EVOLUTION OF AHP IN MANUFACTURING INDUSTRY

Rafique I. Pathan, Planning engineer at Hawavalves (I) pvt. Ltd. Navi Mumbai, Prof. T.Z. Kazi HOD Automobile Engg. Dept. SCOE Kharghar, Navi Mumbai.

Abstract
In many industrial engineering applications the final decision is based on the evaluation of a number of alternatives in terms of a number of criteria. This problem may become a very difficult one when the criteria are expressed in different units or the pertinent data are difficult to be quantified. The Analytic Hierarchy Process (AHP) is an effective approach in dealing with this kind of decision problems. This paper provides an overview of AHP method used in engineering applications.

Key words: Multi-Criteria Decision-Making, Analytic Hierarchy Process, Pair wise Comparisons.

Introduction

Background:

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach and was introduced by Saaty (1977 and 1994). The AHP has attracted the interest of many researchers mainly due to the nice mathematical properties of the method and the fact that the required input data are rather easy to obtain. The AHP is a decision support tool which can be used to solve complex decision problems. It uses a multi-level hierarchical structure of objectives, criteria, sub-criteria, and alternatives. The pertinent data are derived by using a set of pairwise comparisons. These comparisons are used to obtain the weights of importance of the decision criteria, and the relative performance measures of the alternatives in terms of each individual decision criterion. If the comparisons are not perfectly consistent, then it provides a mechanism for improving consistency. Some of the industrial engineering applications of the AHP include its use in integrated manufacturing (Putrus, 1990), in the evaluation of technology investment decisions (Boucher and McStravic, 1991), in flexible manufacturing systems (Wabalickis, 1988), layout design (Cambron and Evans, 1991), and also in other engineering problems (Wang and Raz, 1991).

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History:

In the late 1960's, Thomas Saaty, one of the pioneers of Operations Research, and author of the first Mathematical Methods of Operations Research textbook and the first queueing textbook, was directing research projects for the Arms Control and Disarmament Agency at the U.S. Department of State. Saaty's very generous budget 5 allowed him to recruit some of the world's leading economists and game and utility theorists. In spite of the talents of the people Saaty recruited (three members of the team, Gerard Debreu, John Harsanyi, and Reinhard Selten, have since won the Nobel Prize), Saaty was disappointed in the results of the team's efforts.

Years later, while teaching at the Wharton School, Saaty was troubled by the communication difficulties he had observed between the scientists and lawyers and by the apparent lack of a practical systematic approach for priority setting and decision making. Having seen the difficulty experienced by that the world's best scientists and lawyers, Saaty was motivated to attempt to develop a simple way to help ordinary people make complex decisions. The result was the Analytic Hierarchy Process – a synthesis of existing concepts that attests to Saaty's genius through its power and simplicity. There is ample evidence that the power and simplicity of AHP has led to a widespread acceptance and usage in the United States as well as throughout the world. In addition to Expert Choice, there have been several other successful commercial implementations of AHP, one with financial backing of the Canadian Government. Many of the world's leading information technology companies now use AHP in the form of decision models provided by the Gartner Group's1 , Decision Drivers2 . The American Society for Testing and Materials (ASTM) has adopted AHP as a standard practice for multi-attribute decision analysis of investments related to buildings and building systems3. The AHP process is taught in numerous Universities and used extensively in organizations such as the Central Intelligence Agency that have carefully investigated AHP's theoretical underpinnings.

Importance Explanation

1 Two criterion contribute equally to the objective
3 Experience and judgement slightly favour one over another
5 Experience and judgment strongly favour one over another
7 Criterion is strongly favoured and its dominance is demonstrated in practice
9 Importance of one over another affirmed on the highest possible order

[2, 4, 6, 8] Used to represent compromise between the priorities listed above

The AHP method is based on three principles: first, structure of the model; second, comparative judgment of the criteria and/or alternatives; third, synthesis of the priorities. In the literature, AHP, has been widely used in solving many decision making problems [11, 12, 14, 15, 16]. In the first step, a decision problem is structured as a hierarchy . AHP initially breaks down a complex multi-criteria decision making problem into a hierarchy of interrelated decision elements (criteria, decision alternatives). With the AHP, the objectives, decision criteria and alternatives are arranged in a hierarchical structure similar to a family tree. A hierarchy has at least three levels: overall goal of the problem at the top, multiple criteria

that define alternatives in the middle, and alternatives at the bottom level.

