Analytic Network Process—A Latest Survey and Review

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Abstract—*ANP or Analytic Network Process is a mathematical modeling tool which is employed in problems in which decisions depend on dependence of high level element on a low level element in a multiple decision criteria environment. It is a mathematical tool which helps in modeling the interdependencies among the selected variables thereby making it the most sought method for modeling problems. Problems that have dependencies on low as well high level criteria are easily modeled by ANP method. This paper gives examples of the different areas such as transportation, safety assessment, risk prioritization, designing of automotive component, facility layout, assessment of alternatives to an existing problem, supplier selection in which ANP has been successfully implemented and how feedback dependency was incorporated in the process to improve the decision making.*

Keywords: *Analytic Network Process, high level element, low level element, dependency, feedback.*

1. INTRODUCTION

Analytical Network Process or ANP is a mathematical modeling tool which takes into consideration the criteria which are based on the views and opinion of people expert in that domain. ANP is a generalized type AHP in which the dependence of a higher level criterion on lower level criteria is considered. ANP also involves incorporation of feedback mechanism so that that accuracy in decision making can be obtained. The feedback structure is a network consisting of source which is the origin and the sink which is the destination. Some problems may have intermediate nodes while some may not have intermediate nodes depending on the type of problem in consideration. The network making is a challenging task as it involves the priority fixation of all the elements present in the network. It is also important to prioritize the alternative of the decision.

ANP finds application in a variety of environments in which there is dependency among high level and low level elements. Many studies have been done using ANP in different areas and the decisions implemented successfully in real life problems.

2. ANP APPLICATIONS

1. Transportation Research: The proposed method is developed as an analytic network process (ANP) containing grey numbers and multiple assessment criteria for a bikeability assessment method to evaluate zone-based friendliness to biking within an area. Lin et al.[1] demonstrated that the grey ANP is unique in bikeability literature is capable of managing the interdependences among criteria and zones and the proposed grey ANP methodology (grey numbers) which is also capable of measuring possible ranges of criteria performances. It is also good at handling various performances within a zone. The application of the methodology to the bikeability assessment of zones in Daan District, Taipei City, Taiwan verifies the effectiveness of the method and also provides action directions to the local administration in developing bike-friendly environments [1].

2. Safety assessment in oil drilling work system: Sun et al. demonstrated that [2] safety assessment is a very important and essential work to guarantee the safety of oil drilling. As there are relations and dependencies between human factors in oil drilling work system it is important that the safety of oil drilling work system should be analyzed in a comprehensive way. In the proposed method, safety questionnaires are conducted in oil drilling industry. A SEM-ANP methodology is used to evaluate the importance of human factors. The frequency is calculated with accident cases. The reasons of accidents and safety recommendations are discussed by the final results.

The constructed model has the Human Factors Analysis and Classification System (HFACS) to establish rational and applicable index system for investigating human errors. The Analytic Network Process (ANP) methodology is used to obtain the priorities of human factors considering the interdependences. The Structural Equation Modeling (SEM) is used to form the ANP model auxiliary, which may be expected to overcome subjective opinions from experts and provide more practical safety strategies [2].

3. Risk prioritization in megaprojects: Megaprojects are complex and expensive projects that involve steep social, technical, economic, environmental and political challenges to the project management. Despite of the challenges of high risks of being over schedule and over budget, project owners and financiers still continue to invest large sums of money in megaprojects. While some risks are considered during project planning, the challenge of risks interactions and impacts on project performance still remains. So, Boateng et al. demonstrated that [3] social, technical, economic, environmental and political affairs are some complex risks in megaproject at construction phase. Risk complexities can lead to a higher possibility of megaprojects running over time and budget. The newly constructed ANP models were based on the three year data collected from the ENT project. Now, the newly constructed tool can be used as a quantitative approach to prioritize potential risks across the project supply network. The methodology can be used to quantify risk areas during construction of various projects [3].

4. Applications of Generalized analytic network process: The analytic network process (ANP) is a methodology for multi-criteria decision making, which is used to derive priorities of the compared elements in a network where the dependences and feedback within and between the elements etc. can be considered. However, the ANP decision making criteria is limited to the input preferences as crisp judgments (fuzzy type), which is unfavorable in most of the practical applications. So, Zhu et al. developed [4] generalized analytic network process (G-ANP) as G-ANP eliminates the drawbacks of the ANP and F-ANP. It useful for decision making problems with big data. It also allows multiple forms of preferences, such as crisp (fuzzy) judgments, interval (interval fuzzy) judgments, hesitant (hesitant fuzzy) judgments and stochastic (stochastic fuzzy) judgments.A concept of complex comparison matrices (CCMs) is constructed to collect decision makers' preferences in the multiple forms. From a stochastic point of view, they developed an eigenvector method based on stochastic preference method (EVM-SPM) to derive priorities from CCMs. The main steps are summarized. A detailed implementation in matlab and excel environments, which is a type of prototype, is also developed by them. An example of the piracy risk assessment to the energy channels of China is proposed for the demonstration of the G-ANP by them [4].

