statement with a default value of zero for the "does not apply" case. If the variables for the particular subgoal are continuous, an appropriate function associating the measure of the variable (to be judged by the evaluators) with its utility value (util) (decided upon by the designers) would be designed.

Whether quantitative or qualitative measures are designed, First Priority will normalize the associated relative values to the relative value of the leaf node. The relative value of the leaf node is likewise normalized to the normalized relative value of the parent goal, and so on up the tree. The top level goals will be normalized to 1 and the expression used to compute the overall value for each list item is simply:

$$\textbf{Value}(\text{item}) = \mathbf{V}_1(\text{item}) + \mathbf{V}_2(\text{item}) + \ldots + \mathbf{V}_k(\text{item})$$

where each V_i is the sum of the normalized leaf node item values under the i-th top level goal.

First Priority provides the instructions, examples, layout and graphing tools to help make all of the above easy.

Stand Alone Evaluation Module

First Priority will generate an evaluation module for use by the evaluators, i.e., the group which will take the "scales" created by the measure designers, and measure each item of the list to be prioritized. This module provides an interactive computer interface through which the evaluators answer the questions which were constructed by the measure designers. From their answers, First Priority generates a completely prioritized list; each list item is tagged with its overall value. The item values can be divided by their associated cost in dollars or other resources and thereby generate the prioritization in terms of these ratios of value/cost or value/resource. This would be represented graphically and could be grouped into collections such as "top priority items", "very important items", "moderately important items", etc.

Interface Description and Interaction

First Priority consists of two environments, the Design Environment and the Runtime Environment. Each environment is a system of windows, editors, and pull-down menus which are used to construct and work with a custom prioritization project. The project can be developed in an Individual Mode or a Committee Mode. The two modes are basically similar except that in the Committee Mode special instructions are given at various points.

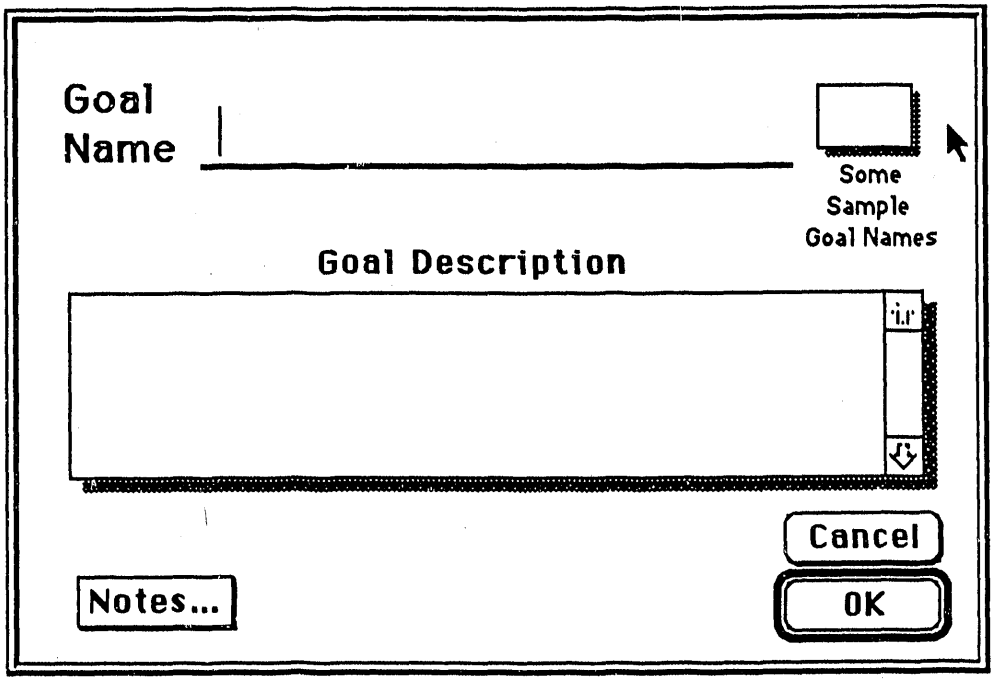
The Design Environment is used to construct and modify the weighted tree structure described above. This tree structure represents the issues and goals which the prioritization is to advance. The process of building this structure is divided into four stages which are generally intended to be followed in order. Recall that these stages are:

- building the goal tree,
- ordering the goal tree nodes,
- weighting the goal tree nodes, and
- designing measurement methods for each leaf node.

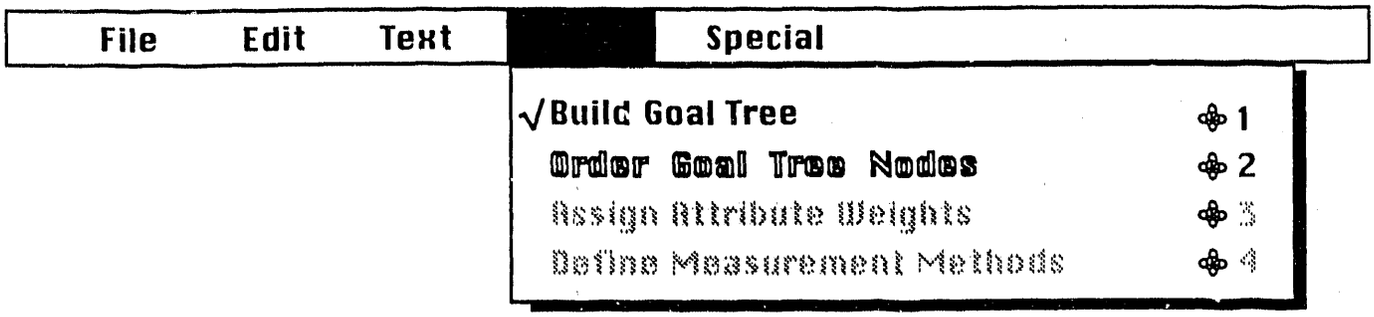
Context sensitive instructions are available for each stage through an instruction window; more detailed information is given in a separate help window. Also, First Priority contains what is referred to as the First Priority–Expert which "watches" the progress of the project and makes suggestions and alerts the user to procedural violations.

