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Application of Multi Criteria Decision Making approaches for personnel selection problem: A survey

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ABSTRACT
Personnel selection is the critical stage of human resource management (HRM). It is undeniable fact that qualified personnel is one of the necessary building blocks for organization success because improper personnel might cause many obstacles for an organization and dissipates it resource as time, effort, and money. Indeed, complexity and the important role of personnel selection problem require the application of robust and equitable methods. An effective, helpful, and reliable approach has been developed to deal with personnel selection problem is multi criteria decision making (MCDM) methods. In this paper, we focus on the application of MCDM methods for personnel selection problem and review numerous international journal articles accessible on famous academic databases.

Keywords **–** Fuzzy set theory, Grey Relation Analysis (GRA), Multi Criteria Decision Making (MCDM), Personnel selection, Expert systems

I. INTRODUCTION

The organization needs resource, such as personnel, money, raw material, and equipment, to produce goods or provide services to customers in order to achieve organizational goals. These needed resources of organization should be determined, provided and managed. Human resource management (HRM) normally refers to identifying, evaluating, selecting, hiring, motivation, training, and developing human resource (HR) to achieve organizational objectives [1]. One of the critical stages of HRM is personnel selection that it is mostly carried out followed by human resource planning and recruitment, and it will also determine the input quality of personnel [2]. Nowadays, organizations and firms confront with an increasingly global competitive. Therefore, many academic researchers believe that personnel selection is a strategic decision since it affects organization performance such as customer satisfaction, innovation, quality, profitability, and competitive power of the company [3-4]. In global competitive environment, much of the success of well-known firms has been attributed to their personnel's competency and aptitude. Competency is consisting of necessary attributes such as knowledge, skills, personality, and behaviors a person needs to fulfill his or her role [5]. As qualified personnel has became one of the necessary tool and a key success factor for organizations, their decision makers should determine essential competences for employee to perform a define job or task in the best way [4,6,7]. As stated by many researchers, personnel selection process is aimed at choosing the best potential employee (candidate) based on predefined attributes to fill the vacant job positions [7-9]. Qualified personnel selection is the main goal of personnel selection process which is consisting of activities in which various methods is used by organization to judge whether candidates are suited for the vacant job positions needing to be occupied. Personnel selection problem is extremely complex and multi dimensional problem since human judgment, cognitive process, multi and different attributes, job environment changes, labor law changes, society changes, organizational changes, and change in marketing have influenced personnel selection and recruiting [7,10]. Duo to complexity and important role of personnel selection problem, call for robust and analytical systematic method rather than just decision makers' biases. One of the well-known methods in decision making is multi criteria decision making (MCDM) methods that are an effective, trustworthy, and analytical helpful approach. Therefore, they are suitable approaches for dealing with personnel selection problem. In real-life situation such as personnel selection problem, decision makers face incomplete, vague, imprecision information, or human beings prefer to express their feeling and preference with verbal expression into numerical ones. Fuzzy set theory was introduced by Zadeh [11], and intuitionistic fuzzy set, the generalization of fuzzy set was introduced by Atanassov [12-16], are helpful tools for dealing with this situation. Consequently, MCDM methods based on fuzzy environment have been applied for personnel selection problem. In addition to, several authors have been used group decision making method (GDM), hybrid decision making models,

expert systems, grey theory, and artificial neural network for dealing with personnel selection problem. Nonetheless, all these methods can be considered in the realms of operation research (OR) science. For this article, the research objectives are to review and classify personnel selection problem from the standpoint of decision making methods. In this paper, we review and classify numerous international journal articles from 1994 to 2014 about personnel selection problem based on decision making methods. Grey relational and expert system are most of the helpful tools that are applied for solving decision making problems. Therefore, we also review the application of these methods for personnel selection. The literature review was done by an expansive search on authoritative academic databases such as Science Direct, Springer, IEEE, Taylor and Francis, Wiley online library, and so on. Although this survey cannot be exhaustive, it has been conducted from a large number of literature references.

II. PRELIMINARIES

2.1. Methods of personnel selection problem

Suppose you are a decision maker of one organization in order to select new employee to work in your organization. Should you take a random sample of applicants for jobs? Or choose applicant (potential candidate) with respect to some information and attributes? Would you like to know which applicant would most likely succeed in performing the jobs or task effectively? The answer to such questions can be found in the use of personnel selection methods. The selection of personnel to fill job vacant position is a task much discussed, and much research have been devoted to it. There are well-known conventional selections techniques are generally related to psychology science that they usually use to evaluate candidates with respect to attributes for solving personnel selection problem. These techniques are include: cognitive ability, work sampling, integrity, biographical date(Biodata), use of application form, age, graphology, interviews, types of testing(such as: personality, aptitude, trainability, intelligence , interest, job knowledge,…), and group methods[10,17,18]. The organization may use the combination of these selection methods based on job nature, time, accuracy, cost, laws, culture and etc [19]. As a scientific and scholarly issue, personnel selection owes psychology science exceedingly. Due to the accuracy of the results of these conventional methods are highly questionable and debatable, some authors have applied decision making methods to cope with personnel selection problem to eliminate the difficulty of conventional personnel selection techniques. Frequently, psychology studies are focused on selection methods and accuracy of them, job analysis, models of work performance, general attributes requirements, and rating importance of personnel selection methods. Nevertheless, it is necessary that in most personnel selection problem more one criterion should be considered simultaneously. Thus, the application of MCDM approach for dealing with personnel selection problem is expanded by industrial engineering.

2.2. History of personnel selection problem

Probably, Hugo Münsterberg (industrial and applied psychologist, 1863-1916) is the first person that applied the first instance of ability testing in personnel selection process for industrial environment in order to select individuals for the job of electric train motormen. With the beginning of the First World War, the US Army tries to establish appropriate methods for selecting best military personnel based on ability test. Therefore, later developments of using ability test in the 1910s found in military environment. The first group intelligence testing called Alpha test was developed through the effort of a psychologist team led by Robert Yerkes [see 20], and Over 1.7 million tests has been implemented to conscripts during the First World War [21]. As a scientific field personnel problem can be considered one hundred years old science. Although, it is old, some historical expert expressed that personnel selection based on testing as an ancient subject, has originated from Chinese civil servant exams established in AD605. It is said that Chinese servant exams, established in AD605 may be the first document modern selection personnel tests and have influenced following examination systems [22].

