A Decision Support Tool for Decision Makers

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Abstract. *Many decisions in a multidisciplinary and interdisciplinary process, as an intelligent activity, are too complex for decision makers to make choices based solely on instinct. The complexity stems from this fact that such activities cannot be defined precisely. Also satisfying goals depend on achievement of several interrelated tasks which cannot be solved simultaneously. Our decision support tool uses a mathematical application so called Analytical Hierarchy Process as a decision making aid. The developed tool provides a powerful and flexible mean for tackling the complex decision process into a simple concept of hierarchy, which incorporates factors influencing the decision alternatives in a systematic way.*

Keywords. *Decision Support System; AHP; Eigenvalue; Construction Industry.*

1. Introduction

Today's typical decision making problem such as strategic planning, portfolio analysis, resource allocation and human resource management involves a variety of tangible and intangible strategic goals, conflicting constraints, dozens or hundreds of alternative initiatives to be pursued, and limited resources. A decision maker cannot meaningfully combine all of this information to make right decisions.

We developed a decision support tool to overcome the aforementioned problems. First we should make the problem hierarchy this means that to separate it into several different factors according to its quality and goal. Then grouping the factors into several levels according to their mutual influence and their subordinate relationship in order to form a multi-hierarchy analysis model. Finally summing up the system analysis as the determination of the weight or relative importance which represents the importance of the lowest level, the scheme for decision, relative to the highest level, system goal. In a stepwise manner our tool guides decision makers to weight criteria using a unique process for developing priorities and building consensus.

This tool embeds a mathematically rigorous application and proven process for prioritization and decision-making which is based on the Analytical Hierarchy Process model was designed by Saaty (1980, 1977) as a decision making aid. AHP provides effective means to deal with complex decision making and can assist with identifying and weighting selection criteria, analyzing the data collected for the criteria and expediting the decision making process. The decision maker judges the importance of each criterion in pairwise comparisons. This method has been found to be an effective and practical approach that can consider complex and unstructured decisions (Partovi, 1994). The method has been used in many domains as well as in construction industry (Cifcioglu, 2005).

Analytical Hierarchy Process is especially suit-

able for complex decisions which involve the comparison of decision elements which are difficult to quantify. It is based on the assumption that when faced with a complex decision the natural human reaction is to cluster the decision elements according to their common characteristics. This process is in fact a relative evaluating mathematical method containing both the people's subjective judgment and objective criteria. It helps capture both subjective and objective evaluation measures, providing a useful mechanism for checking the consistency of the evaluation measures and alternatives suggested by experts thus reducing bias in decision making.

Our decision support tool provides three steps for decision makers in order to make their decisions in a given problem. They are: constructing decision hierarchies; giving comparative judgments; and synthesizing priorities. In fact these steps are involved in building a hierarchy of decision elements and then making comparisons between each possible pair in each cluster as a matrix. This gives a weighting for each element within a cluster or level of the hierarchy. By reducing complex decisions to a series of pairwise comparisons and then synthesizing the results this tool not only helps decision makers arrive at the best decision but also provides a clear rationale for the decision.

The user interface of the decision support tool lets users build a hierarchy of decision elements as a tree like structure. So the nodes at the first level of the tree show the main decision elements. The second level of the tree consists of nodes representing the sub-elements of the main decision elements of the first level. Dividing the nodes of the tree to sub-nodes into lower levels can go on as users want depending on the nature of the problem. After constructing the hierarchy of decision elements users must give the pairwise weight values of the associated decision elements. Our tool provides facilities for users to select the relevant decision elements at any level of the tree built before. Selecting the nodes of the tree containing the interrelated decision elements a table like menu pops up where users put the pairwise relative importance values.

Giving all pairwise values the embedded AHP module will be activated within the tool to compute the results. The outcome of the computations is the priority vectors or matrices representing the attribute relations. Such relations provide a knowledge model of the decision elements. By means of this model the effect of the decision element in the solution can be monitored. The user interface provides some means to represent the priority vectors or matrices in tabular forms or graphical bar charts.

