Journal of Manufacturing Systems 33 (2014) 488–497

Contents lists available at ScienceDirect

Journal of Manufacturing Systems

journal homepage: www.elsevier.com/locate/jmansys

Application of the Analytic Network Process to facility layout selection

Tarek Al-Hawari*, Ahmad Mumani, Amer Momani

Jordan University of Science and Technology, Irbid, Jordan

ARTICLE INFO

Article history:
Received 11 February 2013
Received in revised form 21 April 2014
Accepted 22 April 2014
Available online 18 June 2014

Keywords:
Facility layout
MCDM
ANP
AHP

ABSTRACT

This paper applies the Analytic Network Process (ANP) method to the selection of the best facility layout plan based on multiple dependent and independent criteria. This is the first time that this method is used in such a context. An ANP model is built taking into account the interdependencies between criteria that are found based on experts' opinions and fundamental equations. A network structure is built that shows all elements and clusters and their interactions that can be used to find the most effective layout. Limit priorities are computed which identify the most important factors in the selection process. A case study is conducted in a wood factory which represents a real demonstration of the developed model. A comparison is conducted between ANP and Analytic Hierarchy Process (AHP) which shows the differences between the two methods. Finally, sensitivity analysis shows the robustness of the model.

1. Introduction

The selection of a facility layout plan should be considered from a strategic perspective because of its high impact on the performance of the system in terms of cost and time. In this process the best layout design is selected from many proposed alternatives which results in an efficient facility and improved productivity [1].

In most literature that are related to facility layout selection, multiple attributes are considered as selection criteria, which makes the selection process a multi-criteria decision making (MCDM) problem. Many methodologies can be used in the selection process, which involve building alternative layouts, identifying selection criteria, and evaluating alternatives against these criteria [2–4]. In many of these methodologies, the criteria were assumed to be independent [4–6], this assumption is inaccurate in real cases and may lead to misleading decisions. An example is using the AHP which is an MCDM tool that has been applied to facility layout selection [5]. The underlying assumption in AHP is having independent criteria, in which the problem can be structured in a hierarchy that gives the decision makers a clear understanding of the problem [7]. AHP has been used as a comprehensive tool to evaluate alternative FLPs. For example, in Refs. [8,9] AHP is applied to the process of evaluating alternative FLPs, against their accessibility, flexibility and maintenance. Also, in Ref. [10] an AHP model is used to evaluate alternative FLPs for a semiconductor wafer fabrication facility. This model was built taking into account many objectives both qualitative and quantitative based on experts' opinions in the field. The criteria used were capacity, productivity, layout flexibility and work-in-process flow. This model produced acceptable results from the perspective of experts because of its logical outputs. Another example is using the preference selection index (PSI) to select the best alternative layout by measuring the performance of alternatives against the selection criteria directly assuming independent criteria [4].

Many decision making problems cannot be structured in a hierarchal way because of the interactions and dependencies between criteria. In such cases the structure of the problem should be built in the form of a network. ANP is the general form of the AHP, and can help in dealing with dependencies and interactions in complex decision making problems [11]. There are many applications for the ANP in the fields of economics, finance, marketing, social sciences, and technology [12]. Recently the applications of ANP in complex decision making problems have seen more attention from researchers in which dependent criteria exist. For example, in Ref. [13] a network model is built to select the most suitable waste water treatment technology using ANP. Moreover, the results of this model were compared to AHP, and differences in results were discussed. Also, in Ref. [1] AHP and ANP were used to build a model to evaluate a manufacturing system in the wafer fabricating industry. Both techniques were used in the same model with AHP being related to independent criteria, and ANP to dependent ones, this shows the flexibility of using ANP accompanied with other tools if required. Additionally, in Ref. [14] a model to measure an organization's competition level using fuzzy ANP is proposed, fuzzy logic is used to help deal with the vagueness associated with evaluation process. Mixing of fuzzy logic and ANP is also evidence of the advantages of ANP.

* Corresponding author. Tel.: +962 27201000.
E-mail address: Tarek321@just.edu.jo (T. Al-Hawari).

http://dx.doi.org/10.1016/j.jmsy.2014.04.006

Up to our knowledge, no research has been found on the application of ANP to facility layout selection which will be discussed in this paper. Multiple independent and dependent criteria, both qualitative and quantitative are considered to evaluate alternative facilities. The ANP model introduced in this paper is a network structured model containing many factors that cover the selection problem from many perspectives. This model will help decision makers in taking strategic decisions with regards to modifying or retaining existing facilities. The paper is organized as follows: an overview of the AHP and ANP is introduced in Section 2. The ANP facility selection model is introduced in Section 3. A case study is discussed in Section 4. Sensitivity analysis is the subject of Section 5. Finally, conclusions are presented in Section 6.