2.3. Personnel selection as a decision making process

In real life, human beings face with many situations that should make decisions in order to choose one action or anything among others. One of the main abilities of human beings is decision making that it differ us from other critters. Decision making can be viewed as the cognitive process resulting in the selection of the best alternative among several potential alternatives or one action among a set of action possibilities. In decision making methods, alternatives are identified and selected with respect to the decision maker's preference and value. In the realms of decision making methods, MCDM methods have been the subjective of interesting academic enquiry. Many problems have more than one decision criteria which are always conflicting; in addition, all criteria should be considered simultaneously. Therefore, MCDM methods have been applied for dealing with this problem. MCDM methods as a modeling and mathematical analysis tools have been started in late-nineteenth-century by applied

mathematicians and economist including Pareto, Morgenstern, Edgeworth, and Von Neumann.

As stated by many practitioners, there are two basic categories to MCDM methods: Multi attribute decision making (MADM) and Multi objective decision making (MODM) [23-24]. In MADM problem, decision space is discrete and decision process is focused on how to select or rank available alternatives that they are given previous and the number of alternatives is also limited. MODM problem contains several characteristics: decision space is continuous, the alternatives are not given previous, number of alternatives may be large or infinite, and objectives are mostly conflicted and formulated with one or several functions and constraints. In MODM methodology, the decision space is established by functions and constraints. Thus, the best solution is searched among this space by decision process. In decision making process, the information of decision makers' assessment can be expressed in the form of crisp (real number), linguistic terms, interval-value number, fuzzy numbers, and intuitionistic fuzzy numbers. Consequently, based on type of this information, MCDM methods can also be classified into classic methods or fuzzy methods. In classic MCDM methods, all decision makers' assessment information are known and they have been expressed in the crisp form and, thus, the rating and ranking of the alternatives can be carried out without any problem. Referring to the criteria perhaps containing vagueness or imprecision inherent in the information, the application of the classic MCDM methods may face serious practical constraints. Therefore, it cannot handle such situation effectively. For these situations, fuzzy MCDM methods (Fuzzy MADM and fuzzy MODM) have been extended. In Fuzzy MCDM methods data are imprecise, unknown, and fuzzy. In other words, assessment information hasn't been expressed in the crisp form. Moreover, a group of decision makers (or experts) can investigate all relevant aspect of decision making problem effectively rather than one individual since the collective knowledge of group can exceed that of individuals. Consequently, group decision making method has been extended to typical MCDM methods by some of the researchers. Therefore, the MCDM methods can be separated as single or group decision methods by considering number of decision makers. MODM methodologies can be separated in variety of ways such as the characteristics of decision making space (e.g., infinite or finite), form of model (e.g., linear, nonlinear, or stochastic), solution process (e.g., prior specification of preferences or interactive) [24]. There are many MADM and MODM techniques. The most popular MADM techniques which we can count as follows: Permutation, Dominant, Maximin, Maximax, Simple Additive Weighting (SAW), lexicographic method, Analytical Hierarchy Process(AHP), Analytical Network Process (ANP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Elimination Et Choix Traduisant laRéalité or Elimination and Choice Translating Reality (ELECTRE), Linear programming for Multi dimensional Analysis of Preference(LINMAP), Preference Ranking Organization Methods for Enrichment Evaluations(PROMETHEE) and Vlsekriterijumska Optimizacija I Kompromisno Resenje (VIKOR) [25]. The most popular MODM techniques are as follows: lexicographic method, Goal Programming(GP), global criterion method, utility function, metric L-P methods, bounded objective method, goal attainment method, surrogate worth trade-off, method of satisfactory goals, interactive GP, the methods as step method (STEM) and related method, goal programming STEM (GPSTEM), sequential multi-objective problem solving (SEMOPS) and sequential information generator for multi-objective problems (SIGMOP) method, method of displaced ideal, method of Geoffrion, parametric method, C-constraint method, and adaptive search method[26].

III. Our classification for the application of decision making approaches for personnel selection

Different separated may be considered for the application of decision making approaches for personnel selection problem. In this paper, with respect to the background of decision making approaches, we have classified the application of decision making approaches in personnel selection into 'Classic MCDM techniques', 'Fuzzy MCDM techniques' ,'Expert systems models', 'Grey Relational models' , and 'Hybrid models'. In this section, we review articles based on our classification. In each section, related decision making category is first mentioned briefly and then literature review is explained.

3.1. Classic MCDM approaches for personnel selection problem

3.1.1. AHP

Analytic hierarchy process (AHP) is one of the most popular classic MADM approaches that were proposed at the Wharton school of business primary by Saaty [27]. This method is a powerful logical approach to solve complex various types of decision making problems with multiple criteria in many fields of science and technology since its simplicity, great flexibility, and easiness of use. In the AHP method, complex problem is decomposed into several levels in order to construct a unidirectional hierarchy structure which is showing the relationships between the goal (objective), criteria, sub-criteria, and

alternatives. The main process of AHP is pairwise comparisons that the result of them is summarized in a "matrix of pairwise comparisons". For each pair of attributes, the decision maker specifies a judgment about "how much more important one attribute is than the other". Pairwise comparisons are made in order to calculate cardinal importance weight of attributes by decision maker [24].

Tavana et al. [28] proposed a group decision support system (GDSS) framework in which AHP and Delphi principles is combined in order to hire a nurse manager at general hospital in the United States. Managerial skill, personnel traits, and experience have been considered as attributes based on questionnaires by three group decision makers (totally12decision makers).

In [29], Saaty's AHP method is used for personnel evaluation problem in order to select college dean with a case study at Texas A&M University in the United States. AHP method is used to determining weights of criteria and rating of candidates. The committee as decision makers identified four criteria which were: a good Publication record, experience in an administrative position related experience, and proven ability at fund raising. Then, importance (weight) of criteria has been determined with pair wise comparison by the committee.

Gibney and Shang [30] applied of both order-ranking based upon group discussion, and AHP method in order to select the dean by academia committee evaluation with a case study. Moreover, they compared the result of two methods against the provost's final decision and discrepancies observed in the result are analyzed and explained.

