

*REVIEW OF LITERATURE*

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Multiple criteria Decision Making (MCDM) refers to the selection of the best action from a set of alternatives, each of which is evaluated against multiple, and often conflicting criteria. MCDM problems are common in everyday life. There are many methods available for solving MCDM problems.

The Analytic Hierarchy Process (AHP) which is a powerful tool in applying MCDM was introduced and developed by Saaty in 1980. The traditional AHP requires crisp judgments. However, due to the complexity and uncertainty involved in real world decision problems, a decision maker may sometimes feel more confident to provide fuzzy judgments than crisp judgments. To overcome this difficulty, fuzzy judgments have been suggested and Fuzzy AHP has been applied in a wide variety of applications. The Fuzzy AHP approach is a systematic method for the alternative choice and justification problems that combines the concept of fuzzy set theory and the hierarchical structure analysis.

During the past two decades, there have been several approaches to Fuzzy AHP proposed by various authors. The earliest study of the FAHP was done by Van Laarhoven and Pedrycz (1983), who directly extended Saaty's AHP with triangular fuzzy numbers and used a logarithmic least-squares method to derive fuzzy weights and fuzzy performance scores for ranking alternatives. Later on, Buckley (1985) extended the classical AHP with trapezoidal fuzzy numbers and obtained the fuzzy weights and fuzzy performance scores via a geometric mean method. Boender et al. (1989) modified Laarhoven and Pedrycz's method and proposed a more robust approach to the normalization of the local priorities. Ruoning and Xiaoyan (1992) discussed the extensions of AHP to fuzzy environments and presented a procedure for constructing the fuzzy judgment matrix. Stam et al. (1996) explore how recently developed artificial intelligence techniques can be used to determine or approximate the preference ratings in AHP. They conclude that the feed-forward neural network formulation appears to be a powerful tool for analyzing discrete alternative multi-criteria decision problems with imprecise or fuzzy ratio-scale preference judgments. Chang (1996) introduces a new approach for handling Fuzzy AHP, with the use of triangular fuzzy numbers for pair-wise comparison scale off Fuzzy AHP and the use of the extent

analysis method for the synthetic extent values of the pair-wise comparisons. Cheng (1996) proposes a new algorithm for evaluating naval tactical missile systems by the fuzzy analytical hierarchy process based on grade value of membership function. Weck et al. (1997) present a method to evaluate different production cycle alternatives adding the mathematics off fuzzy logic to the classic AHP. Any production cycle evaluated in this manner yields a fuzzy set. The outcome of the analysis can finally be defuzzified by forming the surface center of gravity of any fuzzy set, and the alternative production cycles investigated can be ranked in terms of the main objective set. Kahraman et al. (1998) use a fuzzy objective and subjective method obtaining the weights from AHP and make a fuzzy weighted evaluation. Cheng et al. (1999) propose a new method for evaluating weapon systems by analytical hierarchy process based on linguistic variable weight. Zhu et al. (1999) make a discussion on extent analysis method and applications of Fuzzy AHP. Kurttila et al. (2000) combined AHP with SWOT to provide a new hybrid method for a forest certification case. Badri (2001) proposed a combined AHP-GP model for quality control systems. Creed (2001), Jansen et al. (2001) and Martinez-Tome et al. (2000) investigate food industry, customer satisfaction and food supply chain. Cebeci (2001) and Cebeci and Kahraman (2002) proposed a Fuzzy AHP model to Measure customer satisfaction of catering service companies. Yu (2002) incorporates an absolute term linearization technique and a fuzzy rating expression into a GP-AHP model for solving group decision-making Fuzzy AHP problem. Kahraman et al. (2004) provide an analytical tool to select the best Turkish catering firm providing the most customer satisfaction. The fuzzy analytic hierarchy process is used to compare three Turkish catering firms in their paper. Tolga et al. (2005) aim at creating an operating system selection framework for decision makers. Since decision makers have to consider both economic and noneconomic aspects of technology selection, both factors are considered in their developed framework. They develop the economic part of the decision process by fuzzy replacement analysis. Noneconomic factors and financial figures are combined using a fuzzy analytic hierarchy process approach. Hsiao and Chou (2006) propose a gestalt-like perceptual measure method by combining gestalt grouping principles and fuzzy entropy. The purpose of the proposed method is not to evaluate the grades of alternatives but to measure the gestalt-like perceptual degrees for home page design. They identify the weights using Fuzzy AHP.

