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Analytic Network Process:- A Powerful Tool for Multi Criteria Decision Making

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ABSTRACT: The Analytic Network Process (ANP) is a general theory of relative measurement used to derive composite priority ratio scales from individual ratio scales that represent relative measurements of the influence of elements that interact with respect to control criteria. Through its super matrix whose elements are themselves matrices of column priorities, the ANP captures the out- come of dependence and feedback within and between clusters of elements. The Analytic Hierarchy Process (AHP) with its dependence assumptions on clusters and elements is a special case of the ANP. The ANP is a new and an essential phase in decision making, neglected so far because of the linear structures used in traditional approaches and their inability to deal with feedback in order to choose alternatives not simply according to attributes and criteria. But according to their consequences, both positive and negative, researchers are giving an essential and proper consideration for the method in decision making.

KEYWORDS: Analytic Network Process, Analytic Hierarchy Process, ANP, AHP, multi-criterion decision making.

I. INTRODUCTION

The Analytic Hierarchy Process (AHP) is a theory of relative measurement with absolute scales of both tangible and intangible criteria based on the judgment of knowledgeable and expert people. How to measure intangibles is the main concern of the mathematics of the AHP. The AHP reduces a multidimensional problem into a one dimensional one. Decisions are determined by a single number for the best outcome or by a vector of priorities that gives an ordering of the different possible outcomes. The judgments can be combining to obtain a single outcome from a group. In AHP the hierarchical dependence of various levels of factors are considered. But the feedbacks and mutual dependencies of variables in same level is not considered for evaluation. The Analytic Network Process (ANP) is a generalization of the Analytic Hierarchy Process (AHP). The ANP is a multi variable decision-making tool proposed by Saaty (1996). This method considers the dependence between the elements of the hierarchy. Many decision problems cannot be structured hierarchically because they involve the interaction and dependence of higher-level elements in a hierarchy on lower-level elements. Therefore, ANP is represented by a network, rather than a hierarchy.

These types of analysis are vital while considering strategic decision making. A firm's competitive strategy specifies the potential products and markets, long-term objectives, and policies for achieving the objectives. Organizations must continuously review their manufacturing strategies to identify the aspects of market priority, product structure, manufacturing configuration, and investment. Improvement programs should match operational goals and objectives.

II. RELATED WORK

Two popular methods for solving multi-criterion decision making (MCDM) problems are analytic network process (ANP) and analytical hierarchy process (AHP). Various studies were reported in the literature arena adopting by these two methods. (Dagdeviren & Yuksel 2010, Ayag & Ozdemir, 2011, Banerjee 2014, Chang et al. 2015, Uygun et al. 2015). But, in the case of AHP, the feedbacks and mutual dependencies of sub-criteria are not accounted for evaluation. (Azimifard et al. (2018), Kiron & Kannan (2014), Kiron & Kannan, (2015)

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III. WHY ANP?

The power of the Analytic Network Process (ANP) lies in its use of ratio scales to capture all kinds of interactions and make accurate predictions, and, even further, to make better decisions. So far, it has proven itself to be a success when expert knowledge is used with it to predict sports outcomes, economic turns, business, and social and political decision outcomes.

Decision making using the analytic network process (ANP)

The ANP is the first mathematical theory that makes it possible for us to deal systematically with all kinds of dependence and feedback. The reason for its success is the way it elicits judgments and uses measurement to derive ratio scales. Priorities as ratio scales are a fundamental kind of number amenable to performing the basic arithmetic operations of adding within the same scale and multiplying different scales meaningfully as required by the ANP.

The Analytic Network Process (ANP) is a new theory that extends the AHP to cases of dependence and feedback and generalizes on the super matrix approach introduced in Thomas Saaty's 1980 book on the Analytic Hierarchy Process. It allows interactions and feedback within clusters (inner dependence) and between clusters (outer dependence). Feedback can better capture the complex effects of interplay in human society. The ANP provides a thorough framework to include clusters of elements connected in any desired way to investigate the process of deriving ratio scales priorities from the distribution of influence among elements and among clusters. The AHP becomes a special case of the ANP. Although many decision problems are best studied through the ANP, it is not true that forcing an ANP model always yields better results than using the hierarchies of the AHP. There are examples to justify the use of both. We have yet to learn when the shortcut of the hierarchy is justified, not simply on grounds of expediency and efficiency, but also for reasons of validity of the outcome.

The ANP is implemented in the software Super Decisions and has been applied to various problems both to deal with decisions and to illustrate the uses of the new theory. The ANP is a coupling of two parts. The first consists of a control hierarchy or network of criteria and sub criteria that control the interactions in the system under study. The second is a network of influences among the elements and clusters. The network varies from criterion to criterion and a super matrix of limiting influence is computed for each control criterion. Finally, each of these super matrices is weighted by the priority of its control criterion and the results are synthesized through addition for all the control criteria.