3.1.2. SAW

This is also called Weighted Sum Method (WSM). SAW is the simplest method in which each attribute is given a weight, and the sum of all weights must be one. Each alternative is assessed with respect to every criterion. Then, the performance score of the alternative is obtained.

Afshari et al. [31] suggested simple additive weighting approach to solve personnel selection problem. They considered seven criteria that they were qualitative and positive for selecting the best one among five personnel and ranking them. The proposed method is illustrated by a case study in a Telecommunication sector in IRAN finally.

3.1.3. ANP

The AHP method decomposed a complex problem into a unidirectional hierarchy structure which is consisting of several levels. The fundamental assumptions behind AHP are that it can be used in functional independence of an upper level of the hierarchy structure from all its lower level and the criteria or items in each level. Nevertheless, many complex decision problems cannot be decomposed into hierarchy structure because they involved the interaction and dependence of higher-level elements on lower elements. Given the difficulty of solving these problem by AHP method, the ANP also introduced by Saaty, is a generalization of the AHP method [32]. The ANP method replaces hierarchy structure with network, in which interrelationships among decision levels and attributes, inner dependencies among elements in every level, are allowed and represented by arcs [33].

In [34], Dagdeviren and Yuksel proposed a method including interdependencies between personnel selection criteria by using ANP method. The network model applied to find out weight of the favorable factors which are to be used in personnel selection problem. A team determined the factors eligible to be accepted as criteria in personnel selection problem, and these criteria are separated into three main group factors that were: Qualitative Factors (such as Self-confidence), Zero-One Factors (such as Driver's License), and Quantitative Factors (Past Experience).

Boran et al. [35] developed a methodology based on ANP method for personnel selection with a case study. Based on ANP methodology, relationships among clusters and within elements in each cluster are demonstrated by a network structure. Four clusters which have been considered by expert include:1-Candidate cluster includes three candidates are labeled C1, C2 and C3; 2-Decision making cluster includes two sub criteria: Risk evaluation (DM1) and initiative (DM2); 3-Cluster of Management includes Planning and Organization (M1), Administrative Orientation (M2), Leadership (M3); 4-cluster of necessary requirements consists of Education and Training (NR1), Behavioral Flexibility (NR2), Global Understanding (NR3), Reward/Punishment (NR4), Teamwork (NR5), International Experience (NR6).

3.1.4. TOPSIS

Technique for order preference by similarity to an ideal solution (TOPSIS) is one of the well-known classical MCDM methods proposed by Hwang and Yoon [25] for solving the decision making problems. The main concept of this method is that: the chosen option should have the shortest distance from the positive ideal solution (PIS) and the farthest distance from the negative ideal solution (NIS) simultaneously. In fact, the ideal solution is derived from the ideal point. Whilst PIS maximizes the benefit criteria and minimizes the cost criteria, NIS, contrary to the PIS, maximizes the cost criteria and minimizes the benefit criteria. In traditional TOPSIS, the weights of the criteria and the ratings of

alternatives are known precisely and are treated as crisp numerical data [24,36].

In [37], Yeh formulated the scholarship student selection as an MADM problem, and explored how multi attribute value theory (MAVT) based MADM approach can be used to assess scholarship candidates. They developed an empirical validity procedure to deal with the ranking inconsistency problem resulting from the use of different MADM methods. They used TOPSIS method, the total sum (TS) method, simple additive weighting (SAW) method, and weighted product (WP) method individually to assess 57 candidates with respect to eight criteria for scholarship student selection at an Australian university, and concluded that SAW is the most appropriate method Since its ranking outcome has a minimum expected value loss when using equal weights for the selection criteria. Eight criteria that are considered in this study include: Community services, sports/hobbies, work experience, communication skills, energy, maturity, leadership, and attitude to business.

Shih et al. [38] investigated an extension of TOPSIS to group decision making environment and provided a few options as normalization, mean operators, and distance measures at each of the corresponding steps of extended TOPSIS. This extended TOPSIS method can be internally aggregated the preferences of group decision makers, whilst in previous group TOPSIS, the preferences of group decision makers have been aggregated within the procedure. They considered separation distance measurement methods by geometric mean or arithmetic mean of the individuals, and normalization methods for TOPSIS to include the multiple preferences of group decision maker. They used their method to a numerical example for choosing a non-line manager in a local chemical company. They considered the following criteria for numerical example: skill tests (professional skills, computer skills), knowledge tests (professional test, language test, and safety rule test), and interviews.

In [39], Dejiang developed an approach based on TOPSIS method for research and development (R&D) personnel selection in an uncertain environment by using grey theory. Firstly, he described both the rating of alternative and the weight of criteria by linguistic variables which can be expressed in interval grey numbers. Then, he identified a relative closeness to determine the ranking order of all alternatives by calculating the grey relational grade (GRG) of each alternative to the ideal and negative ideal solution simultaneously**.** They considered eight criteria for R&D personnel selection problem that were: job performance, education, job training, work experience, title level, age, innovation capability, and loyalty.

3.1.5. PROMETHEE

The PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) method is a multi-criteria decision making technique developed by Brans and Vincke [40] and Brans, Vincke, and Mareschall [41]. It is well adapted to problems where a finite numbers of alternatives are to be ranked considering several, often conflicting, criteria [42].

In [43], Chen et al. presented a flexible method based on different evaluation information (both qualitative and quantitative) in order to personnel selection problem by means of multiple linguistic PROMETHEE. They used 2-tuple linguistic valuable to express qualitative information, and crisp value to express quantitative information. And then, they applied linguistic PROMETHEE to calculate the outranking index of each alternative and determine the ranking order of candidates. A numerical example for choosing an overseas marketing manager is given to illustrate the presented method finally. They considered communication ability and market ability as quality criteria, and experience and English ability as two quantity criteria.

3.2. Fuzzy MCDM approach for personnel selection problem

Accordingly was mentioned in introduction section, decision making frameworks with fuzzy environment are applied in some real-life situations in which decision making information is vagueness, imprecision, or decision makers prefer to express their preference with the linguistic term. Traditionally, personnel selection is recognized a decision-making problem under multiple criteria and fuzzy environment since imprecision or vagueness inherent has in the decision making information. Consequently, many researchers focused on the personnel selection under fuzzy environment which is explained in this section.