Nang-Fei Pan (2008) introduces a new Fuzzy AHP approach for selecting the suitable bridge construction method, by using the combination of triangular fuzzy numbers and trapezoidal fuzzy numbers. Kahraman (2008) presented a comprehensive literature survey of the most important Fuzzy AHP methods and illustrated the performance of each method by means of solving a numerical example for each one. Seçme et al. (2009) proposed a fuzzy multi-criteria decision model to evaluate the performances of some banks. In their implementation, a Fuzzy Analytic Hierarchy Process (FAHP) and Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) are integrated to evaluate the five largest commercial banks of Turkish banking sector in terms of several financial and nonfinancial indicators. Yang (2009) proposed a logarithm triangular fuzzy number-Analytic Hierarchy Process (AHP) method expanding from the traditional AHP method to analyze the efficiency and advantages of supply chain in a scientific manner and validate the usability of methods on performance evaluation index system. Debmallya Chatterjee and Bani Mukherjee (2010) introduced a new Fuzzy AHP Method using Triangular Fuzzy Numbers to search the criteria's for the evaluation of best technical institutions, which can tolerate vagueness and uncertainty of human judgment. Serhat Aydin and Cengiz Kahraman (2011) proposed a Modified Fuzzy Analytic Hierarchy Process in which, decision makers use not only positive fuzzy numbers but also negative fuzzy numbers in pairwise comparison matrices. Chien-Chang Chou and Ker-Wei Yu (2013) presented a New Hybrid Fuzzy AHP Model and is applied to the location choice of international logistics centers within the international ports from the perspective of multinational corporations. Zeshui Xu and Huchang Liao (2013) extended the classical AHP and the FAHP to the intuitionistic fuzzy circumstances and develop the IFAHP procedure for handling comprehensive multicriteria decision-making problems.

The following are some articles published on Fuzzy Analytic Hierarchy Process in decision making problems.

1. "A Fuzzy AHP Approach to the Determination of Importance Weights of Customer Requirements in Quality Function Deployment", Kwong, C. K. and Bai, H., 2002 [40].

2. "Applying Fuzzy Analytic Hierarchy Process To Evaluate Success Factors Of E-Commerce", Kong, Feng. and Liu, Hongyan., 2005 [38].
3. "Application and Development of a Fuzzy Analytic Hierarchy Process within a Capital Investment Study", Tang, Yu-Cheng. and Malcolm, J. Beynon., 2005 [62].
4. "Fuzzy Multi-Attribute Selection among Transportation Companies Using Axiomatic Design and Analytic Hierarchy Process", Kulak, Osman. and Kahraman, Cengiz., 2005 [39].
5. "Determining Key Capabilities In Technology Management Using Fuzzy Analytic Hierarchy Process: A Case Study Of Turkey", Erensal, Y. C., Oncan, T. and Demircan, M. L., 2006 [29].
6. "Priority Mix Planning For Semiconductor Fabrication By Fuzzy AHP Ranking", Kang, He-Yau. and Lee, H.I., 2007 [34].
7. "Global Supplier Development Considering Risk Factors Using Fuzzy Extended AHP-Based Approach", Chan, F. T.S. and Kumar, N., 2007 [15].
8. "A Selection Model for ERP System by Applying Fuzzy AHP Approach", Chi-Tai, Lien. and Hsiao-Ling, C., 2007 [23].
9. "Prioritization of Human Capital Measurement Indicators Using Fuzzy AHP", Bozbura, F. T., Beskese, A. and Kahraman, C., 2007 [11].
10. "Fuzzy Analytical Hierarchy Process in GIS Application", Vahidniaa, M. H, Alesheikhb, A, Alimohammadic, A and Bassirid, A, 2008 [64].
11. "Developing A Fuzzy Analytic Hierarchy Process (AHP) Model For Behavior-Based Safety Management", Dagdeviren, M. and Yuksel, I., 2008 [25].
12. "A Linear Goal Programming Priority Method For Fuzzy Analytic Hierarchy Process And Its Applications In New Product Screening", Wang, Ying-Ming. and Chin, Kwai-Sang., 2008 [67].

13. "On The Extent Analysis Method for Fuzzy AHP and Its Applications", Wang, Ying-Ming., Luo, Ying. and Zhongsheng Hua., 2008 [70].
14. "Application of Fuzzy Extended AHP Methodology On Shipping Registry Selection: The Case Of Turkish Maritime Industry", Metin, Celik, Deha, Er. I, and Fahri, O. A., 2009 [46].
15. "A Method For Selecting Third Party Logistic Service Provider Using Fuzzy AHP", Cakir, Erdal., Tozan, Hakan. and Vayvay, Ozalp., 2009 [13].
16. "Designing a Fuzzy Expert System to Evaluate Alternatives in Fuzzy Analytic Hierarchy Process", Hamed, F., Hamid, E. and Hamidreza, S., 2010 [32].
17. "Integration of Fuzzy Analytic Hierarchy Process (FAHP) with Balance Score Card (BSC) in order to Evaluate the Performance of Information Technology in Industry", Hamid, Reza. Feili., Nazanin, V. F. and Naghme, V., 2011 [31].
18. "Applying Fuzzy Analytic Hierarchy Process (FAHP)  $\alpha$ -Cut Based and TOPSIS Methods to Determine Bali Provincial Road Handling Priority", Wedagama, D.M.P. and Frederika, A., 2011 [73].
19. "A Portfolio Selection Using Fuzzy Analytic Hierarchy Process: A Case Study Of Iranian Pharmaceutical Industry", Solmaz Ghazanfar Ahari, Nader Ghaffari-Nasab, Ahmad Makui, and Seyed Hassan Ghodsypour, 2011 [59].
20. "Fuzzy Analytical Hierarchy Process (FAHP): A GIS-based Multicriteria Evaluation/Selection Analysis", Mehdi, Ziaei. and Fateme, Hajizade., 2011 [45].
21. "Rating and Ranking Criteria for Selected Islands using Fuzzy Analytic Hierarchy Process (FAHP)", Ali, Noraida Haji., IlyAmalina, Ahmad Sabri., Noor, MaizuraMohamad, Noor. and Fathilah, Ismail., 2012 [1].
22. "Selection of Academic Staff Using The Fuzzy Analytic Hierarchy Process (FAHP): A Pilot Study", Rouyendegh, B. D. and Erkan, T. E., 2012 [54].