5. Conceptual design of composite automobile engine rubber mounting: An engine rubber mounting is one of the most important and essential parts of a vehicle as it isolates or absorbs the vibration caused by the engine unit to reduce vibration to the vehicle body and to the passenger itself. As the engine compartments have a heated and massive vibrating environment, the lifespan of the product gets reduced. Several studies have been conducted to upgrade and increase the material lifespan of the engine rubber shock absorber to make it more reliable and better engine mounting components. So, [5] Assamia et al. developed a conceptual design of kenaf

fiber polymer as automotive engine rubber mounting composites using the integration of Theory of Inventive Problem Solving (TRIZ). The solution is developed using 40 inventive principles and TRIZ contradiction method. The selection for the solution parameter for specific design character is done using the morphological chart to develop a systematic conceptual design for the component. Four (4) innovative design concepts were developed using Analytic Network Process (ANP) methodologies to perform the multi-criteria decision-making process for selecting the best concept design for the polymer composite engine rubber mounting component.[5]

6. Evaluation of mobile text entry methods: Speed and accuracy are the two main factors considered in the Evaluation of text entry methods in literature. The research showed that QWERTY is the most preferred and sound format and method for evaluation of text entry methods. Occampo et al. developed a [6] multi-criteria decision-making approach for preference evaluation of text entry methods. The developed method is an alternate method for user specified text input formats, which uses the multi- criteria decision making approach. It uses the ANP decision making methodology that can be used for user specified keyboard evaluation formats [6].

7. Threat Evaluation: A proper threat evaluation system is required for the defense systems regarding aircraft bombing. The method is to use multi- criteria decision making for prioritizing threats. Unver et al.'s objective is to apply the [7] Saaty's well-known multi criteria decision making method, Analytic Network Process (ANP) to Threat Evaluation process and comment on the results. In order to do that, a scenario is created with a number of aircrafts approaching to a defended asset from different directions. Some of them are ignored regarding their intent while others are evaluated and assigned with a target value. By that, obtained values can be used in sequencing or prioritizing the targets in a war environment [7].

8. Assessing stakeholders' influence in project management: The proposed methodology is a novel proposal for the definition of "influence" among stakeholders based on a multiperspective approach. Developed by Beltrán et al., it is an ANP based contribution for the[8] stakeholder influence analysis in project management. They present a methodology to measure stakeholders' influences within a project from the point of view of the Project Manager. The concept of influence is broken down into various and different criterions evaluating different aspects that together define an index which measures the influence of each stakeholder with respect to the rest of the project team..They also measured influence of an individual stakeholder on the project management. A Case study application to a railway maintenance project is also given by them. The methodology has been successfully applied to a maintenance project for the Spanish National Railway Infrastructure company by them. The results show that the most influential stakeholders such as the Contractor

and the Signaling systems provider account for 40% of the total influence on the project management system. The results have greatly helped the Project Manager to be aware of the two most influential stakeholders such as the contractor and the Signaling systems provider and set the guidelines for the stakeholder's management in the future [8]

9. Multiple criteria material selection: The proposed methodology is a new application of the analytic network process for multiple criteria material selection. It aims at presenting a new concept for [9] multicriteria material selection by means of allowing feedback and interactions within and between sets of design criteria and alternatives.. Developed by Milani et al., it uses Incorporating feedback/interactions within and between sets of design criteria/alternatives. The approach and its advantages are discussed by them using a multi criteria material selection case study on non-metallic gears under multifunctional design requirements such as thermal performance, mechanical performance, and weight. The methodology in particular shows that the selection of material alternatives under different criteria can be viewed as a network problem, as opposed to a conventional hierarchical decision-making process [9].

10. A measure of regional influence : A metropolitan region is defined as a social and a spatial network of urban nodes that are linked in territory and in function, which is differentiated by size and dominance of the linked nodes and is characterized by physical or virtual flows of a wide-ranging variety. Banai et al. proposed that the analytic network process (ANP), which is a multi-criteria analytic method can be used [10] to measure the influence or dominance of the nodes in a network with feedback. They illustrated that Analytic Network Process determines county rank as a measure of influence in a metropolitan statistical area (MSA), which is defined by its interrelated social, economic and spatial elements qualitatively and quantitatively. They compared the ANP results to similar measures of regional influence in the literature [10].