Liang and Wang [44] developed a fuzzy MCDM methodology which is involved a two-stage algorithm for the personnel selection problem under fuzzy environment. Firstly, this method aggregated decision makers' linguistic assessment about subjective criteria and obtained fuzzy suitability index and it ranking value. Secondly, developed method obtained the final ranking values for personnel suitability evaluation and determined the most suitable personnel. Furthermore, the algorithm can be computerized. Thus, the decision makers can obtain the ranking order of the candidates automatically for final decision-making after providing fuzzy linguistic assessments and non-fuzzy objective test scores. A hypothetical example for hiring an industrial engineering is given to demonstrate the computational process of this developed methodology. In this example, eight

criteria were: leadership, emotional steadiness, self-confidence, oral communication skill, personality, general aptitude, past experience, comprehension.

Yaakob and Kawata [45] studied a problem of workers' placement in an industrial environment problem by using fuzzy triangular numbers (TFNs) and the concept of fuzzy linguistic variables. They performed both individual evaluation and group evaluation to find better combination. They used centre values of TFNs to rank the order of candidates approximately. Two typical example problem of workers' placement for production line are designed to demonstrate the effectiveness of proposed method. In these examples, they considered five criteria that were: Quality, Speed, Leadership, Professional knowledge, and Self-confidence in order to find the best worker for production line.

In [46], Tsao and Chue claimed that the proposed method by Liang and Wang [44] in their article is unreliable because membership function has limited and the multiplication for each weighted rating should be executed before the weighted rating of each alternative is added. They endeavored to use an improved fuzzy MCDM algorithm for personnel selection. Improved fuzzy MCDM displayed the multiplication for two positive triangular fuzzy numbers and can be solved the fuzzy personnel selection problem. A numerical example, which has been addressed in an earlier work by Liang and Wang [44], for hiring an industrial engineering in a manufacturing company, is given to illustrate feasibility of proposed method.

Lazarevic [47] presented a two-level personnel selection fuzzy model which is minimized subjective judgment in the process of distinguishing between an appropriate employee and inappropriate for a job vacancy. Proposed personnel selection fuzzy model (PSFM) applied the AHP as a basis to choose the appropriate candidates for an employment opportunity. Duo to avoid subjective judgment of PSFM in lower-level decisions influence on the higher-level decision, the lower level, worth and corresponding worth weight is explained by linguistic fuzzy variable. The proposed method is illustrated by using a case study of senior economic and financial analyst selection for the corporate unit of a telephone company.

In [48], Karsak developed a distance-based fuzzy MCDM method that is interrelated to TOPSIS method. Proposed method is represented crisp and fuzzy data as linguistic variables in order to consider subjective and quantitative performance criteria simultaneously. Proposed procedure employed a linear scale transformation to normalize the original information that enables the scale of measurement to vary precisely in the [0, 1] interval for each criterion. He suggested eight criteria for hypothetical example that criteria were: Aptitude test scare, personality assessment, annual salary request ($ 000), leadership excellence, past experience, oral communication skills, computer skills, fluency in foreign language.

Capaldo and Zollo [49] focused on the reliability of rating scales in personnel assessment and they endeavored to improve the effectiveness of personnel assessment within a major Italian company operating in the research sector, FIAT Research Center (CRF), as a case study. In the first step, the raters' behavior is analyzed in order to elicit the judgment categories and prototypes They applied in the judgment formulation based on rating method is adopted in the company. In the second step, they improved the rating method by using fuzzy logic. They suggested three main groups factors for personnel selection, each one of which being managerial skills, personnel characteristics, and professional skills.

Golec and Kahya [50] developed a comprehensive hierarchy structure, and a fuzzy model for competency based upon employee evaluation and selection. They used linguistic variable for criteria importance, and linguistic terms was used for evaluating of the competency of each employee for factor indicators. They developed a fuzzy rule–base (FRB) system based on the competency factors to select the best employee.

In [51], Canos and Liern developed a flexible decision support (DSS) by using ordered weighted average (OWA) in order to help manager in their decision making process. They presented two personnel selection models depending on the kind of information. In the first personnel selection model, weight of each competence was unknown. Accordingly, OWA operators are used to aggregate both crisp inputs and interval – valued inputs information about every candidate. In the second personnel selection model, it is assumed that the weights associated with the competences can be stated a priori as fuzzy numbers. Therefore, parametric aggregation techniques are used to aggregate information.

A personnel selection problem based on fuzzy AHP, which is applied to evaluate the best adequate personnel for dealing with the rating of both quantitative and qualitative criteria, is proposed by Gungor et al. [6]. Based on proposed method, all pair – wise comparisons information are converted into triangular fuzzy number to adjust fuzzy rating and fuzzy attribute weight. They also compared the results are obtained by FAHP method with the results are produced by Yager's weighted goals method under different α– cut levels. Moreover, they introduced a practical computer – based decision support system to provide more information and help to manager make better decisions under fuzzy circumstances. A hierarchy framework for personnel selection problem have been composed categories in three main groups: Category one: general factors

pertaining to work, Category two: complementary factors pertaining to work, and Category three: individual work factors.

In [52], Ayub et al. proposed fuzzy ANP method for personnel selection problem. Most importance criteria and sub-criteria are identified to select post lecturer of university by means of a committee that is including fifteen professors. They considered four criteria that were: personnel attributes, education and knowledge, skill attributes, experience other attributes, and results of proposed model are also compared with crisp ANP and AHP method.

Polychroniou and Giannikos [53] proposed a fuzzy MCDM methodology based on TOPSIS method for choosing employee to fill certain employment position in a Greek commercial bank. They considered eight criteria for credit officer selection in the Mortagages Department of a major Greek bank. Eight criteria were: annual salary request, communication skills educational background, experience in credit analysis, age, personality profile leadership ability, knowledge of foreign languages.

Dursan and Karsak [54] developed a fuzzy MCDM algorithm by using of fusion of fuzzy information, 2 - touple linguistic representation model, and TOPSIS method, which developed method, can be dealt with a multiple information sources problem. They employed OWA operator for aggregation information that it involved several aggregation operators, and it can combine the information through assigning weight to the value with respect to their ordered position. A numerical example, which has been addressed in an earlier work by Liang and Wang [44], for hiring an industrial engineering in a manufacturing company, is given to illustrate the computational procedure of the developed model.