23. "Constrained Fuzzy Hierarchical Analysis for Portfolio Selection Under Higher Moments", Nguyen, T. T. and Gordon-Brown, L., 2012 [50].
24. "Applying Fuzzy Analytic Hierarchy Process (FAHP)  $\alpha$  -Cut Based And TOPSIS Methods To Determine Regencial Road Handling Priority (Case Study: Badung Regency - Bali)", Wedagama, D. M. P. and Andnyana, Rai. I. B., 2012 [72].
25. "A Spatial Load density forecasting Method Based on Cloud Theory and Fuzzy Analytic Hierarchy Process", Gao, Yan., Yang, R. G. and Li, Wei., 2012 [30].
26. "Integrating Fuzzy Delphi with Fuzzy Analytic Hierarchy Process for Multiple Criteria Inventory Classification", Kabir, G. and Razia, S. S., 2013 [33].
27. "A Structure-Based Software Reliability Allocation Using Fuzzy Analytic Hierarchy Process", Chatterjee, S., Jeetendra B. Singh. and Arunava, Roy., 2013 [18].

In this review of literature a brief survey of some of the articles published on Fuzzy Analytic Hierarchy process Methods and their applications are given.

### **1. A Fuzzy AHP Approach To The Determination Of Importance Weights Of Customer Requirements In Quality Function Deployment**

**Kwong, C.K. and Bai, H. (2002) [40]**

Quality Function Development (QFD) is an important tool in product planning that could contribute to increase in customer satisfaction and shortens product design and development time. In this paper a Fuzzy AHP approach to the determination of the important weights of the customer requirements for QFD is described. In this methodology, triangular fuzzy numbers were introduced into the conventional AHP in order to improve the imprecise ranking of customer requirements. Firstly, the linguistic assessment on customer requirements is converted into triangular fuzzy numbers. These triangular fuzzy numbers are used to build the comparison matrices of AHP based on pairwise comparison technique. The important weights of customer requirements can be calculated by applying

fuzzy AHP. Finally, an example of bicycle splashguard design is used to illustrate the proposed approach.

## **2. Applying Fuzzy Analytic Hierarchy Process To Evaluate Success Factors Of E-Commerce**

**Kong, Feng. and Liu, Hongyan. (2005) [38]**

In this paper, a new Fuzzy AHP method to evaluate the success factors of E-commerce is proposed. Here a substitute membership scales in the place of Saaty's 1-9 scales to reduce adjusting times are introduced. Moreover, this study discusses about the key factors that affect success in E-commerce using Fuzzy AHP, and give an evaluation method for E-commerce in order to help researches and managers to determine the drawbacks and opportunities.

## **3. Application and Development of a Fuzzy Analytic Hierarchy Process within a Capital Investment Study**

**Tang, Yu-Cheng. and Malcolm, J. Beynon. (2005) [62]**

Capital budgeting as a decision process is among the most important of all management decisions. The importance (consequents) of the subsequent outcome may bring a level of uncertainty to the judgment-making process by the decision maker(s) in the form of doubt, hesitancy, and procrastination. The application problem in question is the selection of the type of fleet car to be adopted by a small car rental company, a selection that accounts for a large proportion of the company's working capital. To solve this problem a modified synthetic extent FAHP is proposed. In this paper, an attempt is made to further the understanding of the Extent Analysis Method and the use of group decision making in the FAHP. A redefining of the measure of the degree of fuzziness in the pairwise comparison judgments is made which removes the restriction on the scale values able to be utilized in future studies. A sensitivity analysis is undertaken to observe the influence of changes in the value of the degree of fuzziness on the sets of weights. Throughout this paper, there is a balance between the size of the problem

considered and the developments of the existing FAHP technique used, and as such there is a level of an expositional approach to the application investigated.