2. Analytical Hierarchy Process

The Analytical Hierarchy Process, AHP, is a widely used multi-criteria decision analysis method that uses pairwise comparisons which allows verbal judgments. This method has been found to be an effective and practical approach that can consider complex decisions. Using AHP decision makers make a hierarchy from the important elements of a complex multi-factor problem. The hierarchy consists of levels and each level is composed of specific elements. The top level of the hierarchy is the goal or objective of the decision and the levels below the top level contain the criteria, sub-criteria and decision alternatives respectively. After constructing a hierarchical model for the problem, pairwise comparisons for each level of the hierarchy must be given to obtain the level's weight factor with respect to one element on the next higher level. This weight factor shows the relative importance of that element with respect to others. The outcome of AHP is a prioritized ranking or weighting of each decision alternative. AHP comprises of three steps that are explained in the following sections.

2.1. Constructing a hierarchy

A decision hierarchy can be made by decomposing the problem into a hierarchy of decision elements. This step allows to construct a tree structure from a complex problem containing several decision factors. These factors are grouped into several levels with respect to an overall objective or goal to various criteria and sub-criteria until the lowest level. The top level of the hierarchy represents the overall goal and the criteria and sub-criteria influencing the decision are represented at the intermediate levels. Finally, the last level of the hierarchy consists of the decision alternatives or selection choices.

There exists no clear guidance how to construct the hierarchical structure from the given problem. This procedure is mainly problem dependent. The structure of the hierarchy depends on the nature or type of managerial decision (Zahedi, 1986). Also how many levels needed in such hierarchical structure depends on the complexity of the problem being analyzed. Therefore the hierarchical representation may vary from one problem to another.

2.2. Providing comparative judgments

After creating the hierarchy the priorities of all elements at each level must be determined. Depending on the number of levels in the hierarchy

a set of comparisons matrices of all elements in a level with respect to an element of one higher level are made containing the pairwise comparative judgments of these elements. A pairwise comparison of two elements, for instance A and B, shows how important is element A compared to element B considering another aspect which is in turn an element in above level. Expert or decision makers usually give those comparison values according to their experiences.

The preferences can be given by numerical judgments such as numbers between 0 and 1 or other scales. Although we can use instead of these numerical values some relative verbal quantifiers that are more familiar in our daily life. Saaty has proposed a comparison scale of relative importance with nine points starting from 1 to 9. Where 1 means two elements are equally importance and 9 meaning that one of the element is extremely more importance than the other element. Obviously, the other seven values convey the relative importance between these two extreme.

2.3. Synthesizing priorities

A matrix of relative rankings or weights for each level of the hierarchy is generated using the given pairwise comparisons. The number of matrices depends on the number of elements at each level of the hierarchy. Also the order of the matrix at each level depends on the number of elements at the lower level that it links to. When all matrices generated and all pairwise comparisons are obtained then eigenvectors or the relative weights (the degree of relative importance amongst the elements) and the maximum eigenvalue (λ_{max}) for each matrix can be calculated. The details of this method are given by Saaty.

Eigenvector W of A, n by n matrix containing all pairwise comparisons is computed by solving the eigenvalue problem:

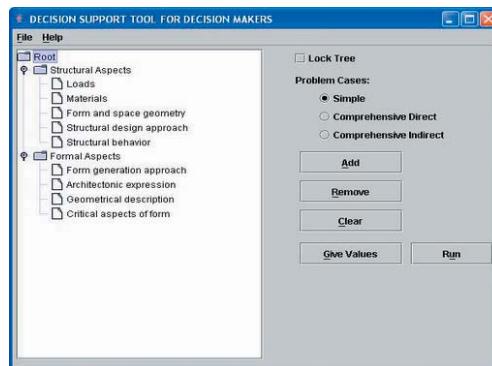$$\mathbf{A} \cdot \mathbf{W} = \lambda_{max} \cdot \mathbf{W} \tag{1}$$

Figure 1. The User Interface.

Where λ_{max} is the largest real eigenvalue of A. The priority vector is the normalized eigenvector corresponding to λ_{max}.

3. Main Features of the Tool

In this section the main features of the developed decision support tool will be explained. Also how to define a problem, to give data, to select a problem case, to activate AHP module and finally to view the results will be discussed. The user interface of the tool is shown in Figure 1. As the Figure shows the user interface consists of two parts. A panel in the left side, some keys like buttons, check box and combo boxes in the right side and few menu items in the menu bar of the user interface. Included items in the user interface facilitate the main features of the tool.