The Runtime Environment is a special environment that is used to create and run the evaluation module (i.e., the interface which First Priority builds, based on the measures which were defined in the Design Environment) of the custom prioritization project. From the evaluator's point of view, the Runtime environment is a complete application for a specific prioritization project. This custom project is used to evaluate the items of a list, then prioritize and group them into categories which have been defined by the user. Sensitivity testing, graphing, and reporting tools are also present in this environment.

The basic operation of First Priority is presented in story book form on the following pages.

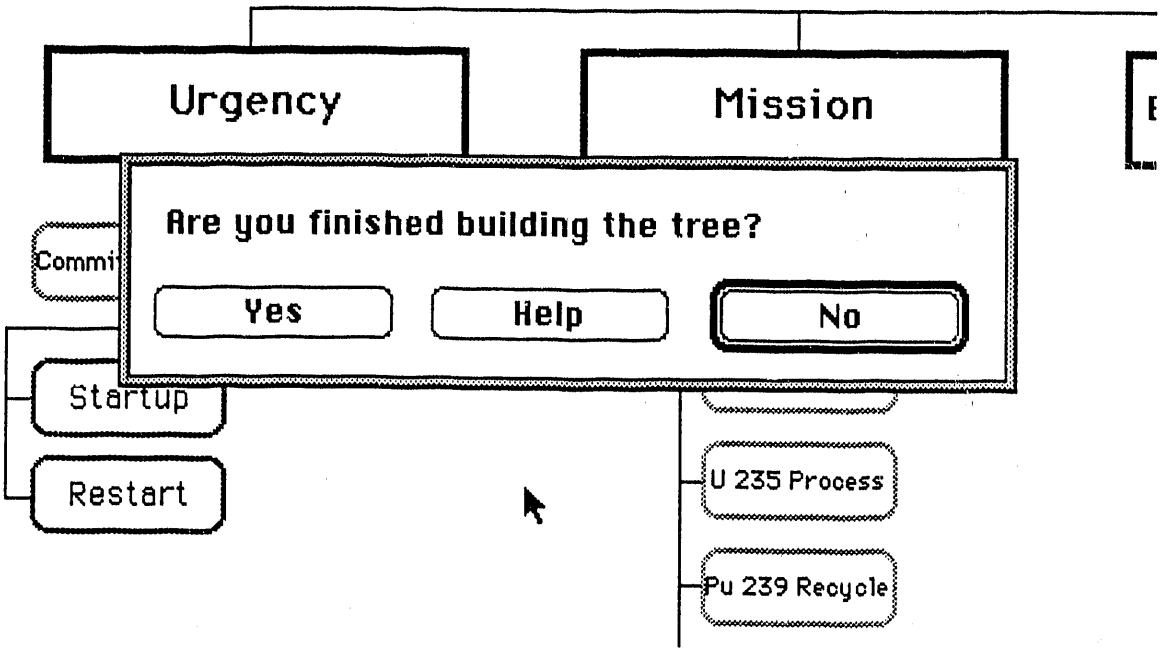


When a new prioritization project is begun, First Priority starts the user in the Build Goal Tree stage. The drawing surface is blank and the menu bar contains the Goal menu. Selecting New Goal from this menu or if a goal is currently selected, New Subgoal, causes the goal information box to appear. (Pressing the command-N key combination is a short cut for this.) The user enters the goal name, description, and notes, and clicks OK. First Priority places the goal in the appropriate location in the goals tree. For example, if a subgoal has been created, it will be drawn under its parent and to the right of its next oldest sibling (if there is one).



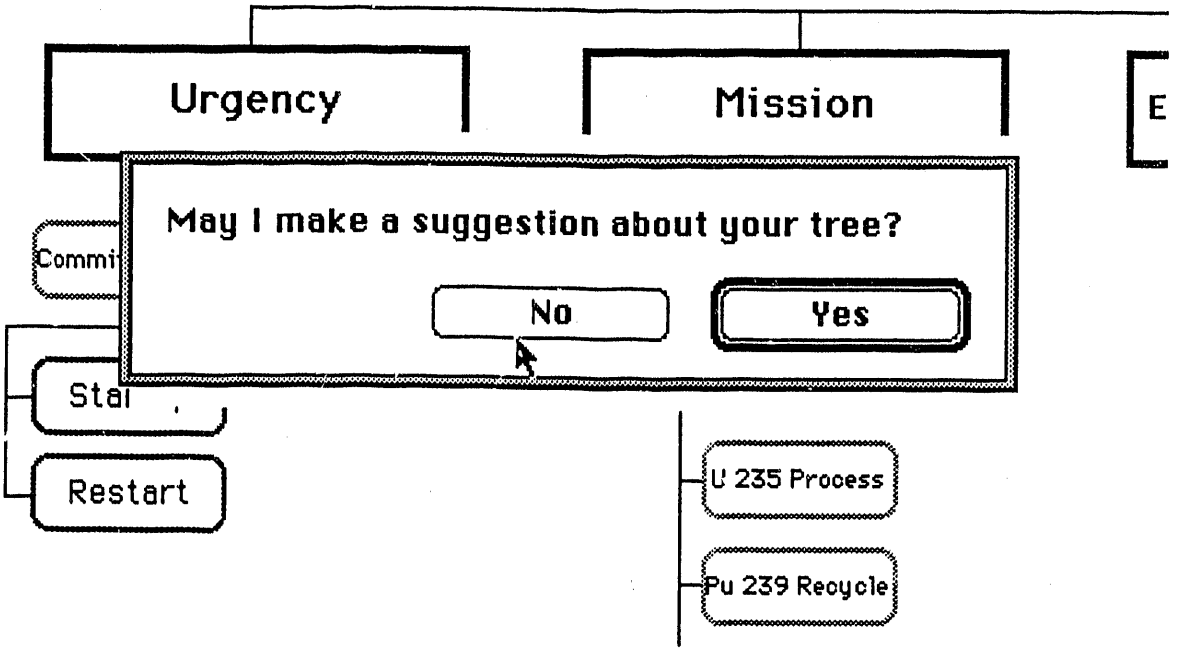
Stage menu

The Stage menu has four items in it. These are: Build Goal Tree, Order Goal Tree, Weight Goal Tree, and Define Measurement Methods. The current stage is indicated in outline font in the menu. Any other available stages appear in normal font, while unavailable stages are grayed. Completed stages are indicated with a check-mark to left of the item.

