**ISTANBUL TECHNICAL UNIVERSITY ★ INSTITUTE OF SCIENCE AND TECHNOLOGY**

# A FUZZY HUMAN RESOURCE ALLOCATION MODEL IN QUALITY FUNCTION DEPLOYMENT

**Ph.D. Thesis by**
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**Department :** **Industrial Engineering**

**Programme:** **Industrial Engineering**

**JUNE 2009**

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**İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ**

# KALİTE FONKSİYONU AÇINIMINDA BULANIK İNSAN KAYNAKLARI ATAMA MODELİ

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## FOREWORD

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February, 2009 Orkun Kozanoğlu

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## ABBREVIATIONS

| | |
|---|---|
| **16PF** | : Sixteen Personality Factor |
| **CA** | : Customer Attribute |
| **CR** | : Consistency Ratio |
| **CC** | : Closeness Coefficient |
| **CIT** | : Critical Incidents Technique |
| **CME** | : Chief Maintenance Engineer |
| **EC** | : Engineering Characteristics |
| **FAHP** | : Fuzzy Analytic Hierarchy Process |
| **FFM** | : Five Factor Model |
| **FJA** | : Functional Job Analysis |
| **FMCDM** | : Fuzzy Multi Criteria Decision Making |
| **FNIS** | : Fuzzy Negative-Ideal Solution |
| **FPIS** | : Fuzzy Positive-Ideal Solution |
| **FPSS** | : Fuzzy Personnel Selection Software |
| **FQFD** | : Fuzzy Quality Function Deployment |
| **FTOPSIS** | : Fuzzy TOPSIS |
| **FVIKOR** | : Fuzzy VIKOR |
| **FWA** | : Fuzzy Weighted Average |
| **HoPD** | : Head of Production Department |
| **HoQ** | : House of Quality |
| **HRS** | : Human Resource Specialist |
| **KSAOs** | : Knowledge, Skills, Abilities and Others |
| **KSAs** | : Knowledge, Skills and Abilities |
| **MCDM** | : Multi-Criteria Decision Making |
| **ME** | : Maintenance Engineer |
| **NIS** | : Negative Ideal Solution |
| **OCB** | : Organizational Citizenship Behavior |
| **PAQ** | : Position Analysis Questionnaire |
| **PBJA** | : Personality-Based Job Analysis |
| **PCM** | : Pairwise Comparison Matrix |
| **PIS** | : Positive Ideal Solution |
| **PM** | : Plant Manager |
| **POB** | : Prosocial Organizational Behavior |
| **PPRF** | : Personality-related Position Requirements Form |
| **QFD** | : Quality Function Deployment |
| **SE** | : Shift Engineer |
| **SME** | : Subject Matter Expert |
| **TC** | : Task Criticality |
| **TF** | : Task Frequency |
| **TFN** | : Triangular Fuzzy Number |
| **TOPSIS** | : Technique for Order Performance by Similarity to Ideal Solution |
| **TS** | : Time Spent |
| **WCI** | : Worker Characteristics Inventory |

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**A FUZZY HUMAN RESOURCE ALLOCATION MODEL IN QUALITY FUNCTION DEPLOYMENT**


## SUMMARY

Human resources are considered as the most important asset of an organization, but very few organizations are able to fully use its potential. Sophisticated technologies and innovative practices alone can do very little to enhance operational performance unless the requisite human resource management practices are in place to form a consistent socio-technical system. For this reason, manufacturing and service organizations need to carefully evaluate their existing human resources, and develop them so that employees can effectively contribute to operational performance improvement.

The primary way of building a high performance workforce is recruitment and selection of personnel. The overall aim of the recruitment and selection process is to obtain at minimum cost the number and quality of employees required to satisfy the human resource needs of an organization. This can be realized by the prediction of the future job performance of applicants. However, it is quite difficult to select the most suitable person for a certain job unless there is a clear understanding of the job's requirements. By identifying such requirements, it is possible to develop selection procedures that will determine whether a particular applicant possesses the necessary and proper characteristics to carry out the tasks involved in the job.

The objective of this study is to develop a personnel selection model based on Fuzzy Quality Function Deployment, which provides the integration of selection processes with the determination of levels of required personnel characteristics. This integration ensures the exact identification of job-related criteria and a structured approach for developing hypotheses about performance-predictor relationships, which are involved in the personnel selection decisions. Linguistic variables and associated triangular fuzzy numbers are used in the proposed model for modeling the vagueness and subjectivity involved in the assessment of the levels of required personnel characteristics and assessments of applicants with respect to these personnel characteristics.

The proposed model has been applied for two real-life problems. The results of these applications reveal that the proposed model can distinguish the candidates accurately with respect to the characteristics required for the job. Also, since decision makers are not capable of analyzing and synthesizing vast amount of job and candidate information judgmentally, the utility of the proposed model is established.

**KALİTE FONKSİYONU AÇINIMINDA BULANIK İNSAN KAYNAKLARI ATAMA MODELİ**

**ÖZET**

İnsan kaynakları bir organizasyonun en önemli varlıkları olmasına rağmen çok az insan bu varlığın potansiyelindentam anlamıyla faydalanabilmektedir. Karmaşık teknolojiler, yenilikçi uygulamalar, istikrarlı bir sosyoteknik sistemi oluşturmak için gerekli olan insan kaynakları uygulamaları olmadan operasyonel performansı geliştirmek için çok az katkı sağlayabilir. Bu nedenle imalat ve hizmet organizasyonları mevcut insan kaynkalarını dikkatle değerlendirmeli ve operasyonel performansı geliştirmeye katkı sağlayacak etkin bir katkı sağlayacak şekilde geliştirmelidirler.

Yüksek performanslı bir iş gücü oluşturmanın ilk yolu personel bulma ve personel seçimidir. Personel bulma ve personel seçiminin genel amacı en az maliyet ile organizasyonun insan kaynakları ihtiyacını karşılayacak gerekli sayıda ve kalitedeki çalışanı organizasyona kazandırmaktır. Bu, başvuran kişilerin gelecekteki iş performansını tahmin etmek yoluyla gerçekleştirilir. Ancak, iş gerekleri açık bir şekilde belirlenmemiş ise, iş için en uygun kişiyi seçmek oldukça zor olacaktır. İş gereklerinin belirlenmesi ile, herhangi bir adayın işi oluşturan görevleri yerine getirmek için gerekli olan niteliklere sahip olup olmadığını belirleyecek seçim prosedürleri geliştirilmesi mümkün olacaktır.

