Available online at: http://www.ijmtst.com/vol5issue11.html

International Journal for Modern Trends in Science and Technology

ISSN: 2455-3778 :: Volume: 05, Issue No: 11, November 2019

Construction Cost and Quality Measurement Using Fuzzy Multi-Attribute Utility Theory and Z-Number

Sharru Shivani S R

PG Scholar, Construction Engineering and Management, Department of Civil Engineering, Arunachala College of Engineering for Women, Kanniyakumari, Tamil Nadu-629203, India

To Cite this Article

Sharru Shivani S R, "Construction Cost and Quality Measurement Using Fuzzy Multi-Attribute Utility Theory and Z-Number", *International Journal for Modern Trends in Science and Technology*, Vol. 05, Issue 11, November 2019, pp: 121-127.

Article Info

Received on 20-October-2019, Revised on 31-October-2019, Accepted on 04-November-2019, Published on 10-November-2019.

ABSTRACT

The Earned Value Management (EVM) has been extensively employed for analyzing the schedule and cost performance indexes. The effect of risk factors on the project has been ignored in previous project. In this paper, a well-organized project control and monitoring system has been developed. Schedule Performance Index (SPI), the Cost Performance Index (CPI) and Risk Performance Index (RPI) are calculated based on z-number.Multi-Attribute Utility Theory (MAUT) and Multi-Objective Linear Programming (MOLP) under fuzzy condition are utilized. The signification risks associated with construction projects need special attention from contractors to analyze and manage the risks. Risk management is the art and science of identifying, analyzing and responding to risk factors throughout the life cycle of the project and in the best interest of its objectives. In proposed model, we firstly identify risks in the construction projects and suitable criteria for evaluate risks and then structure the proposed AHP model. Finally we measure the significant risks in construction projects (SRCP) based on the project's objectives by using fuzzy analytical hierarchy process (FAHP) technique

KEYWORDS: *Multi-attribute utility theory, Multi-objective linear programming*

I. INTRODUCTION

The main goals of any successful construction project management systems are to complete the project on time, within the planned budget, and with the required quality limits. The three goals are inter-related where each of them is affecting, and being affected by, the others. Risk management is the identification, evaluation and prioritization of risks followed by coordinated and economical application of resources to minimize, monitor and control the probability or impact of unfortunate events are to maximize the realization of opportunities. Earned Value Management (EVM) helps project managers to measure project performance. It is a systematic project management process used to find variances in projects based on the comparison of worked performed and work planned. EVM is used on the cost and schedule control and can be very useful in project forecasting. The project baseline is an essential component of EVM and serves as a reference point for all EVM related activities. EVM

provides quantitative data for project decision making.

II. MULTI-OBJECTIVE LINEAR PROGRAMMING (MOLP)

Multi-objective linear programming is a subarea of mathematical optimization. A multiple objective linear program (MOLP) is a linear program with more than one objective function. An MOLP is a special case of a vector linear program. Multi-objection linear programming is also a subarea of Multi-objective optimization.
Multi-Objective Linear programming has the following methods

- Analytic hierarchy process (AHP)
- Typical Pair-wise Comparison
- Fuzzy set-based contingency

a. Analytic hierarchy process (AHP)

The analytic hierarchy process (AHP) is a structured technique for dealing with complex decisions. It provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions. The base of this model is comparing variables by pair wise by Matrix relationship. In this way, pair wise of the effective variables on the concrete Pavement were considered and based on relative weights the output was extent.

b.Typical Pair-wise Comparison

- ❖ The diagonal elements are all equal to one because they represent the comparison of a criterion against itself.
- ❖ The lower triangle values are the reciprocal of the upper triangular values (i.e. aij= 1/aji).
- ❖ All numbers in the matrix are positive.
- ❖ After determining the weights of each factor in the hierarchy, the time contingency.
- ❖ Determine the relative weight of each major category; i.e. project conditions, management conditions and environmental conditions.
- ❖ Determine the weights (Wi) of the sub factors relative to the weight of its category.
- ❖ Calculate the factors score (Si) for each of the thirteen factors (using a 1 – 9 scale) in which one represents the most ineffective and nine represents the most effective to the contingency value.
- ❖ Calculate the Probability of occurrence average (Pi) for each of the thirteen factors.
- ❖ Multiply the three values Wi * Si * Pi.
  - Sum all the values of multiplication, which constitute the time contingency value CD.