As explained in section 2 a hierarchy should be made from the important elements of a complex multi-factor problem. Using three buttons so called Add, Remove and Clear a user can make such a hierarchy. Clicking the Add button one sub-node will be added to the selected current node in the panel. The hierarchy is a tree structure containing a single node called root in the beginning and it grows by adding new nodes and sub-nodes to it. The levels in the tree can be hidden or expanded by clicking on the icon to the left of the corresponding node in the tree. Selecting a node in the tree and clicking the Remove button that node will be removed from the tree. Using the Clear button all nodes except the root will be deleted from the tree. After constructing the hierarchy and probably modifying it the user can lock the tree by selecting the check box called Lock Tree. When you select this box three buttons explained before will be grayed meaning that those functions are not available any more unless you unlock the tree by deselecting the corresponding check box.

After creating a hierarchy from the given problem you should select a problem case to solve it.

Three problem cases are available for selection that cover all problem types. With respect to the problem in our hand we choose one of cases which is more relevant to the given problem for solving. Some menus are provided for giving input, saving the given values, running the AHP module and solving the problem. Before executing the AHP module the pairwise values representing the importance of the decision elements must be given. Menus of the tool help to achieve these tasks.

To activate the AHP module of the tool users first click the Give Values button to enter the pairwise weight values of the associated decision elements. Then they click on the Run button of the user interface to start executing the AHP module. After execution the results can be shown numerically or graphically using provided buttons in other menus of the tool.

4. An Example

To exemplify the utilization of our tool we resort to an example in construction industry taken from the literature and the AHP method is applied to it. For detailed discussion of the given example refer to the first reference. Suppose we want to determine the relations of the structural aspects to the formal aspects. In doing so first the problem must be defined, to do that we choose the decision elements of structural and formal aspects. After choosing these elements a hierarchy can be created using some features of the tool as explained before. The hierarchy of the given example is depicted in Figure 1. As shown the structural aspects and the formal aspects have five and four attributes or elements respectively.

4.1. Entering Input Data

AHP computes the priority vector that ranks the relative importance of attributes being compared. The expert supplies the pairwise comparisons of the relative importance of attributes. The expert input compares two attributes with respect
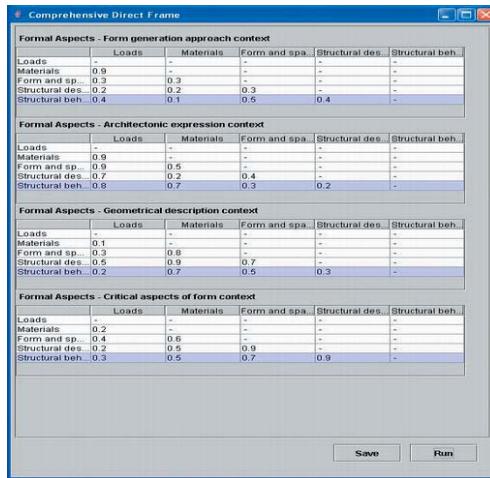
Figure 2. The matrices for data entry of the relative importance values.
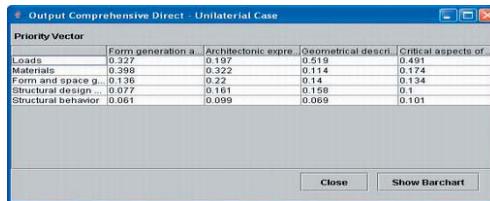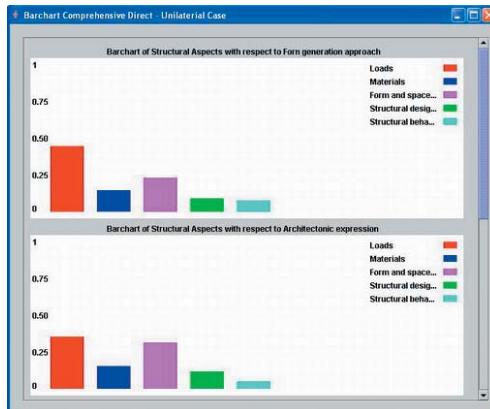

Figure 3. The Priority Matrix.