Bu çalışmanın amacı, personel seçim sürecini gerekli personel niteliklerinin ve bu niteliklerin seviyelerinin belirlenme süreciyle entegre eden Bulanık Kalite Fonksiyonu Açılımı temelli bir personel seçim modeli geliştirmektir. Bu entegrasyon işe ilişkin kriterlerin doğru şekilde belirlenmesini ve personel seçiminde var olan performans-tahmin değişkenlerine ilişkin hipotezlerin planlı bir şekilde geliştirilmesini sağlayacaktır. Önerilen modelde, gerekli personel niteliklerinin seviyelerinin belirlenmesi ve adayların bu niteliklere göre değerlendirilmesi sırasında var olan belirsizlik ve subjektifliği modellemek amacıyla dilsel değişkenler, ve bu değişkenlere ilişkin üçgen bulanık sayılar kullanılmaktadır.

Önerilen model iki gerçek hayat problemi için uygulanmıştır. Bu uygulamaların sonucu, önerilen modelin adayları, iş için gerekli niteliklere göre doğru bir şekilde ayırabildiğini ortaya koymuştur. Ayrıca, karar vericilerin büyük miktardaki iş ve aday bilgilerinin analiz ve sentezini muhakeme yolu ile gereçekleştirmelerinin mümkün olmamasından dolayı, önerilen modelin yararlılığı kanıtlanmış olmaktadır.

# 1. INTRODUCTION

Employing adequate numbers of suitably trained personnel is a problem which faces many companies today since the nature of work in the $21^{st}$ century presents many challenges for staffing. For example, knowledge-based work places greater demands on employee competencies; there are widespread demographic, labor, societal, and cultural changes creating growing global shortfalls of qualified and competent applicants; and the workforce is increasingly diverse. A survey of 33,000 employers from 23 countries showed that 40% of them had difficulty in finding and hiring the desired talent, and approximately 90% of nearly 7,000 managers indicated talent acquisition and retention were becoming more difficult (Axelrod, Handfield-Jones, and Welsh, 2001). Because talent is rare, valuable, difficult to imitate, and hard to substitute, organizations that better attract, select, and retain this talent should outperform those that do not (Barney & Wright, 1998). Thus, recruitment and selection of competent personnel are very significant for the ongoing success of any organization. Although recruitment and selection are closely interrelated parts of a multistage decision process, recruiting activities generate applicants for jobs, and selection decisions must then be made to choose the subset of applicants, or the applicant, most likely to succeed. The overall aim of the recruitment and selection process should be to obtain at minimum cost the number and quality of employees required to satisfy the human resource needs of the company.

This study concentrates on the personnel selection, which is considered as a multi-criteria decision making problem since it aims to satisfy many characteristics required by new personnel for satisfactory or high performance. Personnel selection involves collecting information about individuals for the purpose of determining suitability for employment in a particular job. This information is collected using one or more selection devices or methods. The most important property of an assessment method in personnel selection is its ability to predict future job performance or job-related learning. However, it is difficult to select the most suitable person for a certain job unless there is a clear understanding of the job's requirements in terms of personnel characteristics. By identifying such requirements, it is possible to develop selection procedures that will determine whether a particular applicant possesses the necessary and proper characteristics to carry out the tasks involved in the job. Thus, success of the personnel selection process is dependent on two basic processes: determination of personnel characteristics required to perform the job and their levels; and assessment of candidates. Improvement of these processes will result in improvement of overall personnel selection process, which means higher predictive efficiency and higher consistency in the outcomes.

The assessment of the level of required personnel characteristics and evaluation of candidates with respect to these characteristics are performed by a number of people within the organization and it is well recognized that people’s assessments of concepts are always subjective and thus imprecise, and the linguistic terms people use to express their judgments are vague in nature. Using objective and precise numbers to represent linguistic assessments are, although widely applied, not very reasonable. Because, people spend more mental effort in making numerical estimates of the concepts when they are forced to do so. Also, humans are unsuccessful in making quantitative assessments, whereas they are comparatively efficient in qualitative evaluations. In essence, human cognitive processes, such as thinking and reasoning and human communication is inherently fuzzy. Thus, a more rational approach is to assign fuzzy numbers to linguistic assessments so that their vagueness arising from mental phenomena and human communication can be captured.

In the light of above discussions, the objective of this study is to develop an improved personnel selection model which will help to select the most suitable person by providing a strong linkage between the content of the job and characteristics of selected candidate(s) and; by involving the vagueness and subjectivity inherent in personnel selection processes. The proposed model is aimed to be applicable for both white-collar and blue-collar positions and it assumes that there are a number of candidates applying for a particular job and a certain number of candidate(s) is to be selected for the job in question. In order to meet these objectives, the model uses Fuzzy Quality Function Deployment (FQFD) as a framework for integrating the determination of required personnel characteristics and final selection processes. The use of FQFD helps to develop hypotheses in a structured approach about performance-predictor relationships tested in a specific personnel selection problem. More specifically, the rationale of using FQFD for personnel selection is to translate the job content which is determined as a result of job analysis into the personnel characteristics and their levels that new personnel must have. This is because; employers may not easily identify the types and levels of knowledge, skills and abilities and other characteristics that are required to perform the job at the desired level by considering the job as a whole. However, if they define the job content at the task level including information about tools and technology used and organizational and work context; they can easily translate them into the personnel characteristics required for the job.

The proposed model also uses fuzzy multi-criteria decision criteria decision making (FMCDM) methods such as Fuzzy Analytical Hierarchy Process (FAHP) , Fuzzy TOPSIS (FTOPSIS) and Fuzzy VIKOR (FVIKOR) under FQFD framework; and it allows multiple decision makers in the determination of personnel characteristics and final selection processes so that various people within the organization who are responsible for; or who are affected by the selection decision can be involved in both phases of the FQFD process. A high predictive power is the expected outcome of the model proposed in this study. However, since criterion-related validity, which involves demonstration of a correlation or other statistical relationship between the performance of the selected candidate(s) in the course of selection process and their future job performance, requires a longitudinal collection of actual job performance data of selected individuals, it is beyond the scope of this study.

The organization of the study is as follows. In Chapter 2, an overview of personnel selection problem will be given, and performance measures related to the personnel selection practices will be introduced. In Chapter 3, concepts about job performance, its dimensions and variables associated with predicting the different facets of job performance will be given. In Chapter 4, basics of fuzzy logic, fuzzy sets and fuzzy numbers will be given. Also, FQFD, and FMCDM methods used in this study, namely, FAHP, FTOPSIS and FVIKOR, will be introduced. Also, previous research about fuzzy personnel selection models will be summarized. In Chapter 5, the proposed personnel selection model will be explained in detail and its application for two real-life problem will be presented. In Chapter 6, the study will be summarized and conclusions will be depicted. The overall contribution of the study will be discussed and recommendations for future research will be made.