#### **4. Fuzzy Multi-Attribute Selection among Transportation Companies Using Axiomatic Design and Analytic Hierarchy Process**

**Kulak, Osman. and Kahraman, Cengiz. (2005) [39]**

The basic concept in axiomatic design (AD) is the existence of design axioms. First of these axioms is the independence axiom and the second one is the information axiom. Information axiom proposes the selection of the best alternative that has minimum information. Analytic Hierarchy Process (AHP) is another multi-attribute method which is a decision-making method for selecting the best among a set of alternatives, given some criteria. The method has been extensively applied, especially in large-scale problems where many criteria must be considered and where the evaluation of alternatives is mostly subjective. Multi-attribute transportation company selection is a very important activity for effective supply chain. In this paper, the selection of the best company under determined criteria (such as cost, time, damage/loss, flexibility and documentation ability) using both multi-attribute AD and AHP is realized. The fuzzy multi-attribute AD approach is also developed and it is compared by one of Fuzzy AHP methods in the literature. The selection process has been accomplished by aiding software that includes crisp AD and fuzzy AD

#### **5. Determining Key Capabilities In Technology Management Using Fuzzy Analytic Hierarchy Process: A Case Study Of Turkey**

**Erensal, Y.C., Oncan, T. and Demircan, M.L. (2006) [29]**

The importance of technology management is a vital determinant of long-run success or failure of organizations in today's world. Since technology is a major driver of the global economic development, business professionals seek more effective ways to manage existing and emerging technology. This paper proposes a model to understand the links between competitive advantages, competitive priorities and competencies of a firm in the context of the technology management.

In this paper, a Fuzzy Analytical Hierarchy Process (AHP) is used to analyze these links. Moreover, the perception of a group of managers from different Turkish firms regarding the technology management is examined. The main result of this paper is that the concept of the management of technology arises to be much more important than both the product technology and the process technology.

#### **6. Priority Mix Planning For Semiconductor Fabrication by Fuzzy AHP Ranking**

**Kang, He-Yau. and Lee, H.I. (2007) [34]**

In this paper, a Fuzzy AHP model is constructed that applies fuzzy set theory and entropy weight concept, to evaluate different priority mixes and to support the selection of priority mix that is efficient for a wafer fab to manufacture. This proposed method is an analytical approach under a fuzzy subjective judgment environment, in which Fuzzy Analytic Hierarchy Process (AHP) method with entropy weight is utilized to deal with uncertainty, to generate performance ranking of different priority mixes which provide guidance to experts in a fab regarding strategies for accepting orders with the consideration of manufacturing efficiency in the aspects of product, equipment efficiency and finance.

#### **7. Global Supplier Development Considering Risk Factors Using Fuzzy Extended AHP-Based Approach**

**Chan, F. T.S. and Kumar, N. (2007) [15]**

Global supplier development is a multi-criterion decision problem which includes both qualitative and quantitative factors. The global supplier selection problem is more complex than domestic one and it needs more critical analysis. This paper identifies some of the important and critical decision criteria including risk factors for the development of an efficient system for global supplier selection. Fuzzy Extended Analytic Hierarchy Process (FEAHP) based methodology will be discussed to tackle the different decision criteria like cost, quality, service performance and supplier's profile including the risk factors involved in the selection of global supplier in the current business scenario. FEAHP is an efficient

tool to handle the fuzziness of the data involved in deciding the preferences of different decision variables. The linguistic level of comparisons produced by the customers and experts for each comparison are tapped in the form triangular fuzzy numbers to construct fuzzy pair-wise comparison matrices. The implementation of the system is demonstrated by a problem having four stages of hierarchy which contains different criteria and attributes at wider perspective. The proposed model can provide not only a framework for the organization to select the global supplier but also has the capability to deploy the organization's strategy to its supplier.

#### **8. A Selection Model for ERP System by Applying Fuzzy AHP Approach**

**Chi-Tai, Lien. and Hsiao-Ling, Chan. (2007) [23]**

The selection criteria of enterprise resource planning (ERP) system are numerous and fuzzy, so how to select an adequate ERP system is crucial in the early phase of an ERP project. In this paper, a Fuzzy Analytic Hierarchy Process (FAHP) method is proposed to evaluate the alternatives of ERP system, which involves more comprehensive viewpoint for the software quality. More specifically, the developed approach proposes a stepwise systematic model for group decision makers to select an appropriate ERP system effectively and efficiently. In this FAHP model, there are 32 criteria sifted out from product aspect and management aspect. Two practical cases are used for the practicability of the model; one is semiconductor industry and another is education industry.