Figure 4. The Graphical Representation of the Results

to a certain aspect. We denote comparison of attributes ith with jth by aij = wi / wj where wi and wj is the relative importance of the ith and jth attributes with respect to a certain aspect. For instance, if wi / wj = 0.8 this means that attribute i is very strongly important than the attribute j in the context of the considered aspect. Value 0.5 means that i attribute is strongly important than attribute j. When this value is 0.1 it conveys that these two attributes, i and j, are equally important with respect to the considered attribute. The relative importance values are between 0 and 1.

To enter these pairwise relative importance values for all pairwise attributes first highlight the structural aspects node in the tree. Second select the problem case in the user interface, in this example Comprehensive Direct, and click the Give Values button. Then highlight the formal aspects node and push the newly appeared Continue button in the user interface. A menu pops up, shown in Figure 2, and allows to enter all values. As shown in this menu there are four different matrices, in fact the number of attributes in the formal aspects, in each matrix you give the relative importance values of every two attributes of the structural aspects with respect to one attribute of the formal aspects. Note that in each matrix you only enter values in the lower part.

4.2. Activating AHP Module and Viewing the Results

After filling the relative importance values for all pairwise attributes the AHP module can be activated by clicking the Run button in the pop up menu shown in Figure 2. From the given relative importance values AHP method computes so called the priority vector for the structural aspects with respect to each attribute of the formal aspects. Each vector represents the overall importance of all attributes of the structural aspects considering one attribute of the formal aspect. In other words this priority vector shows which attributes of the structural aspects is more or less related to

the considered attribute in the formal aspect. The higher the value is in the priority vector the more related that attribute of the structural aspect is to the considered attribute. Obviously the lower value shows there is no relationship between the corresponding attributes.

The final result of the AHP method is a priority matrix such that every column of the matrix is in fact the priority vector of the structural aspects with respect to one attribute of the formal aspects. The priority matrix is depicted in Figure 3.

As shown in the Figure, the first column indicates which attributes of the structural aspects is more or less related to the form generation approach attribute of the formal aspects. The material attribute of the structural aspects is more related than the other structural attributes to the considered attribute, form generation approach, because its priority, 0.398, is higher than the other priorities. Structural design approach and structural behavior attributes don't have any effect on the form generation attribute. The second column is the priority vector of the structural aspects with respect to the architectonic expression attribute of the formal aspects. As this column shows the material attribute is the most related to the architectonic expression attribute and the structural behavior attribute is the least related one. The last two columns represent the priority vectors of the structural aspects with respect to the last two attributes of the formal aspects respectively.

In general the priority matrix conveys the relationship among the attributes of the structural aspects and the attributes of the formal aspects. Clicking on the Show Barchart button in the previous menu the priority matrix will be shown graphically as depicted in Figure 4. Since the formal aspects have four attributes therefore there are four bar charts each one represents a priority vector of the structural aspects as explained before. Scroll the menu shown in this Figure to see the other bar charts as well.

5. Conclusions

To solve problems three steps must be taken. First, we make the problem hierarchy from the given problem to separate into several different factors according to its quality and goals. Second, these factors must be grouped into several levels according to their mutual influence and their subordinate relationship in order to form a multi-hierarchy analysis model. Finally, the system analysis is summed up to determine the weight which represents the importance of the lowest level, the alternatives or selection choices, relative to the highest level, overall goal.

We believe that the developed decision support tool provides a powerful and flexible means for tackling the complex decision process into a simple concept of hierarchy, which incorporates factors influencing the decision alternatives in a systematic way. It also provides for decision makers with a proven process for synthesizing data and developing priorities in an easy to use and a stepwise manner application that doesn't require an advanced knowledge.

AHP method has been applied in many diverse applications especially in dealing with problems cannot be defined well. The present work shows the ability of this method in the architectural domain to handle conceptual, collaborative and intelligent design. We demonstrate the usefulness of the method to architectural community as well. Embedding this method in our developed tool makes it as a general decision making tool for all decision makers in many domains.

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