11. Integrating social network analysis: The social relationships between development agencies, non-governmental organizations, private companies, and other groups working on development projects play a very important and essential role in the overall success of projects. Traditional project selection and project prioritization processes ignore the organizational and the social relationships. Grady et al. studied the link between social network analysis and project selection and developed a multi-criteria model to [11] integrate social network information into project selection to enhance the effectiveness and the performance of project selection. Organizational relationships integrated into the analytic network process (ANP) to form a multi-criteria ANP project selection model are quantitatively measured by set of topological metrics of social network by them. Empirical social network data of a water and food security research was utilized by them for development

network in the Mekong River Basin. The model developed by them is purely extendable to a variety of project selection decision processes. They investigated the effectiveness of the proposed model and the results showed that the proposed methodology will offer companies, government agencies, and other donor organizations the opportunity to prioritize strategic network goals simultaneously with research and development priorities simultaneously helping companies and research organizations to increase their impact and reach within networks [11].

12. A customer based supplier selection process: The overall objective of the proposed methodology suggested by Asadabadi et al. is to introduce a [12] customer oriented supplier selection method, which structures a customer oriented opinion for the solution to the supplier selection problem. The methodology takes into account customer needs as a determinant i.e. the main factor in finding the best supplier which considers possible changes in the priorities of customer needs as time passes. The methodology introduces an innovative customer based approach to select the best supplier that is independent of initial CNs.

The proposed methodology uses a method integrating the analytic network process (ANP), quality function deployment (QFD), and a Markov chain is used to address the supplier selection problem. To trace the changing-priorities of customer needs and find a pattern for the customers, they proposed a methodology which utilizes a Markov chain. To connect this pattern to product requirements (PRs) and PRs to supplier qualifications, they utilized ANP–QFD methodology. They selected the best supplier on the basis of fulfilling and agreeing on the changing-priorities of customer needs [12].

13. Assessment of wastewater treatment alternatives for small communities: ANP methodology is appropriate and suitable to select the most appropriate wastewater treatment alternative. The proposed methodology uses ANP to compare [13] wastewater treatment alternatives for small communities. Incorporating interdependent relationships between elements is a major advantage of ANP.

As many alternatives are available and many criteria are involved in the decision-making process, the selection of the most appropriate wastewater treatment technology is a complex problem. Senate et al. applied analytic network process for the first time to rank a set of seven waste water treatment technology set-ups for secondary treatment in small communities to deal with this challenge. Results showed that various technologies such as extensive technologies, constructed wetlands and pond systems are the most preferred alternatives by waste water treatment experts. The sensitivity analysis and survey verified that the ranking of waste water treatment alternatives is very stable as constructed wetlands are almost always placed in the first position. The methodology proposed by them showed that ANP analysis is suitable and appropriate to deal with complex decision-making problems, such as the selection of the most appropriate system

contributing to better understand the multiple interdependences among elements involved in the assessment [13].

14. Analysis of Causes of Disputes in the Construction Industry: The methodology proposed by Cakmak et al. aims [14] to analyze the main causes of disputes which occur in the construction industry. A literature review was also undertaken by them to identify the common construction disputes in order to analyze the main causes of disputes which occur in the construction industry. Classification of disputes derived from cross section of literature was done into main categories and the main causes of construction disputes were determined by them. Finally, to determine relative importance of disputes, an analysis was carried out using the analytical network process (ANP) approach by them [14].

15. facility layout selection: The proposed methodology uses the Analytic Network Process (ANP) methodology for the first time for the selection of the best [15] facility layout plan. Hawari et al. built a model taking into account the interdependencies between multiple dependent and independent criterions which has not been done before. They computed the limit priorities which identify the most important factors in the selection process. They conducted a case study in a wood factory which represents a real demonstration of the developed model based on experts'opinions and fundamental equations. They also built a network structure that shows all elements and clusters and their interactions that can be used to find the most effective layout. They conducted a comparison between ANP and Analytic Hierarchy Process (AHP) which shows the differences between the two methods [15].

16. Risk assessment of co-creating value relationships with customers: Co-creating value relationships with customers is becoming an important competitve strategy for companies as it provides a feasible way to meet customers' personalized requirements. This strategy needs effective management to obtain most benefits because it may involve many potential risks. Extra-budgetary costs, wrong decision of product investment or loss of customers are the results of neglecting these risks. Till now, little attention has been paid so far to the risk assessment of co-creating value with customers. The proposed methodology is a novel multi-criteria decision making approach for risk assessment of co-creating value relationships with customers .