## 2. PERSONNEL SELECTION PROBLEM

Building a high performance workforce certainly starts with hiring new personnel. Two main hiring phases can be distinguished (See Figure 2.1): the attraction phase and the selection phase (Schneider, 1995). Both consist of a planning and an execution part. The planning part determines the overall strategy and concrete measures to attract qualified employees as well as the specific selection methods. The execution part consists of two main groups of activities. Employer branding comprises all long-term marketing measures intended for establishing an attractive employer image and, thus, indirectly attracting qualified candidates. Personnel attraction aims at generating applications for open job positions.

| | Attraction phase | Selection phase |
|---|---|---|
| Planning Activities | • Determination of target groups<br>• Design of measures to attract or directly approach candidates from target group | • Defining the requirements<br>• Determination of appropriate selection methods |
| Execution Activities | • Employer branding<br>• Attraction of direct applications | • Pre-screening<br>• Final selection |
| | Applicant management | |

**Figure 2.1 :** Phases of new personnel hiring process (Schneider, 1995).

The execution part of selection phase typically starts with the screening of resumes and other submitted application documents (e.g., references, certificates). This step is called pre-screening or pre-selection. Candidate pre-screening refers to the initial evaluation of candidate qualifications. The purpose is to reduce a potentially large candidate pool to a more manageable number that can be progressed to more rigorous assessment phases. In today's job market with jobs relatively scarce and large numbers of available candidates, it is highly likely that efficient pre-screening becomes more critical.

Pre-screening of the candidates is based on the identification of the minimum qualifications required to perform the job. Minimum qualifications (MQs) are among the most common selection procedures used in both the private and public sectors (Ash, Johnson, Levine, and McDaniel, 1989; Gatewood and Feild, 2001; Levine, Maye, Ulm, and Gordon, 1997; Summerlin and Prien, 1999). Organizations may choose varying forms or types of MQs, such as task-based systems or education and experience statements in order to initially screen applicants before they progress further into selection systems that may include tests or interviews. MQs are typically characterized by a focus on a lower threshold of some attribute (e.g., education or experience) needed to succeed on a given job. Although there may be differences in the definition and operationalization of MQs, they often serve as a device to realistically limit the number of candidates remaining in the selection process (Gibson and Prien, 1977; Johnson, 2001; Levine et al., 1997). The final selection of candidates is then conducted with the set of candidates that has not been filtered out during pre-screening. Finally, applicant management serves as a supporting function. It includes the communication with applicants, the administration of applicant data and internal processes such as forwarding applications to the members of the organization involved in the selection decision.

Although both are closely interrelated parts of a multistage decision process, recruiting activities generate applicants for jobs, and selection decisions must then be made to choose the subset of applicants, or the applicant, most likely to succeed. The process of personnel selection involves collecting information about individuals for the purpose of determining suitability for employment in a particular job. This information is collected using one or more assessment tools or tests which will be discussed further in detail in the following sections. There will be cases in which a test score or procedure will predict someone to be a good worker, who, in fact, is not. There will also be cases in which an individual receiving a low score will be rejected, when he or she would actually be a capable and good worker. Such errors in the assessment context are called selection errors. Selection errors cannot be completely avoided in any assessment program. An employment test is considered to be successful if the following can be said about it:

1. The test measures what it claims to measure consistently or reliably. This means that if a person were to take the test again, the person would get a *similar* test score.

2. The test measures what it claims to measure and; what it measures is job-relevant so that future job performance of the candidates can be predicted based on their test performance.

The degree to which a test has these qualities is indicated by two technical properties: reliability and validity.

## 2.1. Test Reliability

Reliability refers to how dependably or consistently a test measures a characteristic. A test that yields similar scores for a person who repeats the test is said to measure a characteristic reliably. Reliable assessment tools produce dependable, repeatable, and consistent information about people. In order to meaningfully interpret test scores and make useful employment or career-related decisions, we need reliable tools. To evaluate a test's reliability, we should consider the type of test, the type of reliability estimate reported, and the context in which the test will be used.

Test-retest reliability indicates the repeatability of test scores with the passage of time. This estimate also reflects the stability of the characteristic or constructs being measured by the test. However, some constructs are more stable than others. For example, an individual's reading ability is more stable over a particular period of time than that individual's anxiety level. Therefore, we would expect a higher test-retest reliability coefficient on a reading test than we would on a test that measures anxiety. For constructs that are expected to vary over time, an acceptable test-retest reliability coefficient may be lower.

Alternate or parallel form reliability indicates how consistent test scores are likely to be if a person takes two or more forms of a test. A high parallel form reliability coefficient indicates that the different forms of the test are very similar which means that it makes virtually no difference which version of the test a person takes. On the other hand, a low parallel form reliability coefficient suggests that the different forms are probably not comparable; they may be measuring different things and therefore cannot be used interchangeably.

Inter-rater reliability indicates how consistent test scores are likely to be if the test is scored by two or more raters. On some tests, raters evaluate responses to questions and determine the score. Differences in judgments among raters are likely to produce variations in test scores. A high inter-rater reliability coefficient indicates that the judgment process is stable and the resulting scores are reliable. Inter-rater reliability coefficients are typically lower than other types of reliability estimates. However, it is possible to obtain higher levels of inter-rater reliabilities if raters are appropriately trained.

Internal consistency reliability indicates the extent to which items on a test measure the same thing. A high internal consistency reliability coefficient for a test indicates that the items on the test are very similar to each other in content (homogeneous). It is important to note that the length of a test can affect internal consistency reliability. For example, a very lengthy test can seemingly inflate the reliability coefficient.

Test reliability is important for selecting the most appropriate test for personnel selection. However, reliability is not the only quality indicator for a personnel selection procedure. Sound recruitment practices require a tangible link between the method of assessment used in the recruitment process, and its ability to predict future job performance. That is, the assessment methods on which the selection decisions are based need to have strong predictive validity. The ability to predict future job performance is demonstrated by the correlation between scores on the assessment instrument and some measure(s) of job performance, and is termed the validity coefficient. The greater predictive validity an assessment method has, the greater its ability to determine how well the candidate is likely to perform on the job. In the following section validity issue will be explained in more detail.

### 2.2. Test Validity

Validity is the most important consideration in developing and evaluating selection procedures. Validity evidence indicates that there is linkage between test performance and job performance. It can tell what may be concluded or predict about someone from his or her score on the test. If a test has been demonstrated to be a valid predictor of performance on a specific job, we can conclude that persons scoring high on the test are more likely to perform well on the job than persons who score low on the test, all else being equal. Validity also describes the *degree* to which we can make specific conclusions or predictions about people based on their test scores. In other words, it indicates the usefulness of the test. In addition, a test’s validity is established in reference to a specific purpose; the test may not be valid for different purposes. For example, the test which is used to make valid predictions about someone’s technical proficiency on the job may not be valid for predicting his or her leadership skills or absenteeism rate.

It is important to understand the differences between *reliability* and *validity*. Validity will show how good a test is for a particular situation; reliability will reveal how trustworthy a score on that test will be. We cannot draw valid conclusions from a test score unless we are sure that the test is reliable. Even when a test is reliable, it may not be valid.