c. Fuzzy set-based contingency

This research focuses on contingency estimation based on fuzzy-set theory and contingency management based on its depletion over project's durations. The outputs of this research are: a new methodology for contingency depletion project duration and development of a tool for project contingency estimation using fuzzy system coded using VB.net. The evaluation of this tool has been done by comparing its results with results of other methods using the same case studies. Finally a result discussion, recommendations and conclusion are drawn.

III. MULTI-OBJECTIVE OPTIMIZATION

Multi-objective optimization (also known as multi-objective programming, vector optimization, multi-criteria optimization, multi-attribute optimization or Pareto optimization) is an area of multiple criteria decision making that is concerned with mathematical optimization problems involving more than one objective function to be optimized simultaneously. Multi-objective optimization has been applied in many fields of science, including engineering, economics and logistics where optimal decisions need to be taken in the presence of trade-offs between two or more conflicting objectives.

IV. OBJECTIVES

- The purpose of Fuzzy theory is to determine the cost and schedule of a project simultaneously.
- It reduces the time and cost of project.
- Minimizes customer inconvenience.
- Reduce the risk, human error and building or equipment failures.

V.LITERATURE REVIEW

A literature review is a detailed report of information obtained from the literature that are related to our topic of study. The review describe, summarize, evaluate and clarify this literature. It gives a base for the research and helps in determining the nature of the study. This section represents the review of literature collected from various journals and articles that are most relevant to the study

1.Mohammad Reza Feylizadeh, Morteza Bagherpour ,Manufacturing Performance Measurement Using Fuzzy Multi-Attribute Utility Theory And Z-Number (2018)

This paper describes the Earned Value Management (EVM) has been extensively employed in the literature for analysing the schedule and cost performance indexes. In this paper, a well-organized project control and monitoring system is developed by incorporating the EVM basic principles, risk analysis, and utility theory for improving the performance of manufacturing systems. The overall utility function is incorporated into SPI, CPI, as well as RPI. The utility of three indexes in 5 cases of utility with risk performance indexes equal to or less than 0.8, 0.85, 0.9, 0.95, and 1 is developed.Also, a decision support system for performing corrective action may be developed.

2.Dragan Simiü1, Ilija Kovaþeviü1, Vasa Svirþeviü and Svetlana Simiü,50 Years of Fuzzy Set Theory and Models for Supplier Assessment and Selection: a Literature Review (2016)

This paper describes that the supply chain management and strategic sourcing are among the fastest growing areas of management.The aim of this paper is to show how fuzzy set theory, fuzzy decision-making and hybrid solutions and synergy based on fuzzy can be used in various supplier assessment and selection models during a 50 year period. DEA is most often used technique with 30% in MCDM. The future work could focus on additional research on hybrid DEA supplier assessment and selection systems which integrate mathematics, statistics, and some soft computing techniques such as evolutionary algorithms and neural networks.

3.Mohsen Askari, Hamid Reza Shokrizadeh,Nina Ghane , A Fuzzy AHP Model in Risk Ranking (2014)

This paper describes that the signification risks associated with construction projects need special attention from contractors to analyse and manage the risks. The significant risks in construction projects (SRCP) based on the project's objectives by using fuzzy analytical hierarchy process (FAHP) technique was measured. Fuzzy group decision making can overcome this difficulty. Identified risks in the construction projects and suitable criteria for evaluate risks and then structured the proposed AHP model. The significant risks in construction projects (SRCP) based on the project's objectives by using fuzzy analytical hierarchy process (FAHP) technique was measured.

4.Sung-Lin Hsueh , A Fuzzy Utility-Based Multi-Criteria Model for Evaluating Households' Energy Conservation Performance: A Taiwanese Case Study (2012)

In this paper, they applied the Delphi method, the analytical hierarchy process, utility theory, and fuzzy logic theory to establish an energy conservation assessment model for households. The case study statistics verified that this model possesses highly objective and scientific calculations and has actual reference value for further application of database management in government-related organizations. The model can not only increase management efficiency and effectiveness, but can also achieve quantified control management objectives and goals.

