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Application of ANP in process models: An example of strategic partnering

Eddie W.L. Cheng[a,*], Heng Li[b]

[a]School of Management, Queensland University of Technology, 2 George Street, Brisbane, QLD 4001, Australia
[b]Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong

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Abstract

Analytic network process (ANP) is a new tool for multi-criteria decision-making (MCDM) but can also be applied in academic research to prioritize factors or criteria. It enhances the function of analytic hierarchy process (AHP) to develop a complete model that can incorporate interdependent relationships between elements from different levels or within levels, which are assumed to be uncorrelated in AHP. Although ANP has recently been applied in the construction field, it cannot be applied easily to process models. This is because its concept does not consider the impacts of an element on another element occurring at different periods in a process, such as stages, phases, etc. This paper uses the strategic partnering model as an example to present a method that helps to form the super-matrix for process models. The procedure of ANP is also highlighted in this paper.

Keywords: Analytic network process; Multi-criteria decision-making; Process models; Strategic partnering; Decision tool

1. Introduction

Analytic network process (ANP) is a new tool for multi-criteria decision-making (MCDM) but can also be applied in academic research to prioritize factors or criteria. It is seen as a generic form of analytic hierarchy process (AHP). In AHP, it is assumed that a decision problem can be translated into a hierarchical structure that consists of uni-directional relations between decision levels. As Meade and Sarkis [1] mentioned, the top level of the hierarchy (apex) is usually the overall goal for the decision model, which can be decomposed to one or more specific levels of clusters until a manageable level of sub-clusters is met. Yet, the strict hierarchical structure may need to be relaxed when modeling a more complicated problem that involves interdependencies among elements between and within model levels, which are assumed to be uncorrelated in AHP. It is expected that by using ANP, researchers are able to establish a complete multi-criteria model without sacrificing the validity due to limitations of the analytical tool. In addition to its usefulness in other areas, its application in construction research has been documented recently (e.g., [2,3]).

Despite the generic form of ANP, it cannot be applied easily to process models where the stages or phases in the process occur at different periods. This is because the basic concept of ANP does not specify the impacts of an element on another element occurring at different periods in the process. In order to strengthen its application in process models, the present research uses the strategic partnering model as an example to present a method that helps to form the super-matrix and the limit matrix for process models. This method is probably the first of its kind to apply ANP in process model study.

*Corresponding author.
E-mail address: e.cheng@qut.edu.au (E.W.L. Cheng).

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2. AHP and ANP

AHP and ANP are two separate concepts introduced by Saaty [4,5] at different stages. Saaty [4] first developed AHP, which helps to establish decision models through a process that contains both qualitative and quantitative components. Qualitatively, it helps to decompose a decision problem from the top overall goal to a set of manageable clusters, sub-clusters, and so on down to the bottom level that usually contains scenarios or alternatives. The clusters or sub-clusters can be forces, attributes, criteria, activities, objectives, etc. Quantitatively, it uses pair-wise comparison to assign weights to the elements at the cluster and sub-cluster levels and finally calculates "global" weights for assessment taking place at the bottom level. Each pair-wise comparison measures the relative importance or strength of the elements within a cluster level by using a ratio scale. One of the main functions of AHP is to calculate the consistency ratio to ascertain that the matrices are appropriate for analysis [4]. Nevertheless, AHP models assume that there are uni-directional relationships between elements of different decision levels along the hierarchy and uncorrelated elements within each cluster as well as between clusters. It is not appropriate for models that specify interdependent relationships in AHP. ANP is then developed for filling this gap.

ANP is the generic form of AHP and allows for more complex interdependent relationships among elements [5]. It is also known as the systems-with-feedback approach [6]. By incorporating interdependencies (i.e., addition of the feedback loops in the model), a super-matrix will be created. The super-matrix adjusts the relative weights in individual matrices to form a new "overall" matrix with the eigenvectors of the adjusted relative weights [6].

There are generic steps for AHP and ANP as well as specific steps for ANP. The generic steps are shown below [2,3].

- *Developing the structure of the decision model*: Researchers must first know what they want to study. This forms the goal or objective of the decision model. This goal would further decompose into clusters, sub-clusters, and so on until a manageable level is reached, which is often the alternatives or options. The decision model of AHP is always restricted to being hierarchical, containing several levels. Only adjacent levels are assumed to have correlations. ANP is a network structure where the hierarchical restriction is relaxed so that correlations can be stipulated in any part of the decision model to form the sub-matrices for the super-matrix.
- *Conducting pair-wise comparisons on the clusters and sub-clusters*: The normal procedure of a pair-wise comparison is to invite experts to compare two elements with respect to their respective adjacent higher level's element. Saaty [4] has developed a 9-point priority scale of measurement, with a score of 1 representing equal importance of the two-compared elements and nine being overwhelming dominance of one element (row element) over another element (column element). When there is overwhelming dominance of a column element over a row element, a score of 1/9 is given.
- *Calculating the relative weights of elements and consistency ratio of matrices*: After the pair-wise comparison matrices are developed, a vector of priorities (i.e. a proper or eigenvector) in each matrix is calculated and is then normalized to sum to 1.0 or 100 per cent. This is done by dividing the elements of each column of the matrix by the sum of that column (i.e. normalizing the column); then, obtaining the eigenvector by adding the elements in each resulting row (to obtain "a row sum") and dividing this sum by the number of elements in the row (to obtain "priority or relative weight") [7]. Moreover, for ascertaining the consistency of the judgment matrices, Saaty [8] suggested three-threshold levels: (1) 0.05 for 3×3 matrix; (2) 0.08 for 4×4 matrix; and (3) 0.1 for all other matrices. Those who want to know the algorithm for computing consistency ratio may refer to Saaty [4] and Cheng and Li [9].

ANP has specific steps for generating the global priorities for elements. This paper will not go into details of the technical component of ANP, which can be acquired in other published ANP papers and the ANP book of Saaty [5]. Nevertheless, the following specific steps are worth mentioning, which would be described more in later sections [10]:

- Placing the resulting relative weights (eigenvectors) of the sub-matrices to form the super-matrix;
- Adjusting the super-matrix so that values in columns of the super-matrix achieve column stochastic; and
- Raising the super-matrix to limiting powers until the weights have converged and become stable.

3. Strategic partnering model

3.1. Process models

Process models always involve stages, phases, etc. A common example is the project life cycle that is composed of several phases mainly including inception, design, construction, and commission. The current study revises the hierarchical process model of strategic