There are three methods for conducting validation studies. These are criterion-related validation, content-related validation and construct-related validation. These three methods of validation should be used to provide validation support depending on the situation. These three general methods often overlap, and, depending on the situation, one or more may be appropriate.

### 2.2.1. Criterion-related validity and criterion development

Criterion-related validation requires demonstration of a correlation or other statistical relationship between test performance and job performance. In other words, individuals who score high on the test tend to perform better on the job than those who score low on the test. If the correlation is high, it can be said that the test has a high degree of validation support, and its use as a selection tool would be appropriate. The criterion-related validity of a test is measured by the validity coefficient. It is reported as a number between 0 and 1.00 that indicates the magnitude of the relationship between the test and a measure of job performance (criterion). The larger the validity coefficient, the more confidence we can have in predictions made from the test scores.

Personnel selection procedures are used to predict future performance or other work behavior. Evidence for criterion-related validity typically consists of a demonstration of a relationship between the results of a selection procedure (predictor) and one or more measures of work-relevant behavior or work outcomes (criteria). The choice of predictors and criteria should be based on an understanding of the objectives for test use, job information, and existing knowledge regarding test validity.

Criteria should be chosen on the basis of work relevance, freedom from contamination, and reliability rather than availability. This implies that the purposes of the validation study are (a) clearly stated, (b) supportive of the organization's needs and purposes, and (c) acceptable in the social and legal context of the organization. The researcher should not use criterion measures that are unrelated to the purposes of the study to achieve the appearance of broad coverage.

Criteria should represent important organizational, team, and individual outcomes such as work-related behaviors, outputs, attitudes, or performance in training, as indicated by a review of information about the work. Criteria need not be all-inclusive, but there should be clear rationale linking the criteria to the proposed uses of the selection procedure.

Criteria can be measures of overall or task-specific work performance, work behaviors, or work outcomes. Depending upon the work being studied and the purposes of the validation study, various criteria such as a standard work sample, behavioral and performance ratings, success in work-relevant training, turnover or rate of advancement may be appropriate. Regardless of the measure used as a criterion, it is necessary to ensure its relevance to work.

Criteria should be free from contamination. A criterion measure is contaminated to the extent that it includes extraneous, systematic variance. Examples of possible contaminating factors include differences in the quality of machinery, unequal sales territories, raters' knowledge of predictor scores, job tenure, shift, location of the job, and attitudes of raters. While avoiding completely (or even knowing) all sources of contamination is impossible, efforts should be made to minimize their effects. For instance, standardizing the administration of the criterion measure minimizes one source of possible contamination. Measurement of some contaminating variables might enable the researcher to control statistically for them; in other cases, special diligence in the construction of the measurement procedure and in its use may be all that can be done.

Criteria should also be free from deficiency. A criterion measure is deficient to the extent that it excludes relevant, systematic variance. For example, a criterion measure intended as a measure of overall work performance would be deficient if it did not include work behaviors or outcomes critical to job performance.

Criteria should also be unbiased. Criterion bias is systematic error resulting from criterion contamination or deficiency that differentially affects the criterion performance of different subgroups. The presence or absence of criterion bias cannot be detected from knowledge of criterion scores alone. A difference in criterion scores of older and younger employees or day and night shift workers could reflect bias in raters or differences in equipment or conditions, or the difference might reflect genuine differences in performance. The possibility of criterion bias must be anticipated. The researcher should protect against bias in so far as is feasible and use professional judgment when evaluating the data.

### 2.2.2. Content-related validity and design of content-based strategies

Evidence for content-related validity typically consists of a demonstration of a strong linkage between the content of the selection procedure and important work behaviors, activities or outcomes on the job. This linkage also supports construct interpretation. When the selection procedure is designed explicitly as a sample of important elements in the work domain, the validation study should provide evidence that the selection procedure samples the important work behaviors, activities, and/or employee's characteristics expressed in terms of knowledge, skills, abilities and others (KSAOs) necessary for performance on the job, in job training, or on specified aspects of either.

The characterization of the work domain should be based on accurate and thorough information about the work including analysis of work behaviors and activities, responsibilities of the job incumbents (job holders), and/or the KSAOs prerequisite to effective performance on the job. In addition, definition of the content to be included in the domain is based on an understanding of the work, and may consider organizational needs, labor markets, and other factors that are relevant to personnel specifications and relevant to the organization's purposes. The domain need not include everything that is done on the job. The researcher should indicate what important work behaviors, activities, and worker KSAOs are included in the domain, describe how the content of the work domain is linked to the selection procedure, and explain why certain parts of the domain were or were not included in the selection procedure.

The process of constructing or choosing the selection procedure requires sampling the work content domain. Not every element of the work domain needs to be assessed. Rather, a sample of the work behaviors, activities, and worker KSAOs can provide a good estimate of the predicted work performance. Sampling should have a rationale based on the professional judgment of the researcher and a job analysis that details important work behaviors and activities, important components of the work context, and KSAOs needed to perform the work. Random sampling of the content of the work domain is usually not feasible or appropriate.

### 2.2.3. Construct-related validity

People differ on many psychological and physical characteristics. In testing, these characteristics are called constructs. For example, people skillful in verbal and mathematical reasoning are considered high on the construct mental ability. Those who have little physical stamina and strength are labeled low on the constructs endurance and physical strength. Constructs can be used to identify personal characteristics and to sort people in terms of these characteristics. Constructs cannot be seen or heard, but we can observe their effects on other variables. For example, we do not observe physical strength but we can observe people with great strength lifting heavy objects and people with limited strength attempting, but failing, to lift these objects. Such differences in characteristics among people have important implications in the employment context. Construct-related validation requires a demonstration that the test measures the construct or characteristic it claims to measure, and that this characteristic is important to successful performance on the job. This method often pertains to tests that may measure abstract traits of an applicant.

## 2.3. Generalizing Validity Evidence

Sometimes, sufficient accumulated validity evidence may be available for a selection procedure to justify its use in a new situation without conducting a local validation research study. In these instances, use of the selection procedure may be based on demonstration of the generalized validity inferences from that selection procedure, coupled with a compelling argument for its applicability to the current situation. Although neither mutually exclusive nor exhaustive, several strategies for generalizing validity evidence have been delineated: (a) transportability, (b) synthetic validity/job component validity, and (c) meta-analytic validity generalization.

### 2.3.1. Transportability

One approach to generalizing the validity of inferences from scores on a selection procedure involves the use of a specific selection procedure in a new situation based on results of a validation research study conducted elsewhere. This is referred to as demonstrating the "transportability" of validity evidence for the selection procedure. When proposing to "transport" use of a procedure, a careful review of the original validation study is warranted to ensure acceptability of the technical soundness of that study and to determine its relevance to the new situation. Key points for consideration when establishing the appropriateness of transportability is, most prominently, job comparability in terms of content or requirements, as well as, possibly, similarity of job context and candidate group.