#### **9. Prioritization of Human Capital Measurement Indicators Using Fuzzy AHP**

**Bozbura, F. T., Beskese, A. and Kahraman, C. (2007) [11]**

People in an organization constitute an important and essential asset which tremendously contributes to development and growth of that company by the help of their collective attitudes, skills and abilities. This is why the human capital (HC) can be considered the most important sub-dimension of the intellectual capital. Since you cannot manage what you cannot control, and you cannot control what you do not measure, the measurement of HC is a very important issue. This study

aims at defining a methodology to improve the quality of prioritization of HC measurement indicators under fuzziness. To do so, a methodology based on the extent Fuzzy Analytic Hierarchy Process (AHP) is proposed. Within the model, five main attributes; talent, strategic integration, cultural relevance, knowledge management, and leadership; their sub-attributes, and 20 indicators are defined. The proposed model can be used for any country. However, the results obtained in the numerical example reflect the situation of HC in Turkey, since the experts are asked to make their evaluations considering the cultural characteristics of Turkey. The results of the study indicate that “creating results by using knowledge”, “employees’ skills index”, “sharing and reporting knowledge”, and “succession rate of training programs” are the four most important measurement indicators for the HC in Turkey.

#### **10. Fuzzy Analytical Hierarchy Process In GIS Application**

**Vahidniaa, M.H, Alesheikhb, A, Alimohammadic, A and Bassirid, A (2008)[64]**

In this paper the application of multicriteria decision making in spatial problems and GIS application was discussed and in resumption AHP as a most applicable tool in this context was introduced. In addition, this deals with the steps of AHP, its manner to apply and its weaknesses and strengths and ultimately the fuzzy modified Analytical Hierarchy Process (FAHP) which is proposed after that the concepts like of fuzziness, uncertainty and vagueness was broadly posed in expert's decision making. In the last part of this paper the Chang's Fuzzy Extent Analysis method and  $\alpha$ -cut based method on Fuzzy AHP is described to obtain a crisp priority vector from a triangular fuzzy comparison matrix.

#### **11. Developing A Fuzzy Analytic Hierarchy Process (AHP) Model For Behavior-Based Safety Management**

**Dagdeviren, M. and Yuksel, I. (2008) [25]**

Safety management (SM) is a very important element within an effective manufacturing organization. One of the most important components of SM is to

maintain the safety of work systems in the workplace. Safety of work systems is a function of many factors which affect the system, and these factors affect the safety of work systems simultaneously. For this reason, measuring work system safety needs a holistic approach. In this study, the work safety issue is studied through the Analytic Hierarchy Process (AHP) approach which allows both multi-criteria and simultaneous evaluation. Another limitation faced in SM is the inability to measure the variables exactly and objectively. Generally, the factors affecting work system safety have non-physical structures. Therefore, the real problem can be represented in a better way by using fuzzy numbers instead of numbers to evaluate these factors. In this paper, a Fuzzy AHP approach is proposed to determine the level of Faulty Behavior Risk (FBR) in work systems. The proposed method is applied in a real manufacturing company. In the application, factors causing faulty behavior are weighted with triangular fuzzy numbers in pairwise comparisons. These factors are evaluated based on the work system by using these weights and fuzzy linguistic variables. As a result of this evaluation FBR levels of work systems are determined and different studies are planned for work systems according to the FBR levels. In this way, faulty behavior is prevented before occurrence and work system safety is improved.

## **12. A Linear Goal Programming Priority Method For Fuzzy Analytic Hierarchy Process And Its Applications In New Product Screening**

**Wang, Ying-Ming. and Chin, Kwai-Sang. (2008) [67]**

Fuzzy Analytic Hierarchy Process (AHP) has been widely used for a variety of applications such as supplier selection, customer requirements assessment and the like. However, the huge majority of the applications just use those sophisticated approaches such as fuzzy least squares method, fuzzy preference programming method and the like while using a simple extent analysis for the sake of simplicity. This paper proposes a sound yet simple priority method for Fuzzy AHP which utilizes a linear goal programming (LGP) model to derive normalized fuzzy weights for fuzzy pairwise comparison matrices. Finally the proposed LGP priority method

is tested with three numerical examples including an application of Fuzzy AHP to new product development (NDP) project screening decision making.

### **13. On The Extent Analysis Method for Fuzzy AHP and Its Applications**

**Wang, Ying-Ming., Luo, Ying. and Zhongsheng, Hua. (2008) [70]**

In this paper by Chang, an extent analysis method on Fuzzy AHP was proposed to obtain a crisp priority vector from a triangular fuzzy comparison matrix. It is found that the extent analysis method cannot estimate the true weights from a fuzzy comparison matrix and has led to quite a number of misapplications in the literature. This paper, shows by examples that the priority vectors determined by the extent analysis method do not represent the relative importance of decision criteria or alternatives and that the misapplication of the extent analysis method to Fuzzy AHP problems may lead to a wrong decision to be made and some useful decision information such as decision criteria and fuzzy comparison matrices not to be considered.