In this study, we use the AHP for prioritization of SWOT elements. Once the problem has been decomposed and the hierarchy is constructed, prioritization procedure starts in order to determine the relative importance of the criteria. In each level, the criteria are compared pairwise according to their levels of influence and based on the specified criteria in the higher level. In AHP, multiple pairwise comparisons are based on a standardized comparison scale of nine levels.

Let $C = \{Cj \mid j = 1, 2, \ldots, n\}$ be the set of criteria. The result of the pairwise comparison on n criteria can be summarized in an (n x n) evaluation matrix A in which every element a ij ($i, j = 1, 2, \ldots, n$) is the quotient of weights of the criteria. This pairwise comparison can be shown by a square and reciprocal matrix.

Equation(1) is ….

$$A = (a_{ij})_{nxn} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ a_{n1} & a_{n2} & \cdot & a_{nn} \end{bmatrix} \quad (1)$$

At the last step, each matrix is normalized and be found the relative weights. The relative weights are given by the right eigenvector (w) corresponding to largest eigenvalue (λ max), as:

$$Aw = \lambda max.w \quad (2)$$

If the pairwise comparisons are completely consistent, the matrix A has a rank 1 and λ max = n. In this case, weights can be obtained by normalizing any of the rows or columns of A. It should be noted that the quality of the output of the AHP is related to the consistency of the pairwise comparison judgments. The consistency is defined by the relation between the entries of A: aij x ajk = aik .

The Consistency Index (CI) can be calculated, using the following formula:

$$CI = (\lambda max - n)/(n-1) \quad (3)$$

Using the final consistency ratio (CR) can conclude whether the evaluations are sufficiently consistent. The CR is calculated as the ratio of the CI and the random index (RI), as indicated in Eq. 4.

$$CR = CR/RI \quad (4)$$

The number 0.1 is the accepted upper limit for CR. If the final consistency ratio exceeds this value, the evaluation procedure has to be repeated to improve consistency

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

APLLICATIONS

Why AHP Is So Widely Applicable?

Any complex situation that requires structuring, measurement, and and/or synthesis is a good candidate for AHP. However, AHP is rarely used in isolation. Rather, it is used along with, or in support of other methodologies. For example to synthesize the results of other methodologies such as in deciding how many servers to employ in a queueing situation taking into account waiting times, costs, and human frustrations, or to derive probabilities for a decision tree. Broad areas where AHP has been successfully employed include: selection of one alternative from many; resource allocation; forecasting; total quality management; business process re-engineering; quality function deployment, and the balanced scorecard.

OVERVIEW OF AHP APPLICATIONS

Following research shows that AHP has variety of application not specific to any field. It can be used in addition to the other MCDM techniques like TOPSIS, FUZZY SETS, WSM, PROMETHEE etc. to rank or to compare the obtained results

A . Ashutosh Kumar, Mishra, Shikhar Deep, Abhishek Chaoudary (2014)

Hasproposed a methodology to identify the suitable zones in the state for the development of the organic farming using Analytical Hierarchy Process (AHP) and Geospatial techniques to boost rural economies and promote rural tourism to make self-sustainable villages

Uttarakhand is covered with 64.76% of its area under Himalayan forest providing the exquisite biodiversity and differences in climate with a miscellany of flora and fauna. Therefore creates great scope for the development of organic farming in rural areas to boost the rural economies. But organic farming is not very much evolved in this state due to lack of adequate transportation services and other socioeconomic reasons. Remote sensing and GIS can play an important role in the identification of the suitable zones for the development of organic farming in more facile manner.

They presented the efficacy of AHP and weighted overlay model for the site suitability analysis of organic farming in the study area.

B . Halim Kazana, Salih Ozçelik, Turkey (2015)

Have taken qualification or factors into account constitute the aim of the research while political parties desiring for government of the country determine their deputy candidates for nomination.

Countries are governed with different regime and government forms. Qualified human factor is needed for operating different regime and governments.

In this study; Common 15 basic criteria they had taken into consideration while political parties elect deputy candidates in general sense were determined. Criteria weight was determined with AHP method by applying FARE (Factor Relationship) method into

the evaluations made by party representatives. Multi-criteria decision-making (MCDM) techniques were applied into these basic criteria. 10 sample deputy candidates were ranked according to PROMETHEE method by the criteria weights obtained with AHP method. Correlation analysis was made among ranking and general ranking obtained was presented as sample ranking method. While this study offers solution for the problem of deputy candidate specifically, it presents participatory decision-making method in cases decision-makers should take opinions of several persons into consideration

C. Chandra Sekhara, Manoj Patwardhanb, Vishal Vyas (2015)

Used Delphi-AHP-TOPSIS methodology and the study was carried out in SMEs manufacturing unit located in central northern part of India.