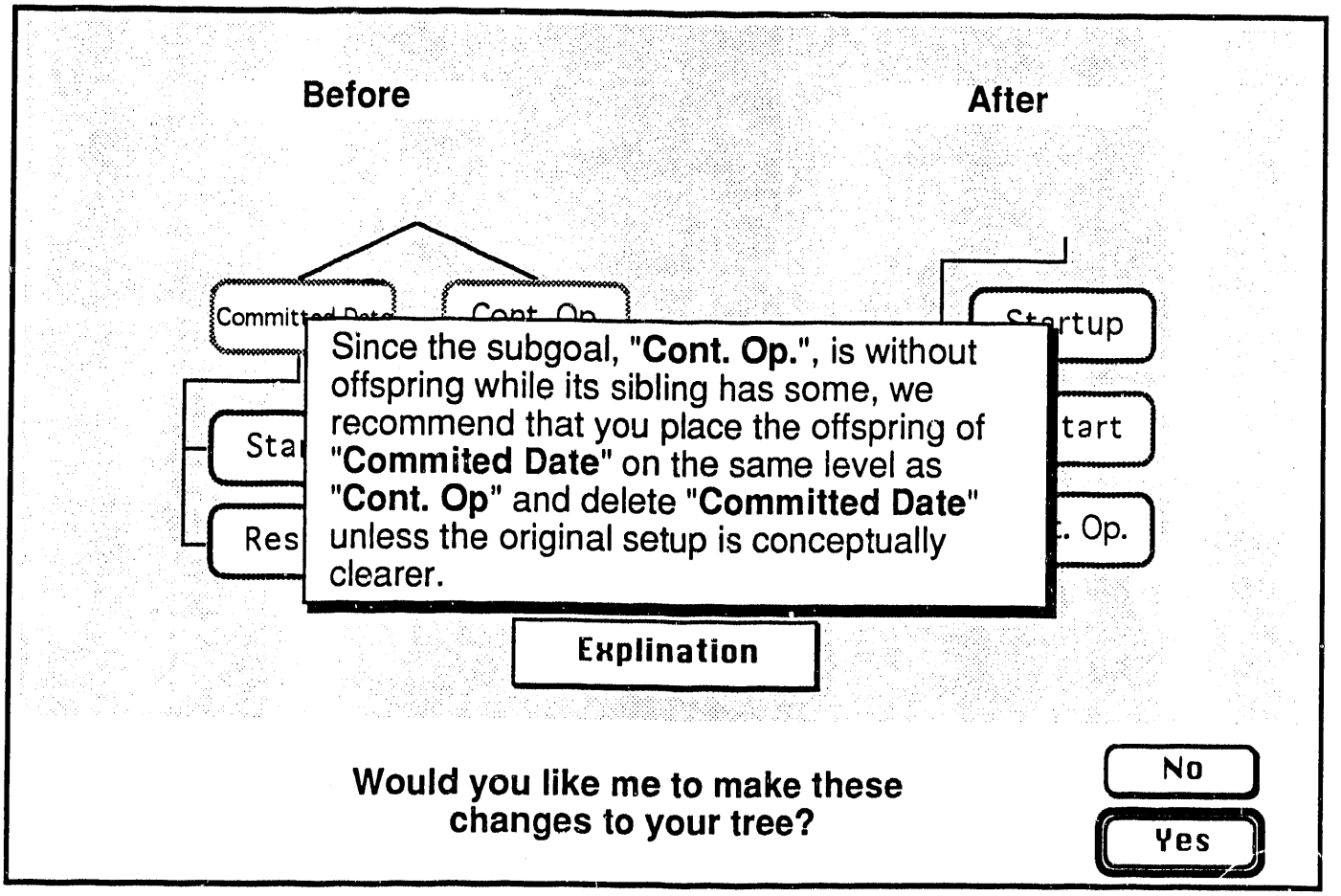


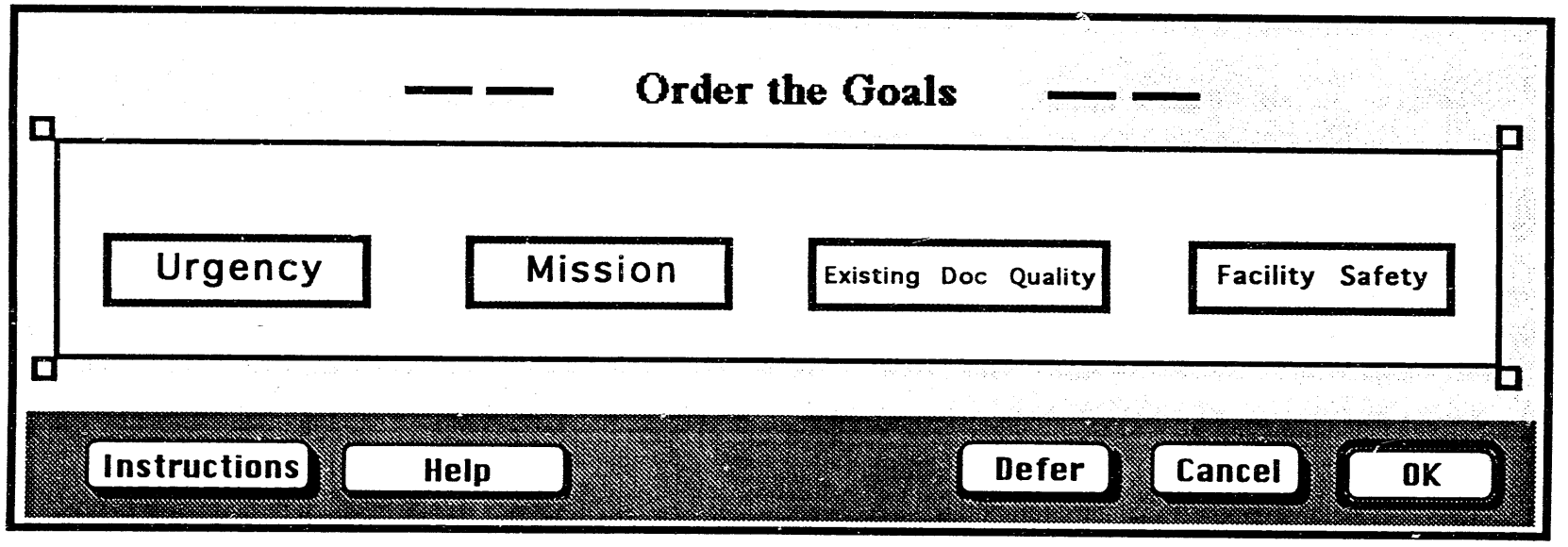
When the user is finished building the goals tree, he selects Order Goal Tree from the Stage menu. First Priority checks the structure of the goals tree against a list of rules.