### **14. Application Of Fuzzy Extended AHP Methodology On Shipping Registry Selection: The Case Of Turkish Maritime Industry**

**Metin, Celik., Deha, Er. I. and Fahri, O. A (2009) [46]**

Selection of the suitable shipping registry alternative for the existing fleet or new building ships is one of the critical decision milestones of the shipping business. In this paper a practical decision support mechanism on ensuring multiple criteria analysis of shipping registry selection is presented, where the Fuzzy AHP methodology, based on Chang's extent analysis, is determined to be utilized in order to model the shipping registry selection. After structuring the fundamental hierarchy, the model is performed with a case application on Turkish maritime industry to be able to obtain illustrative results. The shipping registries of Turkiye, Panama, and Malta are determined to evaluate as the potential alternatives for Turkish ship owners. Moreover, the literature was examined for the applications of analytical methodologies on maritime business; it was seemed that they were so

rare. Therefore, the originality of this study appears on modeling of the critical process under multidisciplinary philosophy in ship management.

#### **15. A Method For Selecting Third Party Logistic Service Provider Using Fuzzy AHP**

**Cakir, Erdal., Tozan, Hakan., and Vayvay, Ozalp. (2009) [13]**

Logistics service provider selection is a complex multi – criteria decision making process; in which, decision makers have to deals with the optimization of conflicting objectives such as quality, cost, and delivery time. Despite to the great variety of methods and models that have been designed to help decision maker for this process in literature, few efforts have been dedicated to develop systematic approaches for logistics service provider selection using these predesigned methods and models. In this paper a decision support system for logistics service provider selection based on a Extent Fuzzy AHP model is designed and implemented. In this proposed model the triangular fuzzy numbers are used for pairwise comparison scale and the extent analysis method is used to find the synthetic extent value  $S_i$  of the pairwise comparison.

#### **16. Designing a Fuzzy Expert System to Evaluate Alternatives in Fuzzy Analytic Hierarchy Process**

**Hamed, F., Hamid, E. and Hamidreza, S. (2010) [32]**

This paper concerns with proposing a fuzzy logic based expert system to break through the problem of alternatives evaluation in Analytic Hierarchy Process (AHP). AHP as a multi criteria decision aid helped decision makers for analyzing and prioritizing the alternatives in a hierarchical structure. During times AHP encountered some problems. Hence, Fuzzy Analytic Hierarchy Process (FAHP) and some other extensions of AHP have been configured to solve those problems. Moreover, the advantages of using expert system to prioritize the alternatives in comparison with Fuzzy AHP are also discussed. Finally, to present the validity and effectiveness of the proposed expert system a numerical example is illustrated.

**17. Integration of Fuzzy Analytic Hierarchy Process (FAHP) with Balance Score Card (BSC) in order to Evaluate the Performance of Information Technology in Industry**

**Hamid, Reza. Feili., Nazanin, V. F. and Naghme, V. (2011) [31]**

The degree of effectiveness of information technology (IT) in industry and the way it aids organizational goals are considered as very key sensitive points in industry's communications and interactions in the worldwide scale. In fact information technology has got various functions in different sectors of industry most of which are not simply quantifiable. Usually a large quantity of the information we deal with in industrial atmospheres are ambiguous and in a way fuzzy. That's why it makes it almost impossible to utilize common ways of decision-making in this area. In this paper, due to integrity of decision-making approach, evaluation of information technology will be based on FAHP and BSC approaches. Ways forward for BSC to express organizational hierarchy are divided into four main sections (financial, buyer, the function's internal process, and training & rate of progress). These factors are considered as functional indicators for each section to be evaluated. The FAHP approach here is mainly advised to be used to clarify the ambiguity of the information. In conclusion this integrated methodology facilitates planning in information systems and gives some clues to create a viable system of information technology in industry. That means provision of ways forward for improvements in performance of information technology in Industries.

**18. Fuzzy Analytic Hierarchy Process: A Logarithmic Fuzzy Preference Programming Methodology**

**Wang, Ying-Ming. and Chin, Kwai-Sang. (2011) [68]**

Fuzzy Analytic Hierarchy Process (AHP) proves to be a very useful methodology for multiple criteria decision-making in fuzzy environments, which has found substantial applications in recent years. The use of Fuzzy AHP for multiple criteria decision-making requires scientific weight derivation from fuzzy

pairwise comparison matrices. Existing approaches for deriving fuzzy weights from fuzzy pairwise comparison matrices turn out to be too sophisticated and rare to be applied, while the approaches for deriving crisp weights from fuzzy pairwise comparison matrices prove to be either invalid or subject to significant drawbacks such as producing multiple even conflict priority vectors for a fuzzy pairwise comparison matrix, leading to distinct conclusions. To address these drawbacks and provide a valid yet practical priority method for Fuzzy AHP, this paper proposes a logarithmic fuzzy preference programming (LFPP) based methodology for Fuzzy AHP priority derivation, which formulates the priorities of a fuzzy pairwise comparison matrix as a logarithmic nonlinear programming and derives crisp priorities from fuzzy pairwise comparison matrices. Numerical examples are tested to show the advantages of the proposed methodology and its potential applications in Fuzzy AHP decision-making.