5.Yi Wang , Jikun Guo, Jun Dai and Chang Chen, A Fuzzy VIKOR Approach for Renewable Energy Resources Selection in China (2016)

In this paper, they utilized a multi-criteria methodology to evaluate and select various renewable energy resources from multiple factors for the purpose of sustainable development in China. The ultimate goal of this study is to offer a practical model to deal with energy selection problems in China.In the future research, further quantitative and qualitative criteria can be added in this analysis. In addition, due to the effectiveness of the fuzzy-based MCDM approach utilized to solve multiple criteria problems.

6.Z. Turskis, E.K. Zavadskas, J. Antucheviciene, N. Kosareva, A Hybrid Model Based on Fuzzy AHP and Fuzzy WASPAS for Construction Site Selection (2015)

The purpose of this article is to propose a fuzzy multi-attribute performance measurement (MAPM) framework using the merits of both a novel Weighted Aggregated Sum-Product Assessment method with Fuzzy values (WASPAS-F) and Analytical Hierarchy Process (AHP). The object of this study is to select the best shopping centre construction site in Vilnius. Selecting the best location for a new construction site in fuzzy environments becomes a difficult task for stakeholders. In the proposed method, the fuzzy AHP was used to determine the weights of the attributes, while WASPAS-F was employed to rank the alternative locations. As a result of the study, they found that the proposed method is practical for ranking alternatives with respect to multiple conflicting attributes for the large scale problems.

7.Mostafa Salari, Morteza Bagherpour, John Wang, A novel earned value management model using Z-number (2014)

This paper presents a novel fuzzy earned-value model based on Z-number theory incorporating

both the impreciseness of real life conditions and a degree of reliability through considering an expert judgment process.The SPI and CPI are also obtained based on a new progress evaluation system.. The proposed model can assist project managers to assess the progress of a project effectively since it incorporates the bias of expert judgment in a progress calculation and presents the fuzzy-based assessment of EVM indices much more realistically. Further recommendation may focus on applying the Z-number to financial performance indexes and invoice control systems.

8.A. Amida,, S.H. Ghodsypourb, C. O'Brienc, A weighted max–min model for fuzzy multi-objective supplier selection in a supply chain (2010)

This paper describes that the fuzzy set theories can be employed due to the presence of vagueness and imprecision of information. In this paper, an analytic hierarchy process (AHP) is used to determine the weights of criteria. The proposed model can help the decision maker (DM) to find out the appropriate order to each supplier, and allows the purchasing manager(s) to manage supply chain performance on cost, quality and service.

9.P.Rezakhani,A Review Of Fuzzy Risk Assessme nt Models For Construction Projects (2012)

This paper is an extensive literature survey in risk modelling and analytic methods with a main focus on fuzzy risk assessment. These and other researches have recommended taking into account the impression, vagueness, fuzziness of the risk factors in a construction project to appropriately deal with a contractor's project risk by using Fuzzy Set Theory (FSI).It is well accepted that Fuzzy Set Theory (FSI) provides a useful way to deal with ill-defined and complex problems in decision making by quantifying imprecise information, incorporating vagueness, and making decisions based on imprecise and vague data.

10. Timur Narbaev, Alberto De Marco, An earned schedule-based regression model to improve cost estimate at completion (2014)

This project describes that the Traditional Earned Value Management (EVM) index-based methods for Cost Estimate at Completion (CEAC) of an ongoing project have been known for their limitations inherent with both the assumption that past EVM data is the best available information and early-stage unreliability.The proposed model shows itself to be more accurate and precise in all early, middle, and late stage estimates than those of four compared traditional index-based formulae. Finally, the method is proposed to practitioners for application to a larger variety of projects at different progress stages and for diffusion in various industries.