If any violations of the rules are discovered, First Priority alerts the user, ...



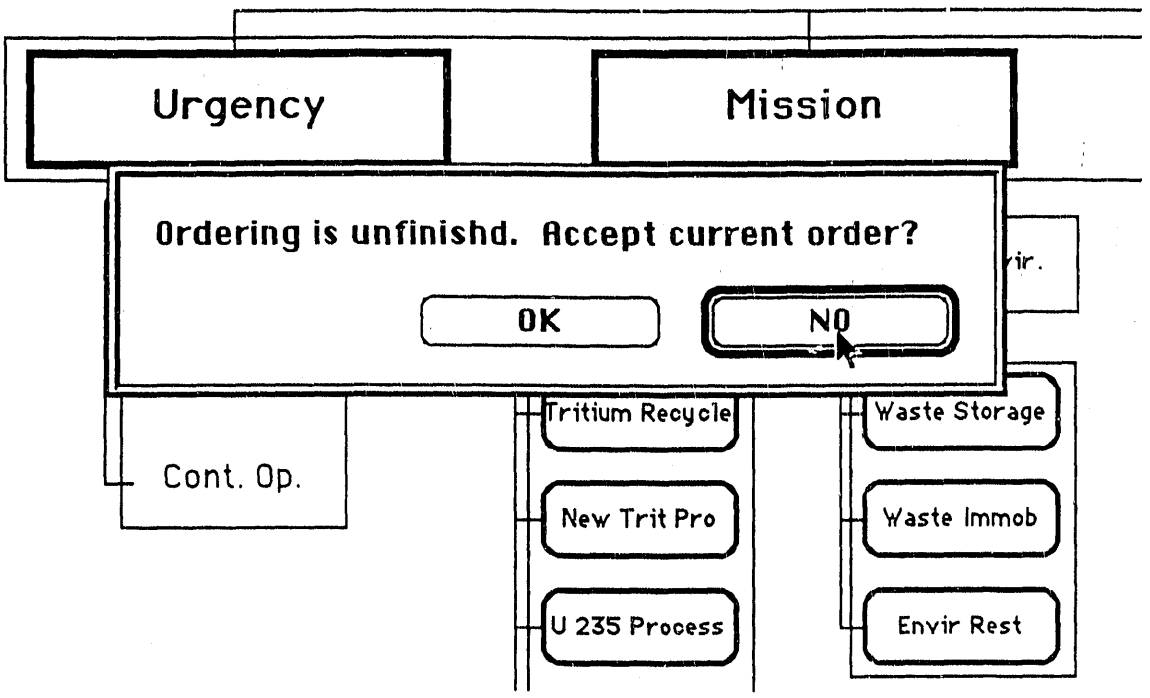
... and attempts to make a recommendation; the user has the option of accepting or rejecting it. If the recommendation is accepted, First Priority makes the appropriate changes to the goals tree.