Small Medium Enterprises (SMEs) are major players in the global economy. Emerging clusters are very common in India. These emerging clusters facilitate competitive advantages and growth of the economy. The paper aims to develop a framework that prioritizes potential alternatives and suggest critical indicators of intellectual capital (IC).

Here, Delphi method is an iterative process and is used in order to analysis of techniques and brainstorming for problems, opportunities and a novel consistent intellectual capital scale is developed. Analytic hierarchy process (AHP) is used to determine the weight of indicators as criteria and technique for order of preference by similarity to ideal solution (TOPSIS) is used to obtain final ranking of IC indicators. The proposed framework can support directors to point out the strengths and weaknesses of IC indicators. The interrelationship between IC indicators can also understand by the managers of the SMEs manufacturing unit with the help of these framework. SMEs manufacturing unit directors may utilize the findings of this paper as base for optimal investment of funds in IC indicators. Due to the wide range application of Delphi-AHP-TOPSIS, it has been an important research subject for many researchers with context to SMEs.

D. Sumit Guptaa, G. S. Dangayachb, Amit Kumar Singh, P. N. Rao (2015)

presented an AHP model of manufacturing sustainability through different manufacturing practices.

Sustainable Manufacturing and operations has become a crucial issue in present scenario for the manufacturing firms. Today manufacturing firms are keen interested to become sustainable in all three aspect economical social and environmental. There are number of manufacturing practices viz. Eco-design, process design, green supply chain, lean practices, product recovery and cleaner production by which firms should achieve sustainability.

In the initial stage of this study a survey methodology used from academia and industry after that an AHP model developed. From this study it is identified that firm EP-3 more conscious towards sustainability with respect to other firm. It is suggested that every electrical panel industry should adopt sustainable manufacturing practices to achieving competiveness in the market.

E. Rosaria De F. S. M. Russoa, Roberto Camanho (2015)

Had a purpose of this study is to develop a systematic review of literature on the real cases that applied AHP to evaluate how the criteria are being defined and measured.

The Analytic Hierarchy Process (AHP) is widely used by decision makers and researchers. The definition of criteria and the calculation of their weight are central in this method to assess the alternatives. However, there are few studies that focus on them.

In the 33 cases selected, they mainly used literature to build the criteria and AHP or Fuzzy AHP to calculate their weight, while other techniques were used to evaluate alternatives.

F. Daniel Podgorski (2014)

demonstrated the application of the AHP method for the selection of leading KPIs for measuring OSH MS operational performance.

Occupational safety and health management systems (OSH MSs) have been implemented in numerous enterprises worldwide since the mid-1980s. While stakeholders still have expectations on better prevention of occupational injuries and diseases, and on improving the working conditions, it suggest that new approaches are now needed to ensure OSH MS effectiveness, including development of new methods that would facilitate measurement of OHS MS operational status aimed at the genuine improvement of OSH management practices. A review of literature on leading pro-active safety performance indicators (PPIs) provided a rationale for a concept to elaborate a relatively small number of key performance indicators (KPIs) for measuring OSH MS operational performance. As a basis for this process an initial set of 109 PPIs was developed, composed of 20 sub-sets assigned respectively to individual OSH MS components. Next, for the selection of KPIs the method of the Analytic Hierarchy Process (AHP) was employed. The ranking and prioritization of leading performance indicators was made in relation to a set of SMART (Specific, Measurable, Achievable, Relevant and Time bound) criteria.

The proposed set of KPIs should be tailored to specific conditions of an enterprise, such as the size, industry sector, types of occurring hazards, or the maturity of OSH management processes

G. Luiz Carlos Barbosaa, Luiz Flavio Autran Monteiro Gomes (2015)

had proposed a methodology for continuous assessment and improvement of the efficiency and sustainability in a Chemical Industry.

This segment was chosen due to its importance both in the international (sixth largest worldwide revenues) and in Brazilian economic scenario (fourth segment in importance in the formation of industrial GDP).

An exploratory analysis was performed by applying nonparametric techniques to measure and compare the efficiency andsustainability in a fictitious chemical production plant. The analyzed variables were identified and it was defined the importance (weight) of each of these by using the AHP (Analytic Hierarchy Process) method. It was defined a standard to be used as a benchmark and it was identified the implemented actions (projects) to achieve the proposed targets, using the technique of Goal Programming. The variables were defined considering sustainability and efficiency performance indicators. For sustainability were used as reference the standards defined in "Responsible Care®" program and the efficiency performance indicators were chosen considering some key items used by the market to assess efficiency of a production plant

H. Mani.Va, Agarwal, Vinay Sharma (2014)

have demonstrated methodology for the development of social sustainability indicators, including equity, health, safety, wages,

education, philanthropy, child and bonded labour which are validated by experts.