#### **19. Applying Fuzzy Analytic Hierarchy Process (FAHP) $\alpha$ -Cut Based and TOPSIS Methods to Determine Bali Provincial Road Handling Priority**

**Wedagama, D.M.P. and Frederika, A. (2011) [73]**

The Analytic Hierarchy Process (AHP) method has been employed in a previous study to determine Bali provincial road handling priority. This method usually overlooks the decision maker's degrees of confidence and optimism of the decision. Meanwhile, Fuzzy Analytic Hierarchy Process (FAHP)  $\alpha$ -cut based and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methods allow to estimate the overall road handling priority considering on degrees of confidence and optimism of the decision. In this paper, FAHP  $\alpha$ -cut based and TOPSIS methods are employed to determine Bali provincial road handling priority. A very high priority scale is used to determine the priority for all provincial (140) road links in Bali. This scale is determined using AHP 0.85 percentile score or greater. In this proposed model, FAHP  $\alpha$ -cut based method is used to determine the weights of the criteria by experts and then TOPSIS method is used to determine road links handling priority. Further, changes of ideal solution under different risk environments are also simulated.

**20. A Portfolio Selection Using Fuzzy Analytic Hierarchy Process: A Case Study Of Iranian Pharmaceutical Industry**

**Solmaz Ghazanfar Ahari, Nader Ghaffari-Nasab, Ahmad Makui, and Seyed Hassan Ghodsypour. (2011) [59]**

Portfolio selection is one of the important problems encountered by any investor. The purpose of this paper is to solve a real stock portfolio selection problem in Iran. According to the uncertain environments in which financial decisions are made, most of the recent works in this field use fuzzy sets theory in order to incorporate these uncertainties into their analysis. The problem is to determine how to allocate a limited fund among the stocks of some pharmaceutical companies in Tehran stock exchange. In this paper, two Fuzzy Analytic Hierarchy Process (FAHP) methods are applied to this problem. Finally, the results obtained from the two methods are compared in terms of the solution quality.

**21. Fuzzy Analytical Hierarchy Process (FAHP): A GIS-based Multicriteria Evaluation/Selection Analysis**

**Mehdi, Ziaei. and Fateme, Hajizade. (2011) [45]**

In this paper the application of multicriteria decision making in spatial problems and GIS application was discussed. FAHP and FMCDM analysis have been applied extensively for decision making problems involving multiple criteria evaluation/selection of alternatives. This paper incorporate the concept of fuzzy set theory and hierarchical structure analysis into the GIS-base MCDA.

**22. Rating and Ranking Criteria for Selected Islands using Fuzzy Analytic Hierarchy Process (FAHP)**

**Ali, Noraida Haji., IlyAmalina, Ahmad Sabri., Noor, MaizuraMohamad Noor and Fathilah, Ismail. (2012) [1]**

Destination choice is one of decision making problems which should carefully be investigated in order to choose the best alternative among popular

alternatives. The structure in modeling decision making may influencing the decision made and different decision making models impose different objectives with the result may not be variant. Therefore island evaluation has become one of important components in the selections. This paper proposed integration between Fuzzy MCDM approaches represented by the Fuzzy AHP to select the best location for a recommendation tourism destination. Multi-Criteria Decision Making (MCDM) is a possible evaluation scale for many characters or quantities of decision makers' evaluation. It could be determined by advantage or ranking. This study presents Fuzzy AHP as a proposed method for dealing with decision making in ten (10) social attributes. Fuzzy Analytic Hierarchy Process (FAHP) is employed to calculate the weights of these criteria and sub-criteria, so as to build the fuzzy multi-criteria model of island evaluation. FAHP performed better than domain experts in tourism when the size of criteria and sub-criteria set increase. Finally, a detailed numerical example, illustrating the application of our approach to criteria evaluation is given.

### **23. Selection Of Academic Staff Using The Fuzzy Analytic Hierarchy Process (FAHP): A Pilot Study**

**Rouyendegh, B. D. and Erkan, T. E. (2012) [54]**

In this paper a Fuzzy Analytic Hierarchy Process (FAHP) for selecting the most suitable academic staff is proposed, where five candidates under ten different sub-criteria are evaluated and prioritized. The FAHP method adopted here uses Triangular Fuzzy Numbers (TFN). The inability of AHP to deal with the impression and subjectiveness in the pair-wise comparison process has been improved in the FAHP. In order to achieve consensus among the decision-makers, instead of a crisp value all pair-wise comparisons were converted into triangular fuzzy numbers to adjust the fuzzy rating and the fuzzy attribute weight. Finally, a real case study is presented to highlight the procedure of the proposed method.