11.Mark Velasquez and Patrick T. Hester2, An Analysis of Multi-Criteria Decision Making Methods (2013)

This paper assessed the more common methods of MCDM in order to benefit practitioners to choose a method for solving a specific problem. Identification of common MCDM methods and identification of strengths and weaknesses is a major step in establishing the foundation of research in this area, but it is only the first step. The industry could then begin to research new methods which utilize and incorporate advantages, while accounting for or altogether eliminating disadvantages.

12.Mohammadreza Sharifi Ghazvini , Vahidreza Ghezavati , Sadigh Raissi and Ahmad Makui, An Integrated Efficiency–Risk Approach in Sustainable Project Control (2017)

This paper describes that the hybrid form can simultaneously control all the parameters, including both quantitative and qualitative variables, time, cost, and risk in conjunction with the project. This method is limited by the correlation between time and cost parameters, the lack of confidence in the SV and SPI compared with the CV and CPI, the lack of usage of buffer time and cost, project risks, and the disregard for the path and the critical chain of the project.41 and that in the second period is equal to $232,983, because of the delays occurring in the control periods. In addition, the estimate duration at completion in the first period is equal to 61 days and that in the second period is equal to 93 days.

13.Abid Hussain Nadeem, Juiping Xu, Muhammad Nazim, Muhammad Hashim, Muhammad Kashif Javed, An Integrated Group Decision-making Process For Supplier Selection and Order Allocation Using Multi-attribute Utility Theory Under Fuzzy Environment (2014)

This paper describes an integrated approach of multi attribute utility theory (MAUT) is applied to represent the decision maker's fuzzy goals for the supplier selection and order allocation problem. The model is used to determine the order quantities to be purchased from each supplier to maximize the quantity of purchase from the most desired suppliers. The systematic framework for supplier evaluation and selection presented in this paper can easily be extended to analyze other managerial decision-making problems.

14.Gopal Agarwal and Lokesh Vijayvargy, An application of supplier selection in supply chain for

modeling of intangibles: A case study of multinational Food Coffee industry (2011)
The objective of this paper is to present a comprehensive method for the evaluation and selection of suppliers' offers in food industry. The recommendations made will not only result in stream lining of supply chain processes in PQR coffee company but will result in substantial savings also due to reduced lead time, reduced inventory level, better service level and effective control and coordination among the partners. The performance measure of supply chain is important building block for decision-making. To take a system optimal decision, trade-offs between many conflicting enablers has to be analysed.
15.P.Urgilés,J.Claver ,andM.A.Sebastián, Analysis of the Earned Value Management and Earned Schedule Techniques in Complex Hydroelectric Power Production Projects: Cost and Time Forecast (2019)
This paper analyses the efficiency of the Earned Value Management technique and its Earned Schedule extension, as a means of forecasting costs and deadlines when applied to complex hydroelectric power production projects.This paper analyses the efficiency of EVM and its ES extension as a tool for forecasting cost and duration in complex hydroelectric power production projects and has detected certain inaccuracy in its forecasting of duration.This would entail building a duration forecasting tool of suitable efficiency to afford project managers enough time to make decisions when facing deviations to scheduled deadlines.
16.Primova H. A., Niyozmatova N. A., Analysis of Using Z-evaluation Uncertainty in Fuzzy Inference Systems (2016)
This paper discusses the construction of a model based on fuzzy inference rules using Z evaluation, aimed at obtaining conclusions with the use of vague, inaccurate or incomplete initial information. It outlines the basic arithmetic operations on discrete Z-numbers.The result of this work is the developed approach to the use of Z-numbers in the system of fuzzy output by converting Z-numbers in the classical fuzzy numbers and the development of an approach to decision-making, which summarizes the current expected utility approach in the case of Z-information. The approach used to solve poorly-formalized process state estimation problems.
17.Natasa Prascevic, Zivojin Prascevic, Application Of Fuzzy Ahp For Ranking And Selection Of Alternatives In Construction Project Management (2017)
This paper proposes a new procedure for determination of the weights of criteria and alternatives in the Fuzzy analytic hierarchy process (FAHP) with trapezoidal fuzzy number using a new method for finding eigen values and eigenvectors of the criteria and alternatives, which is based on expected values of the fuzzy numbers and their products.. In the presented case study, applying proposed method, from imprecise input data are obtained enough accurate and useful results for rational ranking of alternatives related to the project realization.
18.Aynur I. Jabbarova, Application of Z-number concept to supplier selection problem (2017)
This paper demonstrates a numerical example, including different selection criteria and methods and also compare the advantages and the disadvantage of the selection methods.In this paper they consider a multi criteria decision problem on supplier selection, where all of the components of alternatives are described by Z-information. For this problems they used of the utility theories. After ranking we found the best alternative.
19.A.M.Nuriyev, Application of Z-Numbers Based Approach to Project Risks Assessment (2019)
This paper describes the potentialities of the Z-numbers in improving the quality of risk assessment.Recently developed and based on arithmetic operations on Z-numbers, the ranking of Z-numbers and aggregation of Z information, as well as Z-rules approach, allows to refrain from excessive assessment simplification and to successfully resolve issues of the multi-risk situations analysis without loss of contained in Z-numbers information. The aim of further research is the solution to the various project risk analysis problems.
20.Fumiko Seo, Basic Concepts in Derivation of Fuzzy Multiattribute Utility Functions (2017)
This paper concerned with basic concepts in fuzzy decision analysis. Conditions and techniques required in construction of the fuzzy utility function and its multi objective extensions are discussed. Fuzzy lottery technique with fuzzy certainty equivalent based on possibility measure is presented in contrast with the classical probabilistic lottery technique. Fuzzy preference independence assumptions are examined for derivation of the fuzzy multi attribute utility functions.