In the proposed methodology by Cao et al., risk factors are identified when providing customized design. Risk assessment is done for the involvement of customers and suppliers by them .To determine the risk factors of co-creating with customers, the scattered literature is combed systemically. The proposed decision making approach can intelligently handle the subjectivity and vagueness of the decision maker, and the dependences and interdependencies, feedbacks among risk factors. Rough numbers are integrated with the analytic network process by them. A case study is presented to

illustrate the application of the proposed multi criteria decision making approach, and the proposed approach is compared with other existing methodologies to demonstrate its advantages.

17. Porter's Five Forces Analysis – Case Study in Philippines*:* The purpose of Jui et al.'s study is to investigate and demonstrate the quantitative indicator from a combination of analytical network process decision making criteria and [17] Porter's five forces .They proposed methodology that show the priority for firm to face on the changing. The combination of analytic network process and fiver forces by them can set up a better procedure to evaluate the current strategy by chosen the most important criteria. The evaluation framework and format by them is based on multi-criteria decision making approach and analysis which can determine the proper method and format from the series of criterions with regard to various conflicting forces of decision making, and analytic network process methodology that can consider the effect of feedback and variance dependence. It is best in identifying the best strategy under global environment and different circumstances changing to gain a wide-ranging perspective and actual execution [17].

18. Weighing and realizing the environmental, economic and social goals of tourism development: The study conducted by Zhang et al. aims to contribute a theoretical framework to decision making approach for the determination of top priorities in tourism development, [18] weighing and realizing the environmental, economic and social goals of tourism development and shows that sustainable tourism implementation in newly-emerging tourism destinations is problematic. Economical, social and environmental priorities are different at different stages in tourism development and at different tourism destinations. The decision is often difficult involving typically complex multi-criteria decision making problems like environmental concerns, social concerns, economical concerns and political concerns. The approach to cope the decision making is done by combining the Delphi method, analytic network process and goal programming in this methodology. They presented a case study on Xisang. According to it, in economically and socially backward region like Xizang, considering the economy first and the environment last is both appropriate and practicable. They also constructed an analytic network process goal programming model to provide the solution to the decision making of two years, 2016 and 2020. This study concludes that in a newly-emerging tourism destination like Xizang, managers should implement specific strategies to raise the GDP and appropriately restrict the growth in the number of tourist coming to the area and good maintenance of the sites and increasing the number of officials and companies working for tourism [18] .

19. Risk assessment and decision analysis*:* The study conducted by Ergu et al. shows that in risk [19] assessment and decision- making analysis and approach, the analytical

network process is widely used to assess the key factors and features of the risks and analyze the impacts and influences and preferences of decision alternatives. A decision has to be made rapidly in emergency cases but in the analytic network process, the reciprocal pairwise comparison matrices (RPCM) are more complicated and difficult than analytic hierarchy process. So, these certain elements need to be simplified. In this methodology, a maximum eigenvalue threshold is proposed as the consistency index for the analytic network process in risk assessment and decision analysis so that the process gets smoother and faster. The proposed threshold developed bY them is equal to the consistency ratio. A block diagonal matrix is introduced for the RPCM to conduct consistency tests simultaneously for all comparison matrices by them, thus, reducing the number of consistency tests and time taken [19].

20. Interdependent ranking of sources and sinks in CCS systems: The important low-carbon technology for reducing greenhouse gas emissions from large industrial point sources.CO_2 capture and storage (CCS) is widely regarded as an It entails the capture of a relatively pure CO_2 from exhaust gases using different techniques, and then storing this captured gas in various geological sinks. Large-scale deployment of CCS systems and setups requires the comprehensive evaluation of candidate sources, decision making and sinks present in a given geographical region. In this study Promentilla et al. proposed that an analytic network process approach to rank simultaneously the potential CO_2 sources and sinks in a CCS system can be used. Such ranking can be used to identify geographic sites which are perfect for CCS demonstration projects. This ANP decision making model constructed by them allows to incorporate the feedback dependency that exist in the preference ranking of sources and sinks due to the importance of geographic proximity and certain criterions as a decision criterion. A case study is then presented and the solution is used by them to demonstrate the proposed model.

3. CONCLUSION

In this article many areas were seen in which the ANP technique has been implemented successfully. As seen from the reported case studies, ANP is a good tool which can be used in multiple areas to solve real life problems with ease. The outcomes can be analyzed on the basis of opportunities, cost, benefits and risk involved. The decisions are practical and can be implemented in real life situations.