#### **24. Constrained Fuzzy Hierarchical Analysis for Portfolio Selection under Higher Moments**

**Nguyen, T. T. and Gordon-Brown, L. (2012) [50]**

Marginal impacts of assets on portfolio higher moments are characterized by triangular fuzzy numbers and then evaluated by fuzzy ranking procedures in order to assemble fuzzy reciprocal matrices that are needed for the constrained Fuzzy Analytic Hierarchy Process (AHP) methods. The proposed methodology increases the scope for emphasizing objective quantitative measures, thus alleviating the influence of subjective qualitative factors. Employing constrained fuzzy arithmetic during Fuzzy AHP application produces greater precision and reliability compared with applications of the standard fuzzy arithmetic. By reference to higher moments, the investor is able to strategize portfolios so that there is a reduction not only in exposure to normal risk (i.e., volatility) but also to risk of asymmetry (skewness) and the risk of “fat tails” (kurtosis). The efficiency of the proposed approach is highlighted in the ability to handle investor preferences regarding higher moment risks. More optimal values for a particular risk can be obtained if that risk is of more concern. Moreover, in terms of obtaining portfolio diversification, the method is shown to be more useful than conventional optimization model.

#### **25. Applying Fuzzy Analytic Hierarchy Process (FAHP) $\alpha$ -Cut Based And TOPSIS Methods To Determine Regencial Road Handling Priority (Case Study: Badung Regency - Bali)**

**Wedagama, D. M. P. and Andnyana, Rai. I. B. (2012) [72]**

This paper examines regencial road handling priority using FAHP  $\alpha$  -cut based and TOPSIS methods using Badung regency in Bali province as the case study area. The study is restricted to regencial roads under severe conditions. Adoption of these FAHP  $\alpha$  -cut based and TOPSIS methods allow the researcher to have estimation regarding the overall road handling priority considering the decision makers's attitude from optimistic to pessimistic situations and decision makers's degree of confidence from under the most uncertain to certain

comparisons. Meanwhile, the previous study has analyzed the same case study area using FAHP extent analysis and TOPSIS methods with no consideration on decision makers's attitude and confidence. This paper concluded that road handling determination using FAHP  $\alpha$  -cut based and TOPSIS methods, considering both pessimistic and moderate situations and highly optimistic situation with uncertain conditions of the decision makers, produced similar top priority as it used FAHP extent analysis and TOPSIS methods.

## **26. A Spatial Load density forecasting Method Based on Cloud Theory and Fuzzy Analytic Hierarchy Process**

**Gao Yan, Yang, R. G. and Li, Wei. (2012) [30]**

Spatial load density forecasting is the basis of distribution network planning. In view of the features of spatial power load density forecasting and the uncertainty of human's judgment, this paper presents a spatial load forecasting method based on cloud theory and Fuzzy Analytic Hierarchy Process (AHP) to improve the forecast inaccuracy. Cloud generators and inference rules were established to quantize the qualitative factors and obtain the objective weights of the influencing factors. Triangular fuzzy number is introduced to the model for indicating the judgments of experts while the AHP is used for dealing with the judgments so as to obtain optimal subjective weights of different factors. The spatial load density was forecasted by using the synthetically weights. An example demonstrates the superiority of the proposed model in spatial load density forecasting.

## **27. Integrating Fuzzy Delphi with Fuzzy Analytic Hierarchy Process for Multiple Criteria Inventory Classification**

**Kabir, G. and Razia, S. S. (2013) [33]**

In this paper, a systematic and logical approach is structured for multiple criteria inventory classification through integrating Fuzzy Delphi Method (FDM) with Fuzzy Analytic Hierarchy Process (FAHP). Fuzzy linguistic terms has been

employed for facilitating the comparisons between the subject criteria, since the decision makers feel much comfortable with using linguistic terms rather than providing exact crisp judgments. Fuzzy Delphi method used to identify the most important and significant criteria and, Fuzzy AHP is used to determine the relative weights of the attributes or criteria, and to classify inventories into different categories. To accredit the proposed model, it is implemented for the 351 raw materials of switch gear section of Energypac Engineering Limited (EEL), a large power engineering company of Bangladesh. Implementation results show that the proposed method can be used in inventory classification.

#### **28. A Structure-Based Software Reliability Allocation Using Fuzzy Analytic Hierarchy Process**

**Chatterjee, S., Jeetendra B. Singh. and Arunava, Roy. (2013) [18]**

In this paper, a software reliability allocation model has been proposed to solve the problem at the planning and design stage of software. The proposed model will be useful for determining the reliability goal at the planning and design phase of a software project, hence making reliability a singular measure for performance evaluation. Proposed model requires a systematic formulation of user requirements and preference into the technical design and reliability of the software. To accomplish this task, a hierarchical structure has been set up to break down the problem from top to bottom. Then the Fuzzy Analytic Hierarchy Process (FAHP) has been applied to derive the required parameters from this hierarchy. A comparison between AHP and FAHP has been carried out based on consistency ratio. Also, sensitivity analysis has been performed to demonstrate the performance of the proposed approach. The reliability allocation model presented in this paper guarantees about the achievement of software system reliability goal. Finally, an example has been given to illustrate the effectiveness and feasibility of the proposed method.