VI.CONCLUSION

The overall utility function is incorporated into SPI, CPI, as well as RPI. For the sensitivity analysis, the utility of three indexes in 5 cases of utility with risk performance indexes equal to or less than 0.8, 0.85, 0.9, 0.95, and 1 is developed, demonstrating maximum sensitivity as compared to the other affecting factors. The obtained results can be entered into a control chart. A multi-attribute utility function is employed to measure the overall cost and quality of a project.

REFERENCE

[1] Tepiü, J., Tanackov, I., Stojiü, G.: Ancient logistics - Historical timeline and etymology. Tehnicki Vjesnik - Technical Gazette, vol. 18 (3), pp. 379-384 (2011)

[2] Zadeh, L. A.: Fuzzy sets, Information and Control, vol. 8, pp. 338-353 (1965)

[3] Simiü, D., Svirþeviü, V., Simiü, S.: An approach of genetic algorithm to model supplier assessment in inbound logistics. Advances in Intelligent Systems and Computing, vol. 188, pp. 83-92 (2013)

[4] Simiü, D., Svirceviü, V., Simiü, S.: A hybrid evolutionary model for supplier assessment and selection in inbound logistics. Journal of Applied Logic, vol. 13(2), pp. 138-147 (2015)

[5] Simiü, D., Svirþeviü, V., Simiü, S.: An Approach of Fuzzy Models for Supplier Assessment and Selection. Advances in Intelligent Systems and Computing, vol. 299, pp. 175184 (2014)

[6] Zadeh, L. A.: Fuzzy sets and systems. In: Fox, J., (ed.). System Theory. Brooklyn, NY: Polytechnic Press, pp. 29-39 (1965)

[7] Black, M.: Vagueness. An Exercise in Logical Analysis. Philosophy of Science, vol. 4(4), pp. 427-455 (1937) https://www.jstor.org/stable/184414?seq=1#page_scan_tab_contents (accessed 30 October 2015)

[8] Kleene, S. C.: Introduction to Metamathematics. Bibliotheca Mathematica, North-Holland (1952)

[9] Robinson, A.: Introduction to Model Theory and to the Metamathematics of Algebra. Studies in Logic and the Foundations of Mathematics, vol. 32, North-Holland Publishing Company (1963)

[10] Weber, C. A., Current, J. R.: A multiobjective approach to vendor selection. European Journal of Operational Research, vol. 68(2), pp. 173-184 (1993)

[11] Ciesla, M.: Aluminium supplier selection for the automotive parts manufacturer. Metallurgy, vol. 55(2), pp. 237-240 (2016)