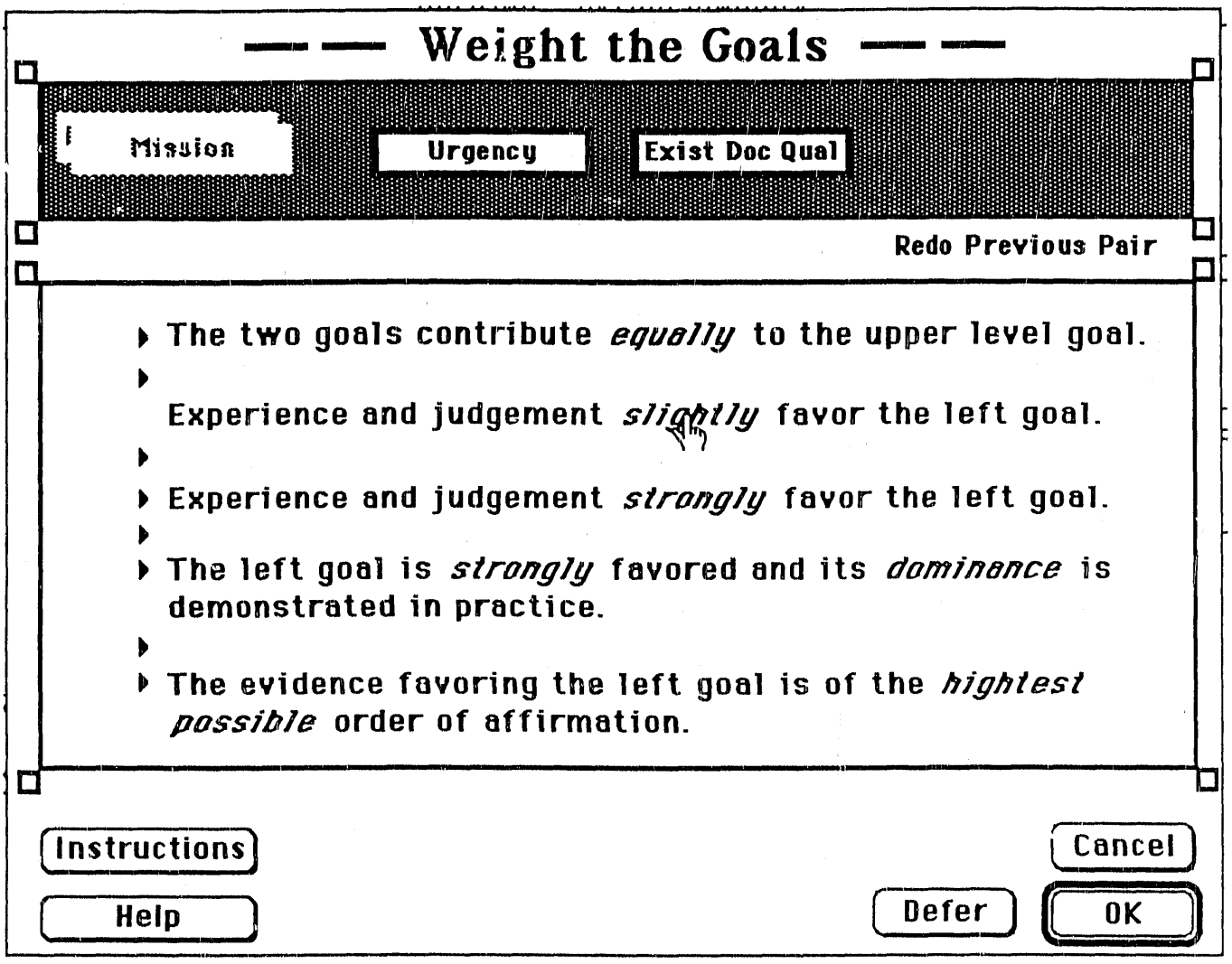


On entering the Order Goal Tree stage, First Priority, displays the goals tree with a colored box around each of the sibling groups and the Goal menu is replaced with the Order menu. The user selects a sibling group by clicking the mouse on it, changing the color of the box. Selecting the Order Goals item from the Order menu opens the editor window for ordering the goals. (Double-clicking on the group box is a short cut.)

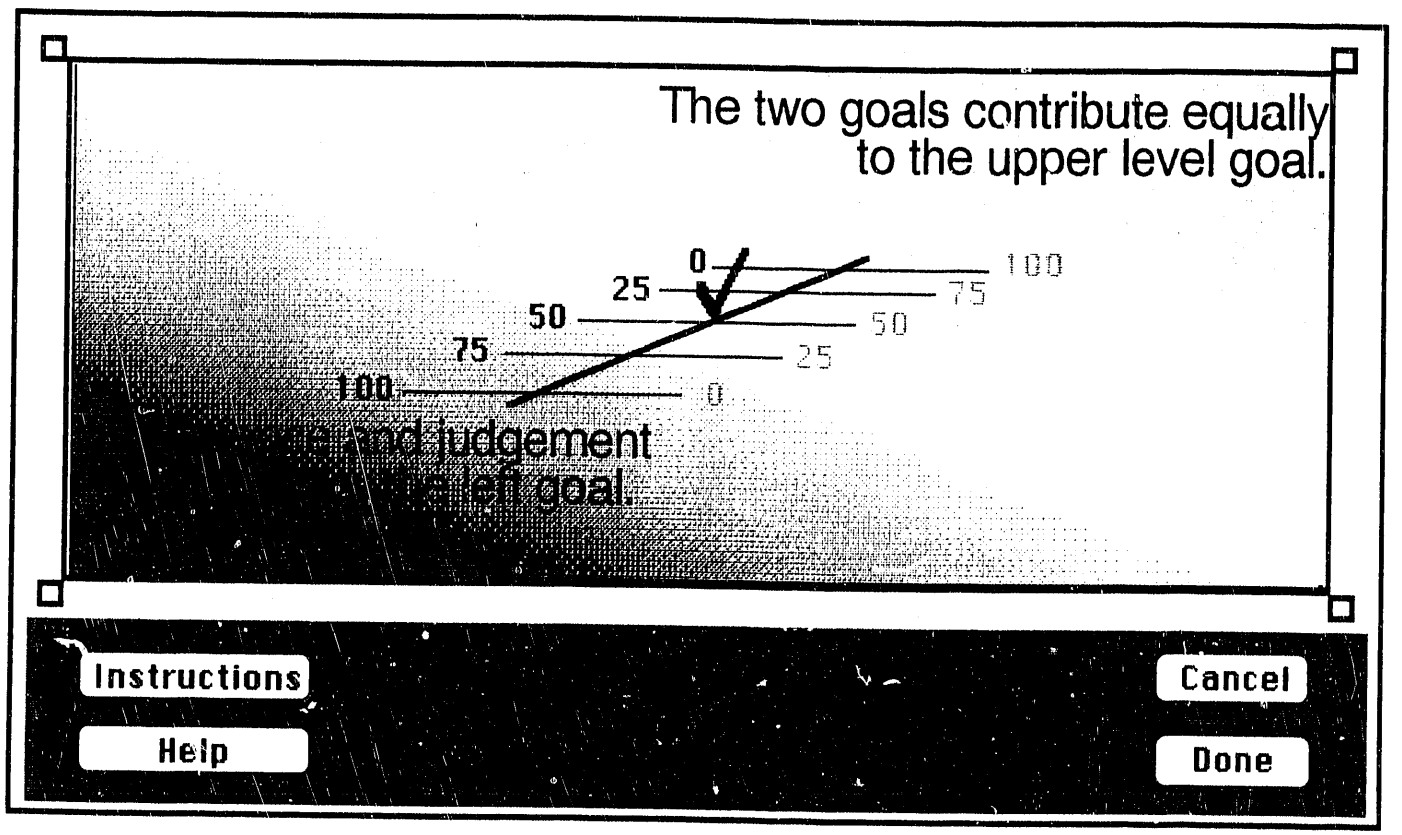
The selected group of goals is displayed in the editor window and the user can rearrange their order by using the mouse to drag a goal to its new location. Clicking the OK button tells First Priority to accept the new order and redraw the tree accordingly. The sibling group is marked with a check mark to show it is done. Clicking the Defer button has the same effect except that the sibling group is marked with a question mark, reminding the user to come back later and finish.