In [55], Kelemenis and Askounis focused on support adequately the decision making process in order to information technology (IT) selection. Consequently, they developed a fuzzy TOPSIS method based on veto concept. Whereas Chosen alternative regards the traditional fuzzy TOPSIS principle, is the shortest distance from positive ideal solution and the farthest distance from negative ideal solution simultaneously, the preferred alternative regards the new fuzzy TOPSIS method based on veto threshold is the one with the higher (positive) distance from the veto threshold of all criteria. Fuzzy linguistic variables are used to criteria importance and evaluation of candidate respect to criteria, and fuzzy linguistic variables are also transferred to triangular fuzzy numbers (TFNs). Additionally, an empirical application on the selection of a chief information officer (CIO) with eleven criteria in a branch office of a multinational IT firm is given to illustrate the suggested method.

Boran et al. [4] proposed a multi criteria group decision-making (MCGDM) process for personnel selection problem by using TOPSIS method in intuitionistic fuzzy environment. The basic concept of intuitionistic fuzzy set (IFS) is originally introduced by Atanassov [12-16]. Intuitionistic fuzzy set (IFS) is the generalization of traditional fuzzy set introduce by Zadeh [11]. Each element in IFS is expressed by a three – parameter ordered pair which is called an intuitionistic fuzzy number (IFN) or intuitionistic fuzzy value (IFV), and each IFN is characterized by a membership degree, a non membership degree, and a hesitancy degree with condition that the sum of these degrees is equal to one. Rating decision makers and candidates respect to criteria are expressed by linguistic terms and then are transferred to IFN. All individual decision makers' opinion is presented by an intuitionistic fuzzy decision matrix. They used intuitionistic fuzzy weighted averaging (IFWA) operator to aggregate all individual decision makers' opinion into a group opinion which is an aggregated intuitionistic fuzzy decision matrix. A numerical example for hiring a sales manager in manufacturing company is given to illustrate proposed method. To evaluate six candidates, they consider six criteria and a decision group. These criteria were: oral communication skill, general aptitude, past experience, willingness, self – confidence, and first impression.

In [56], Kelemenis et al. proposed a novel multi criteria approach based on fuzzy TOPSIS for group decision making and they applied it for Support managers' selection. Firstly, they reviewed recent literature on human resource selection problem and summarized it into a table. They introduced three new concepts, namely the relative importance of the decision makers per criterion, veto thresholds, and the similarity-proximity degree among the decision makers. They employed fuzzy triangular number to be associated to the linguistic variables with 11 point scales for defining criteria importance and candidates rating. A numerical example for the hiring of a middle level manager for the position of a Wireless Product Marketing/Presales Engineer in group decision making environment in a large IT Greek firm is given to illustrate the proposed method finally. They classified the evaluation criteria two category, were ten "soft" managerial skills and two "technical" skills.

Safarzadegan Gilan et al. [57] developed a computing with words (CWW) approach based on Linguistic Weighted Average (LWA) and the specific architecture of Perceptual Computer (Per-C), for hierarchical competency based selection of human resources in construction firms. In the developed model, all the inputs to the personnel selection model were words, and were represented by Interval type-2 fuzzy set (IT2 FS) that were directly exploited from

the perception of a group of experts. They used Per-C architecture and LWA methods to flow and aggregate all the uncertainties about the words, criteria, and sub-criteria. Moreover, With an Empirical example of Iranian construction companies for choosing a project manager, they illustrated the use of the suggested procedure.

In [9], Balezˇentis et al. extended the fuzzy Multi- Objective Optimization by Ratio Analysis Plus for linguistic reasoning to cope with group decision making by employing fuzzy weighted averaging (FWA) operator and applied this method for personnel selection problem. They illustrated the fuzzy MULTIMOORA in group decision making environment (MULTIMOORA-FG) with an empirical personnel selection example. They considered eight attributes for personnel selection problem that these criteria have been expressed by linguistic variables with seven-point scale.

Afshari et al. [58] proposed a new linguistic extension of fuzzy measure and fuzzy integral and applied it for personnel selection problem under group decision making environment in which possible dependencies among the criteria have been considered. Whilst the general assumption in traditional MCDM methods is the criteria are independent, they focus on dependence among criteria in MCDM problems as a research gap in the published literature on this topic. They said that ANP and fuzzy integral are two methods for dealing with dependence among criteria topic in MCDM problems. They investigated ANP method completely and concluded that the ANP method is suitable in MCDM problems if only the number of alternatives and criteria are limited. Consequently, in MCDM problems with large number criteria and alternatives, use of the fuzzy integral method should be preferred than ANP method. They applied their model for choosing project manager in MAPNA enterprise, which is the large multi disciplinary power holding Iranian organization.

In [59], Wan et al. investigated multiple attribute group decision-making (MAGDM) problems in which the rating of alternatives are expressed with Triangular intuitionistic fuzzy numbers (TIFNs), are a special intuitionistic fuzzy set (IFS) on a real number set, and the weights of the attributes and decision makers (DMs) are completely unknown. Firstly, they defined the crisp weighted possibility mean of TIFNs, and the Hamming distance and Euclidean distance for TIFNs are defined based on Hausdorff distance. They developed the triangular intuitionistic fuzzy weighted average (TIF-WA) operators. Then, Shannon entropy measure is used to calculate the weights of attributes and the weights of DMs are determined objectively by combining the evidence theory with Bayes approximation. The TIF-WA operator is used to aggregate individual decision matrixes for all DMs into the group decision matrix. Thereby, they extended the classic VIKOR method for solving the MAGDM with TIFNs. The ranking order of alternative is determined according to the closeness of alternative with respect to the ideal solution finally. With a numerical example for the selection of a department manager in an investment company, they showed the validity of their model.

Rouyendegh and Erkan [60] presented fuzzy ELECTRE algorithm to select best candidate and applied it for academic staff selection with using the opinion of experts in group decision making environment. They suggested a hierarchy chart for staff selection and classified decisive factors into three main criteria; academic factors, work factors, and individual factors. Individual factors were self-confidence, compatibility, age. Academic factors were team work, academic experience, technical information, research paper writing. Work factors were oral presentation, bachelor degree, GRE and Foreign Language. Presented method can convert all pairwise comparisons into triangular fuzzy numbers to achieve consensus among the decision makers. A numerical example of one university in Turkey for academic staff is given to illustrate the proposed method, and results from fuzzy ELECTRE algorithm are also compared with results from fuzzy AHP method.