### 2.3.2. Synthetic validity/job component validity

A second approach to generalizing the validity of inferences based on scores from a selection procedure is referred to as synthetic validity or job component validity. A defining feature of synthetic validity/job component validity is the justification of the use of a selection procedure based upon the demonstrated validity of inferences from scores on the selection procedure with respect to one or more domains of work (job components). Thus, establishing synthetic validity/job component validity requires documentation of the relationship between the selection procedure and one or more specific domains of work (job components) within a single job or across different jobs. If the relationship between the selection procedure and the job component(s) is established, then the validity of the selection procedure for that job component may be generalizable to other situations in which the job components are comparable.

### 2.3.3. Meta-analysis

Meta-analysis is a third procedure and strategy that can be used to determine the degree to which predictor-criterion relationships are specific to the situations in which the validity data have been gathered or are generalizable to other situations, as well as to determine the sources of cross-situation variability (Aguinis and Pierce, 1998). Meta-analysis requires the accumulation of findings from a number of validity studies to determine the best estimates of the predictor-criterion relationship for the kinds of work domains and settings included in the studies.

While transportability and synthetic validity/job component validity efforts may be based on an original study or studies that establish the validity of inferences based on scores from the selection procedure through a content-based and/or a criterion-related strateg***y,*** meta-analysis is a strategy that only can be applied in cases in which the original studies relied upon criterion-related evidence of validity. The question to be answered using a meta-analytic strategy is whether the valid inferences about work behavior or job performance can be drawn from predictor scores across given jobs or job families in different settings.

Professional judgment in interpreting and applying the results of meta-analytic research is important. Researchers should consider the meta-analytic methods used and their underlying assumptions, the tenability of the assumptions, and artifacts that may influence the results (Bobko and Stone-Romero, 1998; Raju, Anselmi, Goodman, and Thomas, 1998; Raju et al., 1991; Raju, Pappas, and Williams, 1989). In evaluating meta-analytic evidence, the researcher should be concerned with potential moderators to the extent that such moderators would affect conclusions about the presence and generalizability of validity. In such cases, researchers should consider both statistical power to detect such moderators and/or the precision of estimation with respect to such moderators. In addition, the researcher should consider the probabilities of both Type I and Type II decision errors (Oswald and Johnson, 1998; Sackett, Harris, and Orr, 1986). Reports that contribute to the meta-analytic research results should be clearly identified and available. Researchers should consult the relevant literature to ensure that the meta-analytic strategies used are sound and have been properly applied, that the appropriate procedures for estimating predictor-criterion relationships on the basis of cumulative evidence have been followed, that the conditions for the application of meta-analytic results have been met, and that the application of meta-analytic conclusions is appropriate for the work and settings studied. The rules by which the researchers categorized the work and jobs studied, the selection procedures used, the definitions of what the selection procedure is measuring, the job performance criteria used, and other study characteristics that were hypothesized to impact the study results should be fully reported.

The quality of the individual research studies and their impact, if any, on the meta-analytic conclusions and their use also should be informed by good professional judgment (Guion, 1998; Law, Schmidt, and Hunter, 1994a, 1994b). Note that sole reliance upon available cumulative evidence may not be sufficient to meet specific employer operational needs such as for the placement of employees or for the optimal combination of procedures. Consequently, additional studies and data may be required to meet these specific needs. If such studies are not feasible in an organization, researchers and employers may engage in cooperative studies.

### 2.4. Other Quality Determinants in Personnel Recruitment and Selection

Several psychologists, notably Taylor and Russell (1939), Brogden (1946) and Cronbach (1960) have shown that assessing the value of a selection device only by means of the correlation between the test and the criterion does not always lead to the best judgment of the usefulness of the test. Taylor and Russell pointed out the importance of the "selection ratio" or the relative number of individuals to be hired.

The selection ratio is expressed as a number from 0.0 to 1.0 and represents the ratio of the number of individuals to be hired to the number of applicants. For example, if 25 individuals are needed to fill positions and 150 individuals apply for those positions, then the selection ratio is 25 ÷ 150 = .167 – a fairly favorable selection ratio (from the employer’s point of view). The higher the selection ratio (closer to 1.0) the less selective one can be in the hiring process; and the lower the selection ratio the greater the gain in the utility (i.e., translation of validity into dollar value terms) of the selection system (Gatewood and Feild, 2001).

In addition to considerations regarding test validity and selection ratio, tests are most useful when they allow for selection decisions that minimize selection errors and avoid adverse impact. Selection errors occur when people who are hired do not meet performance standards (i.e., false positives) or when people are not hired but could have met performance expectations (i.e., false negatives) (Cascio and Aguinis, 2005). Adverse impact is usually operationalized as a ratio of two selection ratios (SRs)

(Biddle, 2005; Bobko and Roth, 2004). Thus adverse impact is $SR_1/SR_2$, where $SR_1$ and $SR_2$ are the number of applicants selected divided by the total number of applicants for the minority and majority groups of applicants, respectively. It is desirable that adverse impact be as close to 1.0 as possible (e.g., for sex, similar selection ratios for men and women).

### 2.5. Costs of Recruitment and Selection

Presumably, also, it is always desirable to perform selection process with minimum cost. Some assessment and selection methods involve much higher costs to develop and administer than others. The cost of recruiting depends on a number of variables, the most obvious two being the availability of individuals having the minimum qualifications required for the job and the number of individuals needed for that job. Although it is desirable to test many more individuals than there are positions to be filled, this advantage can be offset by the increased cost of testing. Depending upon the cost of testing and the savings to be realized by hiring more productive people, this factor can sometimes be of considerable importance.

Another cost factor that human resources (HR) professionals need to consider is whether the organization desires to use a commercially available assessment or prefers to develop its own customized assessment. If HR professionals choose to use a commercially available assessment, they will need to enter into a licensing agreement with the test publisher, and the organization will be charged either for each use of the test or for the duration of time the test is used. The advantages of a commercially available assessment are that it can usually be implemented quickly, it is typically maintained and updated by the publisher over time, and the data usually continue to be amassed across the different organizations using the assessment. The most important disadvantage of commercially available assessments is that licensing agreements can be expensive. If an organization wishes to use a commercially available assessment, it is important to identify and use a reputable test publisher.

In addition to the costs mentioned above, there are enormous costs to an organization of consistently hiring employees who do not perform effectively or who leave the organization after investments have been made in training them. Even the highest development and administration costs generally remain insignificant in comparison to the costs associated with unproductive or unsuccessful employees. Furthermore, implementation of effective assessment procedures has been shown to result in very substantial productivity and revenue increases as well as cost savings for organizations. Therefore, it is important not only to consider the costs associated with developing and administering effective assessments, but also to see these investments in light of the financial and other benefits that will be gained.