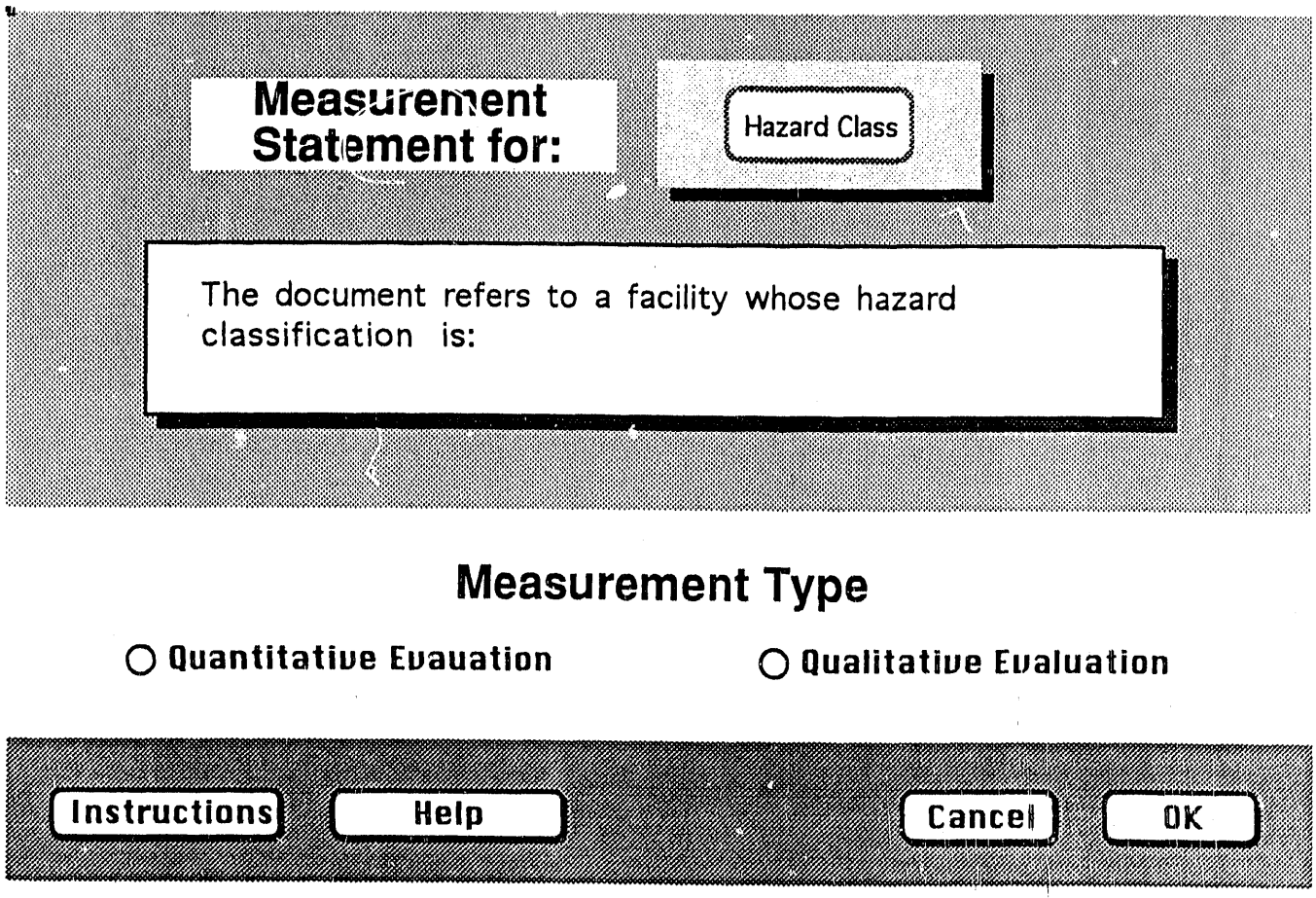
Ordering the sibling groups proceeds this way until all the groups have been ordered or the user elects to go on without finishing the ordering. If not all of the groups have been ordered, First Priority will alert the user and give him the options of finishing or accepting the current order of the goals as correct.



In the Weight the Goals stage, the goals tree is displayed in a manner similar to that of the Order stage and the user selects a sibling group in the same manner. Here, the editor allows the user to give relative values to the previously ordered sibling groups by allowing him to select the statement which most accurately describes the relationship between the two goals displayed in the top center of the editor window.