In [61], Liu et al. presented an extended VIKOR method combined with interval 2-tuple linguistic variables to choose appropriate individuals among candidates in a group decision-making environment. If $S = \{s_0, s_1. \ . \ . \ s_g\}$ be a linguistic term set then an interval 2-tuple linguistic variable is composed of two linguistic terms and two crisp numbers, denoted by $[(s_i, \alpha_i), (s_j, \alpha_j)]$. In the evaluation process, the rating of each candidate, which is given with linguistic information, is represented as interval 2-tuple linguistic variables. The VIKOR method was used to obtain the ranking of candidates and find an optimal individual for personnel selection. A numerical example of one hospital for hiring a head nurse is given to demonstrate the applicability and effectiveness of the interval 2-tuple linguistic VIKOR method. They considered four main criteria for head nurse selection that were: oral communication skill, past experience, Leadership, Self-confidence.

Dodangeh et al. [62] developed a fuzzy MCDM model for linguistic reasoning under new fuzzy group decision making that new linguistic reasoning for group decision making is able to aggregate subjective evaluation of the decision makers and hence create an opportunity to perform more robust human resource selection procedures. They explained different phases based on algorithm of modeling process for selecting human resource. These phases were as follows; Phase 1: in which selecting relevant criteria and sub criteria is done, Phase 2:in which calculating the importance

weight of criteria is done, Phase 3:forming decision making matrix based on established criteria, and finally in Phase 4 modeling of Fuzzy MCDM(FMCDM) is performed. They validated the proposed model by using a case study of Project manager selection in MAPNA firm, which is large multi disciplinary power holding located in Tehran, capital of IRAN.

Pant et al. [63] defined a methodology based on Delphi method as well as Fuzzy Analytic Hierarchy Process (FAHP) to identify and prioritize Human Capital Measurement Indicators for Personnel Selection. They enumerated various Human Capital performance measurement indicators through a review of the literature and industry interviews and 35 indicators have been selected for measuring performance of Human Capital. Thereafter, based on subjective judgment data of a group of experts, 20 indicators have been sorted using by Fuzzy-Delphi method. Finally, ranking of each indicator is obtained by Fuzzy Analytic Hierarchy Process (FAHP).With a numerical example in an Indian organization, they showed Employees satisfaction with advancement opportunities, Employee skills, Creating results by using knowledge, Internal relationship index, Percentage of employees with access to appropriate training and development opportunities was the most important indicators for the human capital in a case study.

In [64], Can´ os et al. Presented a personnel selection methods that depended on the definition for an ideal candidate. They obtained aggregated fuzzy valuations of each candidate with respect to account the individual valuation provided by experts. They ranked the candidate based on their similarity with the ideal candidate. They considered three different situations which are: the ideal candidate is explicitly known by the firm, the ideal candidate is known implicitly, and the ideal candidate cannot be identified by the firms. Each of these situations required a different approach to measure the similarity between each candidate and the ideal candidate. In the first case, similarity or inclusion indexes are used; in the second, the experts used ordered weighted average operators that it allows experts to simulated global valuations for the candidates. An ideal profile can be constructed from the competences' valuations of candidates if there is not an ideal profile. To illustrate the proposed methods, they presented real personnel selection example and it is solved by using a program called "*StaffDesigner*" which is used JAVA and MATLAB languages.

Md Saad et al. [67] presented a novel approach is based on Hamming distance method with subjective and objective weights (HDMSOW's) for personnel selection problem. Hamming distance as one of the well-known distance measure method is introduced by Hamming in 1950. Hamming distance is used to calculate the difference between two elements or two sets and it can be applied in personnel selection problem. They extended classical Hamming distance by adding two types of weight which were objective and subjective weights. They used Shannon's entropy concept to determine the objective weights and they used preference of the decision maker to obtain subjective weight. They used weighted Hamming distance to identify the distance value between the ideal alternative and the other alternatives. Additionally, ranking of alternatives is made based on the overall evaluation of the criteria. An example on the personnel selection in an academic institution for choosing a lecturer is provided to validate the proposed algorithm.

In [1], Safari et al. determined human resource management main criteria and sub-criteria which are influencing the organizational performance based on a survey on the literatures and theoretical principles. They determined the relative weight and ranking of relevant criteria and sub-criteria affecting the organizational performance using Fuzzy AHP and Fuzzy TOPSIS techniques. In addition, final ranking of these criteria have been determined by calculating mean ranking method. With numerical example as case study for identifying and ranking the human resources management criteria influencing on organizational performance in Isfahan, famous tourist city in IRAN, Municipality, they illustrated the proposed method finally.

3.3. Expert systems (ESs) approach for personnel selection problem

Edward Albert Feigenbaum, American computer scientist, is the first person that introduced expert systems (ESs), as a successful branch of applied Artificial intelligence (AI), through Stanford (university) heuristic programming project in the 1970s. He developed EPAM (Elementary Perceiver and Memorizer) one of first computer models of how human beings learn. Based on the main concept of ES, The expertise of a specific knowledge area from a talent people is transferred to a computer. Consequently, decision making is performed based on this knowledge by the computer. Expert systems are easily understood, rapid prototype, and reviewed or edited by domain experts since it can treat the complex problems by reasoning about knowledge represented as IF-Then rules rather conventional procedural code that was used in traditional computer program by IT specialist[66]. Duo to the advantages of expert systems, some scholars focus on the expert systems for solving personnel selection problem.

Byun and Suh [67] provided an excellent overview of the ways in which ES can be successful in assisting managers in critical decision-making. They suggested the most appropriate domains in

which ES can be built successfully include planning, job analysis, recruitment, selection, performance evaluation, training and labor-management relations, and compensation. Furthermore, they proposed a wheel model for the Human resource management expert systems (HRMES) and a semantic net, as a graphic technique for knowledge representation, is used for HR planning, Recruiting, Compensations, and Labor-management relations.