Concepts of the Analytic Network Process

- Feedback, inner and outer dependence.
- Influence with respect to a criterion.
- The control hierarchy or system.
- The super matrix.
- The limiting super matrix and limiting priorities.
- Primitivity, irreducibility, cyclicity.
- Make the limiting super matrix stochastic: why clusters must be compared.
- Synthesis for the criteria of a control hierarchy or a control system.
- Synthesis for benefits, costs, opportunities, and risks control hierarchies.
- Formulation to compute the limit.
- Relation to Neural Network Firing - the continuous case.

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Paired comparisons and the fundamental scale

To make tradeoffs among the many objectives and many criteria, the judgments that are usually made in qualitative terms are expressed numerically. To do this, rather than simply assigning a score out of a person's memory that appears reasonable, one must make reciprocal pair wise comparisons in a carefully designed scientific way. The Fundamental Scale used for the judgments is given in Table 1. Judgments are first given verbally as indicated in the scale and then a corresponding number is associated with that judgment. The vector of priorities is the principal eigenvector of the matrix. This vector gives the relative priority of the criteria measured on a ratio scale. That is, these priorities are unique to within multiplication by a positive constant. However, if one ensures that they sum to one they are then unique and belong to a scale of absolute numbers.

Networks, dependence and feedback

Here we exhibit a hierarchy and a network. A hierarchy is comprised of a goal, levels of elements and connections between the elements. These connections are oriented only to elements in lower levels. A network has clusters of elements, with the elements in one cluster being connected to elements in another cluster (outer dependence) or the same cluster (inner dependence). A hierarchy is a special case of a network with connections going only in one direction. The view of a hierarchy such as that shown in Figure 1 the levels correspond to clusters in a network. There are two kinds of influence: outer and inner. In the first one compares the influence of elements in a cluster on elements in another cluster with respect to a control criterion. In inner influence one compares the influence of elements in a group on each one. If we think about it carefully everything can be seen to influence everything including itself according to many criteria. The world is far more interdependent than we know how to deal with using our existing ways of thinking and acting. The ANP is our logical way to deal with dependence.

Supermatrix

Take a control criterion, the priorities of the elements derived from paired comparisons with respect to that control criterion are arranged both vertically and horizontally according to components. The elements in each component are listed for that component in a matrix known as the Super matrix. Each vector taken from a paired comparison matrix is part of the column of the super matrix representing the impact with respect to the control criterion of the elements of that component on a single element of the same or another component listed at the top.

Weighted Super matrix

All the clusters are pair wise compared according to their influence on a given cluster X with respect to the control criterion. This yields a vector of priorities of the impact of all the clusters on a given criterion. Each component of a vector is used to weight all the elements in the block of column priorities of the super matrix corresponding to the impact of the elements of that cluster on X . The process is repeated for all the clusters resulting in a weighted super matrix.

In each block of the super matrix, a column is either a normalized eigenvector with possibly some zero entries, or all of its elements are equal to zero. In either case it is weighted by the priority of the corresponding cluster on the left. If it is zero, that column of the super matrix must be normalized after weighting by the cluster's weights. This operation is equivalent to assigning a zero value to the cluster on the left when weighting a column of a block with zero entries and then re-normalizing the weights of the remaining clusters.

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Limiting super matrix

The weighted super matrix is now column stochastic from which one then derives the limiting super matrix. There are four major cases to consider in deriving the limiting super matrix depending on the simplicity or multiplicity of the principle eigen value and on the reducibility and irreducibility of the matrix.

Selection of the best alternative for a determinant

In this case an index named as “Total desirability Index” was evaluated for the selection of the best alternative. The desirability index, Dia, for the alternative ‘i’ and the determinant ‘a’ is defined as

$$Dia = \sum_{j=1}^J \sum_{k=1}^K P_{ja} A_{kja}^D S_{ikja}$$

where P_{ja} is the relative importance weight of dimension. A_{kja}^D is the relative importance weight for enabler k of dimension of j in the determinant of service control hierarchy network a for the dependency (D) relationships between component levels, A_{kja}^I is the stabilized relative importance weight (determined by the super matrix) for attribute enabler k of dimension. j in the determinant of control hierarchy network a for interdependency (I) relationships within the attribute enablers’ component level, S_{ikja} implies the relative impact of the implementation alternative i on attribute enabler k of dimension j, kja is the index set attribute enablers for dimension of j.

Calculation of overall weighted service index (owsi)

The OWSI for an alternative i (OWSI) is the summation of the products of the desirability indices (Dia) and the relative importance weights of the determinants (C_a) of the overall weighted index. It is represented as:
 $OWSI_i = \sum_{a=1}^A Dia_a C_a$

IV. CONCLUSION

Analytic Network Process (ANP) is a powerful tool for solving multi criteria decision making problems. In industrial applications, managers have to solve various MCDM problems which are considered as complex decision-making problems. Knowledge about techniques like ANP will assist them to make good decisions.

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