### 2.6. Assessment Tools and Methods

Employees and applicants vary widely in their knowledge, skills, abilities, interests, work styles, and other characteristics. These differences systematically affect the way people perform or behave on the job but they are not necessarily apparent by simply observing the employee or job applicant. Professionally developed employment tests and procedures that are used as part of a planned assessment program may help selecting and hiring more qualified and productive employees especially when they are used in combination. This approach will help reduce the number of selection errors and boost the effectiveness of decision making. The candidate information can be collected using one or more assessment tools or methods, which are categorized below.

#### 2.6.1. Mental and physical ability tests

When properly applied, ability tests are among the most useful and valid tools available for predicting success in jobs and training across a wide variety of occupations. Ability tests are most commonly used for entry-level jobs, and for applicants without professional training or advanced degrees. Mental ability tests are generally used to measure the ability to learn and perform particular job responsibilities. General ability tests typically measure one or more broad mental abilities, such as verbal, mathematical, and reasoning skills. These skills are fundamental to success in many different kinds of jobs, especially where cognitive activities such as reading, computing, analyzing, or communicating are involved. *Specific ability tests* include measures of distinct physical and mental abilities, such as reaction time, written comprehension, mathematical reasoning, and mechanical ability, which are important for many jobs and occupations. For example, good mechanical ability may be important for success in auto mechanic and engineering jobs; physical endurance may be critical for fire fighting jobs.

### 2.6.2. Achievement tests

Achievement tests, also known as proficiency tests, are frequently used to measure an individual's current knowledge or skills that are important to a particular job. These tests generally fall into two formats: knowledge tests and work-sample or performance tests. Knowledge tests typically involve specific questions to determine how much the individual knows about particular job tasks and responsibilities. Traditionally they have been administered in a paper-and-pencil format, but computer administration is becoming more common. Knowledge tests tend to have relatively high validity. Work-sample or performance tests require the individual to actually demonstrate or perform one or more job tasks. These tests generally show a high degree of job-relatedness. For example, an applicant for machine repairman position may be asked to diagnose the problem with a malfunctioning machine. Test takers generally view these tests as fairer than other types of tests. However, they can be expensive to develop and administer.

### 2.6.3. Biodata inventories

Biodata inventories are standardized questionnaires that gather job-relevant biographical information, such as amount and type of schooling, job experiences, and hobbies. They are generally used to predict job and training performance, tenure, and turnover. They capitalize on the well-proven notion that past behavior is a good predictor of future behavior. Some individuals might provide inaccurate information on biodata inventories to portray themselves as being more qualified or experienced than they really are. Internal consistency checks (checking for consistent responses to items of similar content) can be used to detect whether there are discrepancies in the information reported. In addition, reference checks and resumes can be used to verify information.

### 2.6.4. Employment interviews

The employment interview is probably the most commonly used assessment tool. The interview can range from being totally unplanned, that is, unstructured, to carefully designed beforehand, that is, completely structured. The most structured interviews have characteristics such as standardized questions, trained interviewers, specific question order, controlled length of time, and a standardized response evaluation format. At the other end of the spectrum, a completely unstructured interview would probably be done with untrained interviewers, random questions, and with no consideration of time. A structured interview that is based on an analysis of the job in question is generally a more valid predictor of job performance than an unstructured interview.

### 2.6.5. Personality inventories

In addition to abilities, knowledge, and skills, job success also depends on an individual's personal characteristics. Personality inventories designed for use in employment contexts are used to evaluate such characteristics as motivation, conscientiousness, self-confidence, or how well an employee might get along with fellow workers. Research has shown that, in certain situations, use of personality tests with other assessment instruments can yield helpful predictions.

### 2.6.6. Honesty and integrity measures

Honesty tests are a specific type of personality test. There has been an increase in the popularity of honesty and integrity. Honesty and integrity measures may be broadly categorized into two types. Overt integrity tests gauge involvement in and attitudes toward theft and employee delinquency. Test items typically ask for opinions about frequency and extent of employee theft, leniency or severity of attitudes toward theft, and rationalizations of theft. They also include direct questions about admissions of, or dismissal for, theft or other unlawful activities. Personality-based measures typically contain disguised-purpose questions to gauge a number of personality traits. These traits are usually associated with a broad range of counterproductive employee behaviors, such as insubordination, excessive absenteeism, disciplinary problems, and substance abuse.

All honesty and integrity measures have appreciable prediction errors. To minimize prediction errors, thoroughly follow up on poor-scoring individuals with retesting, interviews, or reference checks. In general, integrity measures should not be used as the sole source of information for making employment decisions about individuals.

### 2.6.7. Education and experience requirements

Most jobs have some kind of education and experience requirements. For example, they may specify that only applicants with high school degrees or equivalent training or experience will be considered. Such requirements are more common in technical, professional, and higher-level jobs. Certain licensing, certification, and education requirements are mandated by law. This is done to verify minimum competence and to protect public safety.

### 2.6.8. Recommendations and reference checks

Recommendations and reference checks are often used to verify education, employment, and achievement records already provided by the applicant in some other form, such as during an interview or on a resume or application form. This is primarily done for professional and high-level jobs. These verification procedures generally do not help separate potentially good workers from poor workers. This is because they almost always result in positive reports. However, use of these measures may provide an incentive to applicants to be more honest with the information they provide.

### 2.6.9. Assessment centers

In the assessment center approach, candidates are generally assessed with a wide variety of instruments and procedures. These could include interviews, ability and personality measures, and a range of standardized management activities and problem-solving exercises. Typical of these activities and exercises are in-basket tests, leaderless group discussions, and role-play exercises. Assessment centers are most widely used for managerial and high level positions to assess managerial potential, promotability, problem-solving skills, and decision-making skills.

### 2.6.10. Medical examinations

Medical examinations are used to determine if a person can safely and adequately perform a specific job. Medical exams may also be part of a procedure for maintaining comprehensive employee health and safety plans. In some limited circumstances, medical exams may be used for evaluating employee requests for reasonable accommodation for disabilities.

## 2.7. Chapter Summary

This chapter introduces the phases of the personnel selection problem and the various criteria for performing a successful personnel recruitment and selection process. A personnel selection process is said to be successful if the reliability and validity of the selection process is high; and overall cost of selection for the organization is low. Various types of reliability and validity have been explained throughout this chapter. Reliability is about the consistency of the selection procedure in terms of its outcomes. More specifically, reliability is the probability to get the same outcome, i.e. selecting the same candidate(s), when the same selection procedure is repeated with the same candidate. Criterion-related validation requires demonstration of a correlation or other statistical relationship between test performance and job performance. In other words, individuals who score high on the test tend to perform better on the job than those who score low on the test. Evidence for content-related validity typically consists of a demonstration of a strong linkage between the content of the selection procedure and important work behaviors, activities or outcomes on the job. Construct-related validation requires a demonstration that the test measures the construct or characteristic it claims to measure, and that this characteristic is important to successful performance on the job.