2. The ANP and AHP methods

AHP introduced by Saaty is a well known tool that can be used in MCDM, in which there are qualitative or quantitative factors. The AHP hierarchy typically contains several levels; the top level represents the main objective or goal of the decision making problem, the intermediate level contains criteria and their corresponding sub-criteria, and the bottom level contains the alternatives. Alternatives are evaluated based on these criteria to select the one that best satisfies the goal [15]. In the AHP hierarchy; elements that are connected to a parent node in upper levels would be pair wise compared with respect to it [16]. Independency of criteria is the main assumption that covers the theory of AHP in which the hierarchal structure cannot hold dependencies or interactions within or between levels [17].

In many cases, an MCDM problem cannot be structured in a top down hierarchy such as in AHP, but rather needs to be built as a network, because of the existence of interdependencies between criteria. For example, the importance of the criteria may be reversely affected by the alternatives, even though these criteria are used to evaluate these alternatives [7]. The network structure also known as the feedback structure can deal with decision making problems that contain interdependencies. The ANP structure is one network structure in which the criteria are represented as nodes or elements that are arranged in clusters or components; each cluster contains all elements with similar functions and their interactions result in a synergy. For a cluster to have a meaning it must be different from its elements [11]. The network structure also contains cycles that connect the clusters or components with others. Additionally, it contains loops which connect a cluster to itself. Nodes or elements are connected by directional arrows that define the path of influence or dependencies. Arrows start from a parent node, and end up at a child node(s) which influence or are influenced by the parent node [11]. The node that represents the origin of the path of influence is called a source node and the destination of this influence path is called a sink node. The direction of influence depends on the user of the network; some consider the base of an arrow as a sink and the node at the head as a source of influence, in other words, children nodes influence parent ones. On other hand, other users may consider the opposite, in which children nodes are influenced by parent nodes. In all cases the user has to be consistent in all paths of influence [12].

ANP starts by finding the dependencies in a network; this is done by scanning all elements in all clusters, and finding if an element influences another element with respect to a pre-specified control criterion. After that, the elements inside a cluster that influence an element would be pair wise compared with respect to the control criterion using the same method and scale used in AHP [18]. Both AHP and ANP use the fundamental (1–9) scale shown in Table 1 in the process of pair wise comparisons. Decision makers convert verbal judgments into numerical form using this fundamental scale [19]. The derived priority vectors that result from the pair wise comparisons are then arranged in a matrix which is known as the un-weighted super matrix. These vectors are arranged in blocks with each block containing all element influence priorities for the corresponding components, each column in the matrix contains the influence priorities of other elements in the network [7,12,18].

Table 1
The fundamental scale for AHP/ANP [19].

Scale	Corresponding verbal judgment
1	Equally importance
2	Between equal and moderate importance
3	Moderately importance
4	Between moderate and strong importance
5	Strongly importance
6	Between strong and very strong importance
7	Very strong importance
8	Between very strong and extreme importance
9	Extreme importance

The un-weighted super matrix only contains direct influences (first order impacts), but does not contain intermediate elements that carry the influence between a pair of elements. These influences can be formed by raising the weighted super matrix (which will be discussed later) to a power equivalent to the specified level of influence required. For example, the second order influence can be found by raising the weighted super matrix to the power of two and so on. This process continues until limit priorities are reached which represent steady state priorities. It is essential to find the limit priorities because the network structure might contain cycles and cycling may continue indefinitely [12].

Limit priorities cannot be reached unless the un-weighted super matrix is converted to a stochastic one in which each column sums to one. This can be done by finding the cluster matrix that can be built by pair wise comparisons of cluster influences with respect to the control criterion, the result will be a matrix in which each column represents the priorities of influence of all clusters on the column heading cluster. After that, each block in the un-weighted super matrix is multiplied by the corresponding priority in the cluster matrix. In other words the elements in the un-weighted super matrix are weighted, which results in the weighted super matrix [12]. The limit matrix can then be found by raising the weighted super matrix to higher powers to catch higher order impacts until all columns in each block in the matrix are identical. This matrix is known as the limit super matrix [19]

The alternatives can be included in the network structure in a separate cluster, with its influences shown in the limit super matrix. In cases where a cluster has no influence on other clusters, it must be removed from the network structure and its priorities would not be shown in the limit matrix [12]. The control criterion may exist in the structure as a goal or main objective, and the control criterion is called a comparison linking criterion. On the other hand, if the control criterion is not included in the structure but rather induces and covers pair wise comparisons, it would be called a comparison inducing criterion [12].

The limit priorities of influence for elements are used in the process of synthesis using the ideal mode of AHP or what is known as the rating mode. This is desired when alternatives are not included in the limit matrix. In ideal mode the priorities of alternatives with respect to each criterion are normalized with respect to the largest one in each column, then multiplied by the corresponding criterion limit priority, and summed over all criteria resulting in total scores for alternatives [12].