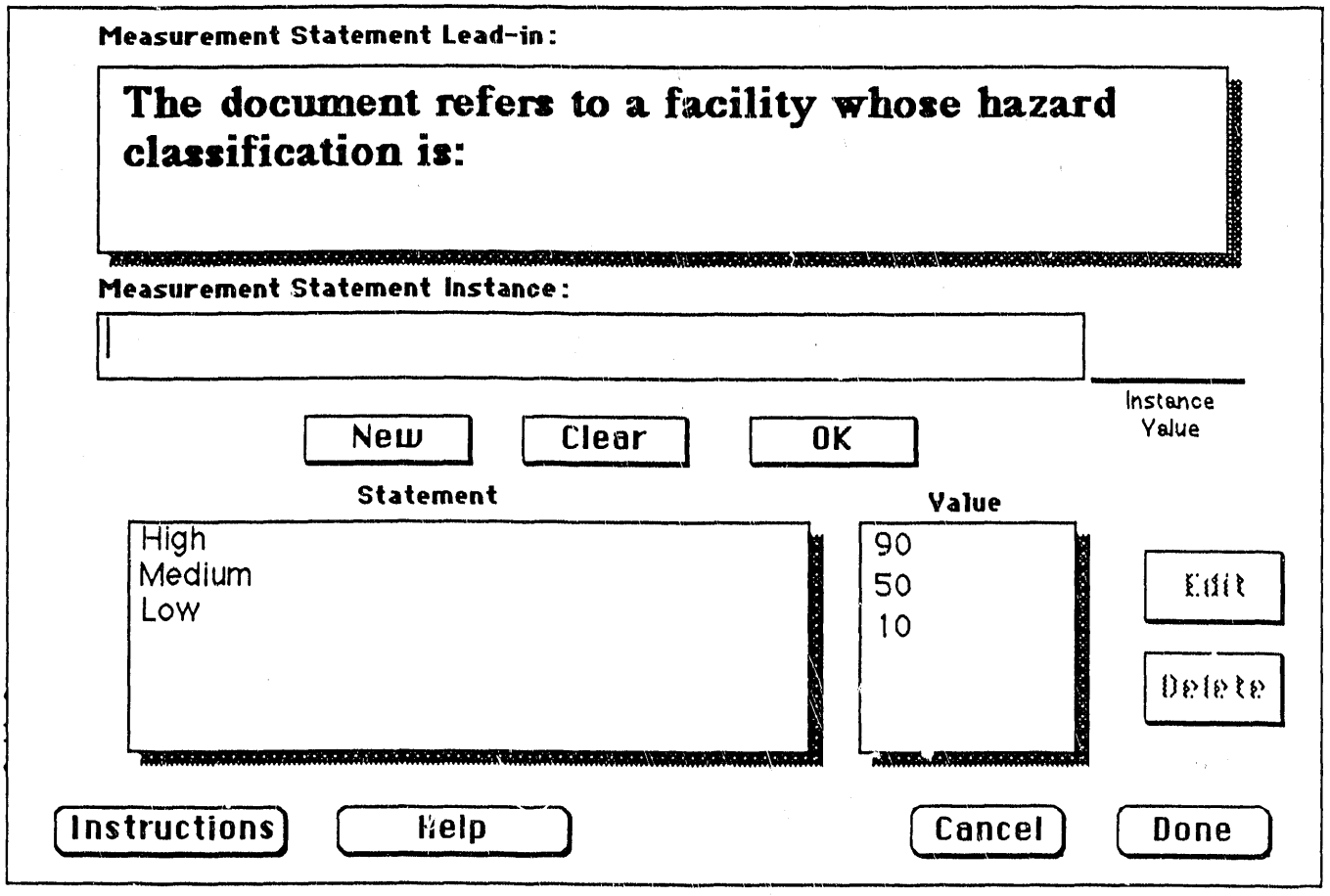


When the truth lies somewhere in the middle, clicking in the space between two statements opens a second editor which allows the user to determine the extent to which each statement applies

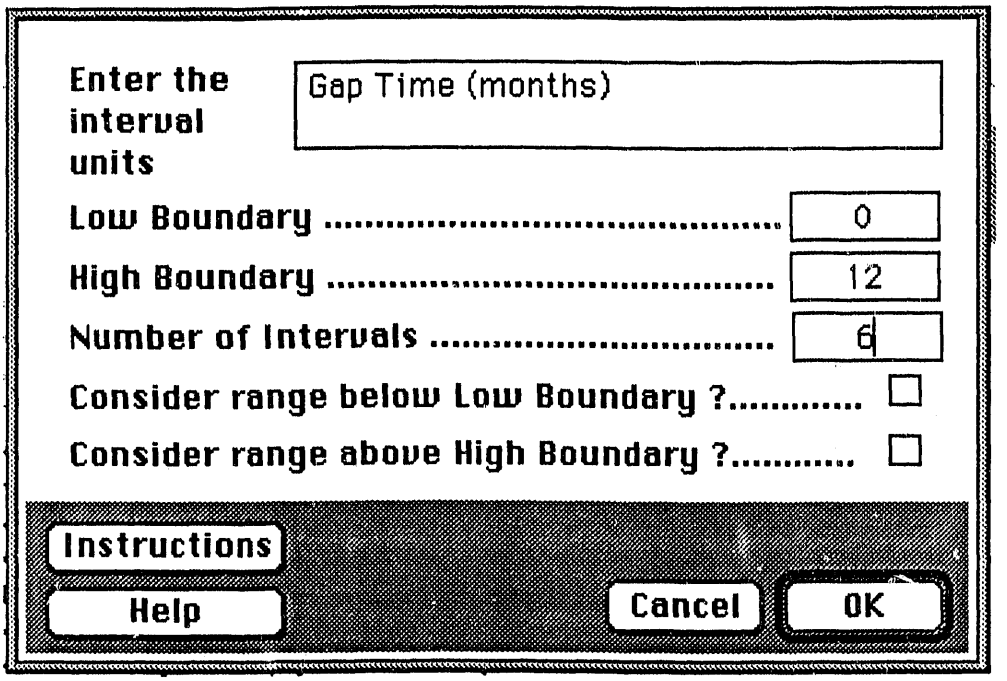


The goals tree has been completed, ordered, and weighted. The remaining step involves defining measurement methods for each of the leaf nodes. These methods will be used by First Priority to construct the evaluation interface.