In [68], Hooper et al. used an expert system in a personnel selection process. The purpose of this study was to begin the development and testing of an Expert System to screen officer personnel records being considered for Command and General Staff College in US Army. The Artificial Intelligence (AI) computer language "PROLOG" is used to develop a basic rule-based expert system called BOARDEX for officer selection in order to education and training in US Army Command and General Staff College. The considered criteria in this paper for officer selection were: grade, military education level, civilian education level, height, weight, assignment history, and Officer Efficiency Report (OER) evaluations.

Huang et al. [69] applied Fuzzy Neural Network (FNN) to construct a new model for evaluation of managerial talent and they developed a decision support system in Human Resource Selection System. They used FNN to train the concrete database, on the basis of 191 questionnaires from experts. Additionally, they adopted simple additive weighting (SAW) and FAHP methods to let decision makers for adjusting weighted values and obtain decisive results of each phase's scores. FNN is used to construct the human resource selection system of JAVA user interface. They used **"**FuzzyTECH software**"** as a tool for FNN to let the output network model transferred the information to six dimensions and JSP dynamic programming language is used to construct a human resource selection system. The criteria in this paper were: Capability trait, personality trait, motivational trait, conceptual skill, interpersonal skill, and technical skill.

In [70], Drigas et al. developed a hybrid expert system job matching of unemployed at certain offered posts. They applied Neuro-Fuzzy methods for analyzing a corporate database of unemployed and enterprises profile data. Sugeno type Neuro-Fuzzy interface system performed the process of matching on unemployed with an offered job. Six fields (criteria) are used to formulate the query/job opportunity. These six criteria were: Age, Education, Previous Employment (Experience), Additional Education (Training), Foreign Language (English), and Computer Knowledge.

Chen and Cheng [71] proposed a new approach to rank fuzzy numbers by metric distance, and developed a computer based group decision support system (FMCGDSS) which is consisted of three ranking methods to help manager make better decision under fuzzy environment. These ranking methods are involved intuition ranking, lee and li's fuzzy mean/spread and metric distance method. Proposed approach is used for information system (IS) personnel selection for the position of a project manager.

Jereb et al. [72] proposed a novel approach to decision making in human resource management that this approach integrated a hierarchical MADM techniques with expert systems and it was based on the explicit articulation of qualitative decision knowledge. They used a computer-based on attributes arranged in a form of a tree structure as supporting tools named DEXi, a specialized expert system shell for interactive construction of the knowledge base that was developed in collaboration between Josef Stefan Institute and University of Maribor, to develop and employ qualitative decision models.

In [19], Saidi Mehrabad and Fathian Brojeny developed an expert systems framework for personnel selection problem. They compared operation research methods and expert systems, and concluded that Expert system approach can use for the personnel operations of organizations extensively. Some of the important features of their expert systems models are flexibility in knowledge base and the ability of the presentation of explanations about the reasoning and decisions which are made. Their model has been used in research and development organization with the following criteria: educational level, work experience and management experience.

Chien and Chen [2] generated useful rules for an expert system in personnel selection framework. A data mining framework has been developed to extract useful rules from the relationships between personnel profile data and their work behaviors. Furthermore, they developed useful strategies with domain experts in the semiconductor Foundry Company, which is located in the Hsinchu Science and industrial Park in Taiwan, and most of the suggestions have been implemented. Through the proposed methodology, they can extract hidden information from large volumes of personnel data and thus the decision makers can have a better understanding and visualization of such latent knowledge.

Rashidi et al. [73] proposed a model Neurofuzzy Genetic System to solve a decision making issue in the construction firms for choosing a qualified Project Managers. The important criteria in selection a project manager is identified based on the opinions of experienced construction managers by means of interviews through a fuzzy system which is based on IF-THEN rules. They used a genetic algorithm to determine initial cluster center, along with membership function parameters, and ANN is also used to determine the efficiency grade of deduction parameters. They analyzed prediction of final model

by using a set of experimental data. They compared the results of proposed model to actual interview results.

Jazebi and Rashidi [74] focused on the selection of a project manager from a set of potential candidates for construction firms and suggested an automated procedure which is required only information for 15 numbers of the most important criteria. Whereas proposed procedure in their study is required only information for 15 numbers of the most important criteria, the same previous study by Rashidi et al. [73] needs information for 23 criteria. They suggested a precise fuzzy system to accurately determine the most suitable person in pair-wise comparisons. They considered two factors and presented an optimal fuzzy system, in which the least number of criteria is considered for selection process in construction firms. They identified all possible criteria for the selection of a project manager and developed an initial fuzzy expert system based on these criteria. They obtained the required database from a number of interviews conducted by the senior managers of a number of major construction firms in Iran. The fuzzy curves method is used to determine the importance of each criterion. Moreover, they validated the developed model by a 62 data from the available dataset, and used this model in a real case study.

3.4. Grey relational approach for personnel selection problem

Grey system theory was originally proposed by Professor Julong Deng in 1982 and it consists of five major parts; grey prediction, grey relational analysis (GRA), grey decision, grey programming, and grey control. In the type of fuzzy multi criteria model, GRA has been widely used in variety of MADM problems as an effective contributor mathematical tool to identify solution from a finite set of alternatives. GRA involves four steps. First step is grey relational generation in which the performance of all alternatives is formulated into a comparability sequence, and in second step ideal target sequence is defined respect to these comparability sequences. In the third step, the grey relational coefficient between all comparability sequences and ideal target sequence is calculated. Finally, the grey relational degree (grade) between ideal target sequence and every comparability sequences is calculated based on grey relational coefficient which has been calculated in third step. After calculating grey relational degree between ideal target sequence and each of comparability sequence translated from an alternative, the best alternative will be selected based on the highest grey relational degree. In other words, alternatives will be ranked according to the decreasing order of their grey relational degree [8, 75-77].

Zavadskas et al. [78] considered the application of Grey Relations Methodology to define the utility of alternatives and developed a multi criteria approach of Complex Proportional Assessment of alternatives with grey relations (COPRAS-G) for analysis to project manager selection. They investigated a related literature and interviews of management personnel involved in the project managers selection and they selected most important criteria for a project manager in construction firm. They identified six criteria for the selection of a construction project manager based on the review of literature, and managers' questionnaires. These six criteria were: personal skills, business skills, technical skills, project management skills, quality skills and time of decision making.