For over a decade, sustainability has been a major concern for organizations as awareness about environmental degradation, natural resource depletion and climate change has increased. In addition, voices raised by social organizations on various social and environmental issues in developing countries have forced organizations to focus on sustainable manufacturing practices. This research mainly focuses on socially sustainable supplier selection through social parameters by using the analytic hierarchy process (AHP) in decision making. The study also describes how the above mentioned metrics may be used to prioritize alternatives for decision making using AHP. The study further demonstrates practical applications of social sustainability dimensions in selecting suppliers for manufacturers operating in emerging economies. Three case studies illustrating this methodology have also been included. The case studies further analyse the results of the methodology along with the tradeoffs supply chain managers make. Findings show that manufacturers of electrical, automotive and cement industries were able to select suppliers based on the social sustainability score. This study helps supply chain managers integrate various social dimensions into the supply chain function. The results of the study draw the attention of all stakeholders towards social dimensions by necessitating the importance of social conditions upon suppliers.

I. Jirí Franeka,, Ales Kresta (2014)

have compared and discussed the application of various judgment scales on the results in particular practical example that has been used in previous paper by Saaty (2003).

The Analytic Hierarchy Process (AHP) is widely used method in multiple-attribute decision making. In the recent literature many authors used different judgment scales which influenced the results and decisions. In this paper the author reviews and discusses effects of utilization of various judgment scales on priority estimation in AHP. There has been studies that have been concerned with the comparison of judgment scales but there were no studies concerned with consistency measures that are needed.

Thus the focus of the paper is to analyze the impact of using different judgment scales on the resulting priorities and consistency to default scale as proposed by Saaty. Results suggest that judgment scales have a profound impact on criteria priorities but not on ranking of criteria. However, the consistency varies among applied judgment scales. Authors calculated the values of random index needed for calculation of the consistency index in AHP for all concerned scales. Based on them the consistency index was computed and compared. Both consistent and inconsistent Saaty matrices were used for comparison.

J. Mohit Tyagia, Pradeep Kumarb, Dinesh Kumar (2014)

has carried out this research with an objective is to select a best alternative with an aim to improve electronic supply chain management (e- SCM) performance of Indian automobile industry located at Delhi region.

To sustain in this competitive environment, it is required for organizations to implement information technology (IT) based functions with their supply chain management (SCM) system. To accomplish the aim, a hierarchy based model has been developed through considering eight criteria and five alternatives. The considered alternatives namely are: investment in web based technologies, investment in advanced manufacturing technologies, role of top management, role of supplier and supply chain integration. The developed model has been analyzed to select a best alternative using analytic hierarchy process (AHP) and technique for order preference by similarity to ideal solution (TOPSIS) as a hybrid approach. Analysis reveals that the alternative, 'investment in web based technologies' holds first rank among all considered alternatives and can play a vital role in improving the e-SCM performance of an organization. The outcomes of this research enable mangers to make better decisions during framing strategies in improving e-SCM performance of an organization effectively.

Conclusion

The AHP provides a convenient approach for solving complex MCDM problems in engineering. It should be noted that there is a software package, called Expert Choice (1990), which has significantly contributed to the wide acceptance of the AHP methodology. However, as this paper demonstrated with some illustrative examples, its use to engineering problems should be a cautious one. There is sufficient evidence to suggest that the recommendations made the AHP should not be taken literally. In matter of fact, the closer the final priority values are with each other, the more careful the user should be. This is true with any MCDM method. The numerical examples in this paper, along with the extensive research of the authors in this area (please also see the reference list for more details), strongly suggest that when some alternatives appear to be very close with each other, then the decision-maker needs to be very cautious. An apparent remedy is to try to consider additional decision criteria which, hopefully, can assist in drastically discriminating among the alternatives. A summary of the results of a number of studies on the AHP and pairwise comparisons by the authors can be found in (Triantaphyllou and Mann, 1994b). The above observations suggest that MCDM methods should be used as decision support tools and not as the means for deriving the final answer. To find the truly best solution to a MCDM problem may never be humanly possible. The conclusions of the solution should be taken lightly and used only as indications to what may be the best answer. Although the search for finding the best MCDM method may never end, research in this area of decision-making is still critical and very valuable in many scientific and engineering applications.

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