[12] De Boer, L.: Operations research in support of purchasing. Design of a toolbox for supplier selection. Ph.D. Thesis, University of Twente, Enschede, The Netherlands (1998)

[13] De Boer, L., Labro, E., Morlacchi, P.: A review of methods supporting supplier selection. European Journal of Purchasing & Supply Management, vol. 7(2) pp. 75-89 (2001)

[14] Dickson, G. W.: An analysis of vendor selection system and decisions. Journal of Purchasing, vol. 2(1), pp. 5-17 (1966)

[15] Sarkis, J., Talluri, S.: A model for strategic supplier selection. Journal of Supply Chain Management, vol. 38(1), pp. 18-28 (2001)

[16] Sucky E.: A model for dynamic strategic vendor selection. Computers & Operations Research, vol. 34(12), pp. 3638-3651 (2007)

[17] Agarwal, P., Sahai, M., Mishra, V., Bag M., Singh, V.: A review of multi-criteria decision making techniques for supplier evaluation and selection. International Journal of Industrial Engineering Computations, vol. 2, pp. 801-810, (2012)

[18] Chen, Y-J.: Structured methodology for supplier selection and evaluation in a supply chain. Information Sciences, vol. 181, pp. 1651-1670 (2011)

[19] Chang, S. L., Wang, R. C., Wang, S. Y.: Applying fuzzy linguistic quantifier to select supply chain partners at different phases of product life cycle. International Journal of Production Economics, vol. 100(2), pp. 348-359. (2006)

[20] Pattnaik, M.: Fuzzy supplier selection strategies in supply chain management. International Journal of Supply Chain Management, vol. 2(1), pp. 30-39 (2013)

[21] Florez-Lopez, R.: Strategic supplier selection in the added-value perspective: A CI approach. Information Sciences, vol. 177 (5), pp. 1169-1179 (2007)

[22] Pattnaik, M.: Supplier selection strategies on fuzzy decision space. General Mathematics Notes, vol. 4(1), pp. 49-69 (2011)

[23] Lin, C. W. R., Chen, H. Y. S: A fuzzy strategic alliance selection framework for supply chain partnering under limited evaluation resources. Computers in Industry, vol. 55(2), pp. 159-179 (2004)

[24] Sarkar, A., Mohapatra, P. K. J.: Evaluation of supplier capability and performance: A method for supply base reduction. Journal of Purchasing and Supply Management, vol. 12 (3), pp. 148-163 (2006)

[25] Kahraman, C., Cebeci, U., Ulukan, Z.: Multi-criteria supplier selection using fuzzy AHP. Logistics Information Management, vol. 16(6), pp. 382-394 (2003)

[26] Chan, F.T.S., Kumar, N.: Global supplier development considering risk factors using fuzzy extended AHP-based approach. OMEGA – International Journal of Management Science, vol. 35(4), pp. 417-431 (2007)

[27] Kilincci, O., Onal, S. A.: Fuzzy AHP approach for supplier selection in a washing machine company. Expert Systems with Applications, vol. 38(8), pp. 9656-9664 (2011)

[28] Koul, S., Verma, R.: Dynamic vendor selection based on fuzzy AHP. Journal of Manufacturing Technology Management, vol. 22(8), pp. 963-971 (2011)

[29] Özkan, B., BaúlÖgil, H., ùahin, N.: Supplier selection using analytic hierarchy process: An application from Turkey. Proceedings of The World Congress on Engineering, pp. 11601165 (2011)

[30] Deng, X., Hu, Y., Deng, Y., Mahadevan, S.: Supplier selection using AHP methodology extended by D numbers. Expert Systems with Applications, vol. 41(1), pp. 156-167 (2014)

[31] Lin R-H.: An integrated model for supplier selection under a fuzzy situation. International Journal Production Economics vol. 138 (1), pp. 55-61 (2012)

[32] Dargi, A., Anjomshoae, A., Galankashi, M. R., Memari, A., Tap, M. B. M.: Supplier Selection: A Fuzzy-ANP approach. Procedia Computer Science, vol. 31, pp. 691-700 (2014)