REFERENCE

[1] Lin Jen-Jia, Wei Yi-Hsuan, Assessing area-wide bikeability: A grey analytic network process, Transportation Research Part A: Policy and Practice, Volume 113, July 2018, Pages 381-396

[2] Sun Zhi Yu, Zhou Jian Lan, Gan Lin Fei, Safety assessment in oil drilling work system based on empirical study and Analytic Network Process, Safety Science, Volume 105, June 2018, Pages 86-97.

[3] Boateng Prince, Chen Zhen, Ogunlana Stephen O., An Analytic Network Process model for risks prioritisation in megaprojects, International Journal of Project Management, Volume 33, Issue 8, November 2015, Pages 1795-1811.

[4] Zhu Bin, Xu Zeshui, Zhang Ren, Hong Mei, Generalized analytic network process, European Journal of Operational Research, Volume 244, Issue 1, 1 July 2015, Pages 277-288.

[5] Azammia A.M. Noor, Sapuan S.M., Ishak M.R., Sultan Mohamed T.H., Conceptual design of automobile engine rubber mounting composite using TRIZ-Morphological chart-analytic network process technique, Defence Technology, In Press, Corrected Proof

[6] Ocampo Lanndon A., Seva Rosemary R., "Using analytic network process for evaluating mobile text entry methods", Applied Ergonomics, Volume 52, January 2016, Pages 232-241

[7] UNVER Seckin, GURBUZ Tuncay, Threat Evaluation Using Analytic Network Process, IFAC-Papers OnLine, Volume 48, Issue 3, 2015, Pages 8-13

[8] Beltrán PabloAragonés, Melón MónicaGarcía, Valera JesúsMontesinos, How to assess stakeholders' influence in project management? A proposal based on the Analytic Network Process, International Journal of Project Management, Volume 35, Issue 3, April 2017, Pages 451-462

[9] Milani A.S., Shanian A., Lynam C., Scarinci T., An application of the analytic network process in multiple criteria material selection, Materials & Design, Volume 44, February 2013, Pages 622-632

[10] Banai Reza, Wakolbinger Tina, A measure of regional influence with the analytic network process, Socio-Economic Planning Sciences, Volume 45, Issue 4, December 2011, Pages 165-173

[11] Grady Caitlin A., He Xiaozheng, Peeta Srinivas, Integrating social network analysis with analytic network process for international development project selection, Expert Systems with Applications, Volume 42, Issue 12, 15 July 2015, Pages 5128-5138

[12] Asadabadi Mehdi Rajabi, A customer based supplier selection process that combines quality function deployment, the analytic network process and a Markov chain, European Journal of Operational Research, Volume 263, Issue 3, 16 December 2017, Pages 1049-1062

[13] Senante MaríaMolinos, Gómez Trinidad, Caballero Rafael, Sancho Francesc Hernández, Garrido RamónSala, Assessment of wastewater treatment alternatives for small communities: An analytic network process approach, Science of The Total Environment, Volume 532, 1 November 2015, Pages 676-687

[14] Cakmak Emre, Cakmak Pinar Irlayici, An Analysis of Causes of Disputes in the Construction Industry Using Analytical Network Process, Procedia - Social and Behavioral Sciences, Volume 109, 8 January 2014, Pages 183-187

[15] Hawari TarekAl, Mumani Ahmad, Momani Amer, Application of the Analytic Network Process to facility layout selection, Journal of Manufacturing Systems, Volume 33, Issue 4, October 2014, Pages 488-497

[16] Cao Jintao, Song Wenyan, Risk assessment of co-creating value with customers: A rough group analytic network process approach, Expert Systems with Applications, Volume 55, 15 August 2016, Pages 145-156

[17] Jui Wu Kuo, Lang Tseng Ming, S.F.Chiu Anthony, Using the Analytical Network Process in Porter's Five Forces Analysis –

Case Study in Philippines, Procedia - Social and Behavioral Sciences, Volume 57, 9 October 2012, Pages 1-9

[18] Zhang Jiekuan, Weighing and realizing the environmental, economic and social goals of tourism development using an analytic network process-goal programming approach, Journal of Cleaner Production, Volume 127, 20 July 2016, Pages 262-273

[19] Ergu Daji, Kou Gang, Shi Yong, Shi Yu, Analytic network process in risk assessment and decision analysis, Computers & Operations Research, Volume 42, February 2014, Pages 58-74

[20] Promentilla M.A.B., Tapia J.F.D., Arcilla C.A., Dugos N.P., Gaspillo P.D., Roces S.A., Tan R.R., Interdependent ranking of sources and sinks in CCS systems using the analytic network process, Environmental Modelling & Software, Volume 50, December 2013, Pages 21-24.