Clicking on a leaf node opens the Measurement Statement editor. The user types the lead-in portion of a measurement statement and selects between qualitative and quantitative evaluation.

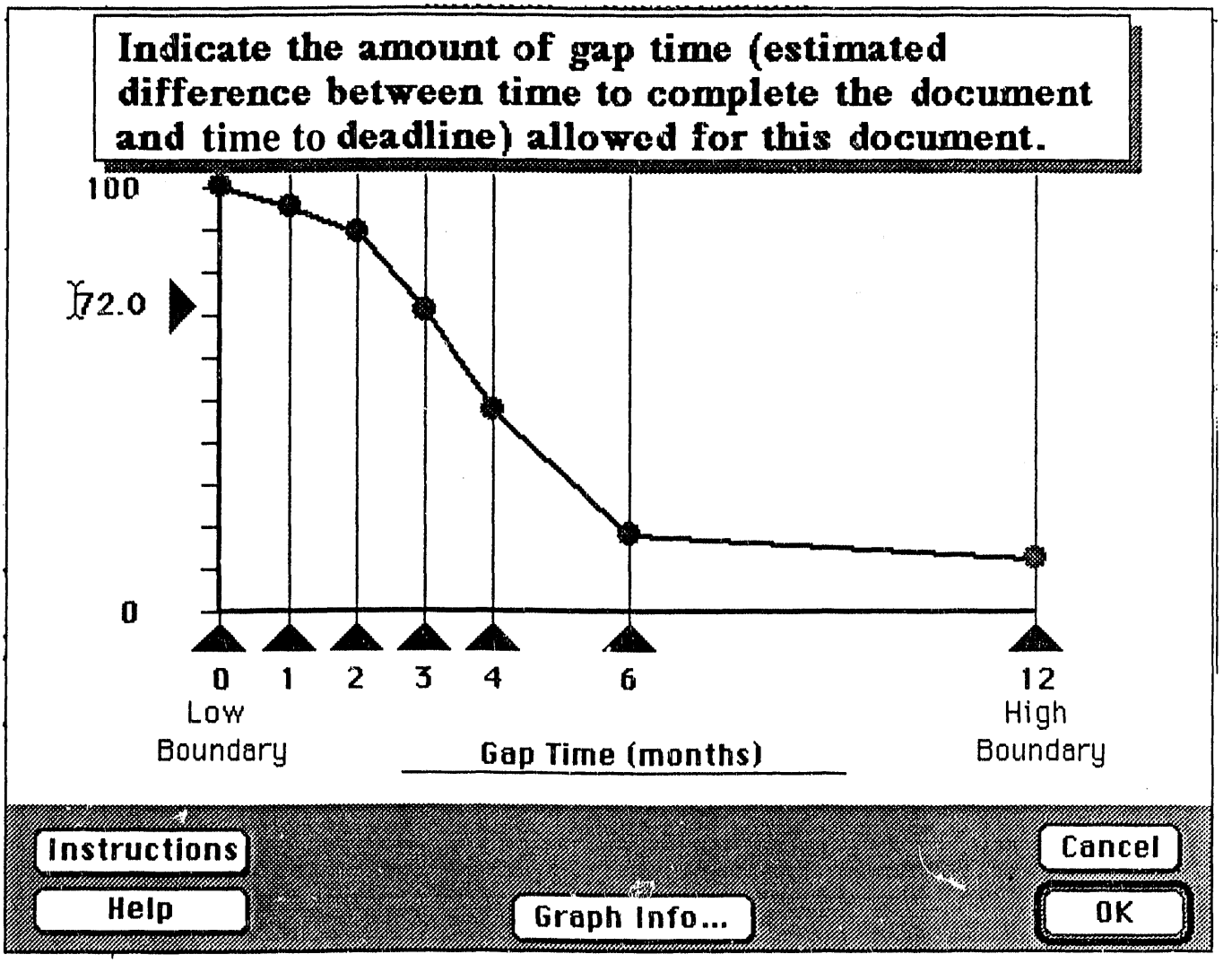


If a qualitative evaluation was selected, the measurement editor allows the user to complete the statement by entering any number of statement instances, along with their value.



If a quantitative evaluation was selected, an information box appears where the user enters the information required to construct an evaluation function.

This is followed by the function editor. Here, the user defines the evaluation function by directly manipulating the graph.



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1. The document refers to a facility whose hazard classification is:
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   - ○ Low

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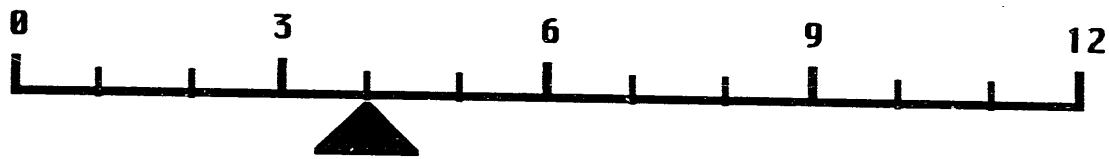

4 **Months**

First Priority uses these measurement methods (along with other input from the user) to construct an evaluation interface which is accessed either in the Runtime environment or as a stand alone application. Here, the user applies the measurement methods to his list of items to be prioritized.

References

[1] Keeney, R. L. and Raiffa, H. (1976), *Decisions with Multiple Objectives : Preferences and Value Trade-offs,* John Wiley.

[2] Detlof von Winterfeldt and W. Edwards, *Decision Analysis and Behavioral Research,* Cambridge University Press, 1988

[3] Saaty, L. Thomas, A Scaling Method for Priorities in Hierarchical Structures, *Journal of Mathematical Psychology,* Vol.15, June 1977, 234 - 281.

[4] Saaty, L. Thomas, *Priority Setting in Complex Problems* , from *Essays and Surveys on Multiple Criteria Decision Making,* Lecture Notes In Economics and Mathematical Systems 209, 1983, 326-336.

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