[33] Galankashi, M. R., Chegeni, A., Soleimanynanadegany, A., Ashkan, M., Anjomshoae, A., Helmi, S. A., Dargi A.: Prioritizing green supplier selection criteria using fuzzy analytical network process. Procedia CIRP, vol. 26, pp. 689-694 (2015)

[34] Buyukozkan, G., Cifci, G.: A novel fuzzy multi-criteria decision framework for sustainable supplier selection with incomplete information. Computers in Industry, vol. 62(2), pp. 164-174 (2011)

[35] Chen, S. J., Hwang, C. L.: Fuzzy Multiple Attribute Decision Making. Methods and Applications, Springer-Verlag, Berlin, (1992)
[36] Wu, C-Y.: Robot selection decision support system: A fuzzy set approach. Mathematical and Computer Modelling, vol. 14, pp. 440-443 (1990)
[37] Bottani, E., Rizzi, A.: A fuzzy multi-attribute framework for supplier selection in an eprocurement environment. International Journal of Logistics Research and Applications, vol. 8(3), pp. 249-266 (2005)
[38] Dowlatshahi1, S., Karimi-Nasab, M., Bahrololum, H.: A group decision-making approach for supplier selection in configuration design: A case study. International Journal of Advance Manufacturing Technology, vol. 81, pp. 1139-1154 (2015)
[39] Bevilacqua, M., Ciarapica, F.E., Giacchetta, G.: A fuzzy-QFD approach to supplier selection. Journal of Purchasing and Supply Management, vol. 12(1), pp. 14-27 (2006)
[40] Karsak, E. E., Dursun, M.: An integrated fuzzy MCDM approach for supplier evaluation and selection. Computers & Industrial Engineering, vol. 82, pp. 82-93 (2015)
[41] Igoulalene, I., Benyoucef, L., Tiwari, M. K.: Novel fuzzy hybrid multi-criteria group decision making approaches for the strategic supplier selection problem. Expert Systems with Applications, vol. 42(7), pp. 3342-3356 (2015)
[42] Amiri-Aref, M., Javadian, N., Kazemi, M.: A New fuzzy positive and negative ideal solution for fuzzy TOPSIS. Wseas Transactions on Circuits and Systems, vol. 11(3), pp. 92103 (2012)
[43] Chen, C-T., Lin, C-T, Huang, S-F.: A fuzzy approach for supplier evaluation and selection in supply chain management. International Journal of Production Economics, vol. 102(2), pp. 289-301 (2006)
[44] Orji, I. J., Wei, S.: A Decision support tool for sustainable supplier selection in manufacturing firms. Journal of Industrial Engineering and Management, vol. 7(5), pp. 1293-1315 (2014)
[45] Zouggari, A., Benyoucef, L.: Simulation based fuzzy TOPSIS approach for group multicriteria supplier selection problem. Engineering Applications of Artificial Intelligence, vol. 25, pp. 507-519 (2012)
[46] Senvar, O., Tuzkaya, G., Kahraman C.: Multi criteria supplier selection using fuzzy PROMETHEE method. In: Kahraman, C., Öztaysi B. (eds.), Supply Chain Management Under Fuzziness, Studies in Fuzziness and Soft Computing, vol. 313, pp. 21-34 (2014)
[47] Sanayei, A., Mousavi, S. F., Yazdankhah, A.: Group decision making process for supplier selection with VIKOR under fuzzy environment. Expert Systems with Applications, vol. 37(1), pp. 24-30 (2010)
[48] Kwong, C. K., Ip, W. H., Chan, J. W. K.: Combining scoring method and fuzzy expert systems approach to supplier assessment: A case study. Integrated Manufacturing Systems, vol. 13(7), pp. 512-519 (2002)
[49] Chou, S.Y., Chang, Y.H.: A decision support system for supplier selection based on a strategy-aligned fuzzy SMART approach. Expert Systems with Applications, vol. 34(4), pp. 2241-2253 (2008)
[50] Amin S. H., Razmi, J., Zhang, G.: Supplier selection and order allocation based on fuzzy SWOT analysis and fuzzy linear programming. Expert Systems with Applications, vol. 38 (1), pp. 334-342 (2011)