In [79], Kose et al. proposed Grey analytic network process (GANP) to solve personnel selection problem, which is focused on sniper selection in uncertain environment. They used GANP to determine assessment of criteria weight. With respect to GANP, contrary to the conventional ANP, they used grey numbers to form comparison matrixes because of ambiguity of DMs judgments. Linguistic variables are used to describe the rating of attributes and grey number correspondences are used for calculations. They also presented a grey possibility degree to compare the ranking of grey numbers and select the most ideal alternative. With a numerical example for sniper selecting, they illustrated the use of the suggested procedure that criteria were quite similar to sniper selection problem has been suggested by Kabak et al. (2012).

3.5. Hybrid models approach for personnel selection problem

Shyur and Shih [80] proposed an effective five-step hybrid MCDM model, in which ANP and modified TOPSIS is combined together, for supporting the strategic vendor selection process in new task situations. They identified the necessary criteria for vendor selection through the Nominal Group Technique (NGT) and it used to determine the degree of interdependent relationship between different criteria by the expert group via NGT. ANP is used to elicit an appropriate weight for each criterion. They modified TOPSIS method, which is exploited a newly defined weighted Euclidean distance, for group decision making, and employed it for finalizing the selection process. An empirical example is used to illustrate the feasibility and effectiveness of the proposed model. They considered seven criteria for evaluation process that these criteria were: on-time delivery, price/cost, product quality, facility and technology, quality of relationship with vendor, professionalism of salesperson, and responsiveness to customer needs.

In [81], Celik et al. proposed fuzzy integrated multi-stages evaluation model (FIMEM) under multiple criteria towards enhancing the execution procedure of academic personnel selection in Maritime and Training (MET) and development processes institutions collaboratively. The proposed methodology is consisted of Fuzzy AHP, Fuzzy TOPSIS, and performing the strengths, weaknesses, opportunities, and threats (SWOT). Fuzzy AHP is applied to assign weights over relevant attributes, Fuzzy TOPSIS is applied to select the suitable candidates, and SWOT analysis over the model outcomes is used to enable continuously development of assigned academic personnel. An example for recruiting a senior lecturer in a MET institution is given to illustrate the proposed FIMEM approach.

Dagdeviren [82] proposed a hybrid model in which ANP and modified TOPSIS is combined together for supporting the personnel selection in manufacturing systems. The Fuzzy ANP is used to analyze the structure of the personnel selection problem and to determine the overall weights of the criteria, and he utilized modified TOPSIS method to obtain final ranking. Proposed model has significantly increased the efficiency of decision-making process in personnel selection. An application of a real case in a Turkish factory that produced specialist machines was conducted to illustrate how the approach was used for the personnel selection problem. In addition, group brainstorming method was employed for criteria selection. Seven criteria were used for personnel selection that these criteria include: the ability to work in different business departments, oral communication skills, past experience team player, strategic thinking, fluency in a foreign language and computer skills.

A decision support tool with three phases by using an integrated ANP method and fuzzy data envelopment analysis (DEA) approach to deal with the personnel selection problem is developed by Lin [83] and it is applied for an electric and Machinery Company in Taiwan. In the first phase, decision makers appraised the alternatives with respect to criteria by linguistic variables and this linguistic variable is transferred to triangular fuzzy numbers (TFN) to quantify the judgment value of linguistic data. In the second phase, the ANP method is used to determine the global Weights of criteria. In phase 3, they developed a fuzzy DEA with assurance region (AR) for evaluating and ranking the applicants. A numerical example for hiring a senior electrical engineer in an electric and Machinery Company in Taiwan is given to illustrate the proposed method. Three criteria consisted of professional knowledge and expertise (C1), previous professional career and educational background as well as achievements (C2) and personality and potential (C3) are considered for numerical example.

Zhang and Liu [8] developed an intuitionistic fuzzy multi-criteria group decision making method with GRA for solving the decision making process and utilized it for personnel selection. They utilized Intuitionistic fuzzy weighted averaging (IFWA) operator to aggregate individual opinions of decision makers into a group opinion and Intuitionistic fuzzy entropy is used to obtain the entropy weights of the criteria. Grey relational analysis (GRA) is applied to the rank and select of alternatives. A numerical example for hiring a system analysis engineer in a software company is given to illustrate the proposed method finally.

Mukhopadhyaya and Pramanik [84] presented an intuitionistic fuzzy multi criteria group decision making (MCGDM) method with grey relational analysis (GRA) for teacher selection in higher education. In their study GRA is used for ranking and selection of alternatives.

In [7], Kabak et al. proposed a fuzzy hybrid multi criteria decision making approach composed of combining three different MCDM techniques for sniper selection as a part of personnel selection. They used the combination of Fuzzy ANP, Fuzzy TOPSIS, and Fuzzy ELECTRE techniques for sniper selection that it enables the use of the combination of both qualitative and quantitative factors. Fuzzy ANP is used to calculate the overall weights of criteria, Fuzzy TOPSIS is used to determine the most suitable candidate, and the top three ranked candidates by Fuzzy TOPSIS are take in order to obtain final ranking of them by Fuzzy ELECTRE.They considered three categories criteria for sniper selection include; Functional factors, Physical factors, and Personality factors that each categories were consisted of sub criteria.

Keršulienė and Turskis [85] proposed an integrated multi-criteria group decision making process is included AHP and a fuzzy MCDM method, the additive ratio assessment method with fuzzy numbers (ARAS-F), for Chief accountant officer selection as a part of personnel selection. They considered set of essential criteria that were Education, academic level, working skills, long life learning; Working knowledge, working skills, work experience, knowledge of legislation system; Responsibility; Strategic thinking; Leadership; Computer skills; Motivation to work in particular position, and Ability to work with clients, consultants and community.

IV. Conclusion

Although, personnel selection problem is very old, it has still attracted the interest of many practitioners and researchers. Due to the accuracy of the results of conventional techniques such as

interviews or employment test most are highly questionable, some researchers have focused on the application of MCDM methods, expert systems, and grey theory to deal with personnel selection problem. In this paper, although we have reviewed recent advances on the application of these techniques for personnel selection problem, we more have focused on MCDM methods. We saw the literature on the application of MCDM techniques for personnel selection problems has been growing increasingly and it also seems that usage of fuzzy decision making and hybrid approaches would increase within next future years.

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