Selection ratio is also an important factor in personnel selection processes. It is the ratio of the number of individuals to be hired to the number of applicants. The higher the selection ratio the less selective a decision maker can be in the hiring process, and inversely, the lower the selection ratio, the more benefit or utility we get from a personnel selection system.

The benefit provided by a personnel selection system should not be measured only by its predictive power. Some assessment methods involve much higher costs to develop and administer than others. In-house development of a selection system typically requires involving job experts working in collaboration with test development experts to design the exercises and scoring protocols. The other option is to use commercially available selection tools which require a licensing agreements with the test publishers and the organization will be charged either for each use of the test or for the duration of time the test is used. Administration of a selection test is also a cost factor in the personnel selection process. Although it is desirable to test many more individuals than there are positions to be filled, this advantage can be offset by the increased cost of testing due to the facilities, tools and materials used and cost of evaluation and scoring of the candidates.

If the decision-maker can select the best candidate without applying a particular selection procedure, then that selection procedure can be avoided due to costs associated with that procedure. This may be due to the high selection ratio in personnel selection process in which case a sophisticated selection system will provide no utility. Also, it may be due to a case where one of the candidates dominates the others with respect to selection criteria. However, this occurs with less probability compared to the former case since a pre-screening process eliminates the candidates who have little chance to be a winner.

Based upon these discussions, this study proposes an improved personnel selection model which, in the first place, aims increasing the content-related and criterion-related validities by integrating job analysis process with the personnel selection process under FQFD framework. Thus, identification of KSAOs required for the job and their importance weights are obtained such that they meet all performance requirements of the job in question. The proposed method also provides an increase in test reliability since it provides a systematic approach to the design and administration of the selection procedure. However, without understanding the multidimensional nature of individual performance, the decision makers may not be able to develop personnel selection hypotheses which include performance-predictor relationships. Thus, the following chapter reveals the definition of individual performance, its components and accepted predictors of these components in the personnel selection and individual performance literature.

# 3. JOB PERFORMANCE AND PERSONNEL SELECTION

Personnel selection is the process of selecting from a pool of applicants those who are likely to perform better on the job compared to those not selected. In order to discriminate the applicants who are likely to perform better, the decision maker must be aware of generic and job-specific components of performance so that personnel selection hypotheses about performance-predictor relationship covering the entire job content can be developed. Thus, the definition and various dimensions of individual job performance and their predictors will be discussed in this chapter.

## 3.1. Definition and Taxonomies of Job Performance

Job performance is defined as the total expected value to the organization of the discrete behavioral episodes that an individual carries out over a standard period of time (Motowidlo, Borman, and Schmit, 1997). Authors agree that when conceptualizing performance one has to differentiate between an action (i.e., behavioral) aspect and an outcome aspect of performance (Campbell, 1990; Campbell, McCloy, Oppler and Sager, 1993; Kanfer, 1990; Roe, 1999). The behavioral aspect refers to what an individual does in the work situation. Not every behavior is subsumed under the performance concept, but only behavior which is relevant for the organizational goals: "Performance is what the organization hires one to do, and do well" (Campbell et al., 1993). Moreover, only actions which can be scaled, i.e., measured, are considered to constitute performance (Campbell et al., 1993). The outcome aspect refers to the consequence or result of the individual's behavior. Results such as numbers of engines assembled, sales figures or number of customers served may be the examples of outcomes aspect of performance.

Campbell, McHenry, and Wise (1990) modeled job performance in a set of 19 entry-level Army jobs and found support for five performance factors. These factors include actions and behaviors that relate to completing tasks, working with others, and maintaining personal discipline. Together, these factors represent a broad range of behaviors that contribute to the goals of the military. Although these components were derived from entry-level Army jobs, they are likely to generalize to jobs in other fields as well.

Unlike the model proposed by Campbell, McHenry, and Wise (1990), which was intended to model the performance of entry-level Army jobs, this model is intended to be more comprehensive and inclusive of all jobs. Murphy (1989) proposed a four-category scheme to model a large group of jobs in the Navy (See Table 3.1). These categories were derived from a set of organizational goals in the Navy. Rotundo (2000) explains that task performance as defined by Murphy is similar to Campbell's core technical proficiency and Job-specific task proficiency in that all three incorporate task behaviors. Similarly, destructive/hazardous behaviors and down-time behaviors reflect the negative pole of Campbell's Personal discipline. These two components of Murphy represent behaviors that prevent the individual from accomplishing tasks or prevent the organization from achieving its goals.

The previous discussion focused on jobs in general or jobs in the Army or Navy. Borman and Brush (1993) modeled the job performance of managers. More specifically, they proposed taxonomy of 18 managerial performance requirements, which they further grouped into four categories. These four categories also represent task, interpersonal, and deviant behaviors. Hunt (1996) analyzed supervisory ratings of non-task elements in a variety of hourly, entry-level jobs. He chose to focus on non-task elements because of the perception that hourly, entry-level jobs require a low level of job-specific knowledge, skills, and abilities. Hunt (1996) defines generic work behaviors as "behaviors that influence the performance of virtually any job". Exploratory and confirmatory factor analyses of supervisory ratings revealed nine categories. Although these dimensions do not include task behaviors, they do represent the interpersonal and deviant behaviors, which are consistent with the other models of job performance.

**Table 3.1:** A summary of efforts to describe the domain of job performance (Rotundo and Sackett, 2002).

| Author | Components | Description |
|---|---|---|
| Murphy (1989) | Task performance. | Accomplishment of duties and responsibilities. |
| | Interpersonal relations. | Cooperating; communicating; exchanging job-related information. |
| | Destructive or hazardous behaviors. | Violating security and safety; destroying equipment, accidents. |
| | Down-time behaviors. | Substance abuse; illegal activities. |
| Campbell (1990) | Job-specific task proficiency. | Core technical tasks. |
| | Non-job-specific task proficiency. | Tasks not specific to a given job. |
| | Written and oral communication proficiency. | Preparing written materials or giving oral presentations. |
| | Demonstrating effort. | Exerting extra effort; willing to work under adverse conditions. |
| | Maintaining personal discipline. | Avoid negative or adverse behaviors (e.g., substance abuse). |
| | Facilitating peer and team performance. | Support and assist peers; reinforce participation. |
| | Supervision and leadership. | Influence; setting goals; rewarding and punishing. |
| | Management and administration. | Organize people and resources; monitor progress; problem-solve. |
| Borman and Brush (1993) | Technical activities. | Planning; demonstrating technical proficiency; administration. |
| | Leadership and supervision. | Guiding; directing; motivating; coordinating. |
| | Interpersonal dealings. | Communicating; maintaining a good organizational image and working relationships. |
| | Useful personal behavior. | Working within the guidelines and boundaries of the organization. |
| Hunt (1996) | Generic Work Behaviors | Adherence to confrontational rules |
| | | Industriousness |
| | | Thoroughness |
| | | Schedule flexibility |
| | | Attendance |
| | | Off-task behavior |
| | | Unruliness |
| | | Theft |
| | | Drug misuse |

As a result of these discussions, job performance can be described by three broad categories of behaviors, which are subsequently labeled task, organizational citizenship, and counterproductive performance. The first category reflects behaviors that are consistent with performing duties and responsibilities. The second domain, organizational citizenship, includes behaviors that are clearly related to organizational goals in a positive way but do not necessarily contribute to the core functioning of the organization (e.g., exerting effort, maintaining professional relationships, and supporting and helping others). The third category or domain is counterproductive behavior. It represents negative behaviors that can harm the well-being of the organization or coworkers (e.g., substance abuse, absenteeism, tardiness, theft). The following sections review research about these components in an attempt to provide a more refined definition of each component and to devise a list of behaviors that comprise each performance component.

### 3.2. Task Performance

According to Borman and Motowidlo (1993) task performance is the proficiency with which job incumbents perform activities that are formally recognized as part of their jobs; activities that contribute to the organization's technical core either directly by implementing a part of its technological process, or indirectly by replenishing raw materials, distributing finished products, or providing support services (e.g., managers, accountants). These researchers define technical core as the set of activities and processes that are used to convert raw materials (e.g., manufacturing) into products the organization produces (See Table 3.2).

Similarly, Murphy (1989) defines task performance as the accomplishment of tasks within an incumbent's job description. Campbell et al. (1993) and Campbell (1990) also include elements related to task performance in their taxonomies of job performance (e.g., core technical proficiency, general soldiering proficiency, job-specific task proficiency, and non-job-specific task proficiency).

Researchers conceptualize task performance as behaviors that contribute directly or indirectly to the technical core and behaviors that are recognized as part of the job or job description. However, Rotundo (2000) notes that restricting a definition of task performance (or any aspect of job performance) to include only those behaviors listed in a job description is problematic because job descriptions for the same job may differ from one organization to the next, which makes it difficult to compare performance across organizations. Furthermore, jobs are constantly changing without these changes being reflected in job descriptions (Rotundo, 2000). Therefore, measures of performance that depend on the content of a job description may not be accurate.

### 3.3. Organizational Citizenship Behavior

Traditionally, organizations and researchers focused on task performance. However, since the 1980's, researchers believe that there are additional activities that are relevant in other ways to the goals of the organization (Borman and Motowidlo, 1993; George and Brief, 1992; Organ, 1997). The term Organizational Citizenship Behavior (OCB) was first proposed by Smith et al., (1983) in an effort to introduce non-task behaviors. Organ (1988) formally defined OCB as "behaviors of a discretionary nature that are not part of employees' formal role requirements, but nevertheless promote the effective functioning of the organization". This conceptualization basically defines OCB as voluntary behavior that is not part of the job description. Organ (1988) identified five categories of OCBs (See Table 3.2). These five categories include behaviors that relate to helping coworkers, behaviors that contribute to the organizational environment, or behaviors that relate to being conscientious. Organ (1997) revised his original definition of OCB, as he noted problems with the term extra-role and acknowledged that some elements of OCB are appraised and likely to be rewarded. His revised definition includes discretionary behavior that contributes to organizational effectiveness.

Brief and Motowidlo (1986) introduced the concept of Prosocial Organizational Behavior (POB) in the late eighties in an attempt to evaluate the role of prosocial behaviors in organizations. They defined it as "behavior that is a) performed by a member of an organization, b) directed toward an individual, group, or organization with whom he or she interacts while carrying out his or her organizational role, and c) performed with the intention of promoting the welfare of the individual, group, or organization toward which it is directed". Brief and Motowidlo list 13 types of POBs. POBs include behaviors that are either functional or dysfunctional to the organization.

George and Brief (1992) introduced the term "Organizational Spontaneity" to define behavior that is extra-role, performed voluntarily, and contributes to organizational effectiveness. They describe five forms of Organizational Spontaneity. Organizational Spontaneity also has direct parallels to OCB and POB: helping coworkers and behaviors that bnefit the organizational environment (Rotundo, 2000).

**Table 3.2:** A Summary of efforts to conceptualize task, OCBs and counterproductive performance (Rotundo and Sackett, 2002).

| Author | Behavioral Component | Categories |
|---|---|---|
| Brief and Motowidlo (1986) | Prosocial Organizational Behavior | Assisting co-workers with job-related matters. |
| | | Showing leniency. |
| | | Providing services/products to consumers in organizationally consistent ways. |
| | | Providing services/products to consumers in organizationally inconsistent ways. |
| | | Helping consumers with personal matters unrelated to organizational services/products. |
| | | Complying with organizational values, policies, and regulations. |
| | | Suggesting procedural, administrative, or organizational improvements. |
| | | Objecting to improper directives, procedures, or policies. |
| | | Putting forth extra effort on the job. |
| | | Volunteering for additional assignments. |
| | | Staying with the organization despite temporary hardships. |
| | | Representing the organization favorably. |
| | | Assisting co-workers with personal matters. |
| Organ (1988) | Organizational Citizenship Behavior | Altruism |
| | | Conscientiousness |
| | | Sportsmanship |
| | | Courtesy |
| | | Civic Virtue |
| George and Brief (1992) | Organizational Spontaneity | Helping co-workers. |
| | | Protecting the organization. |
| | | Making constructive suggestions. |
| | | Developing oneself. |
| | | Spreading goodwill. |
| Borman and Motowidlo (1993) | Task Performance | Formally recognized as part of the job and contribute to the organization's technical core. |
| | Contextual Performance | Discretionary; not necessarily role prescribed; contribute to social/psychological environment. |
| Raelin (1994) | Professional / Deviant Adaptive | Work-scale (e.g., unethical practices, absenteeism, work-to-rule, bootlegging) |
| | | Self-scale (e.g., flaunting of external offers, rationalization, alienation, apathy) |
| | | Career-scale (e.g., premature external search, external performance emphasis) |
| Van Dyne, Cummings, and Parks (1995) | Extra-Role Behavior | Affiliative/Promotive (e.g., helping and cooperative behaviors) |
| | | Challenging/Promotive (e.g., constructive expression of challenge) |
| | | Challenging/Prohibitive (e.g., criticism of situation to stop inappropriate behavior) |
| | | Affiliative/Prohibitive (e.g., unequal power or authority) |
| Robinson and Bennett (1995) | Employee Deviance | Property deviance |
| | | Production deviance |
| | | Political deviance |
| | | Personal aggression |

Borman and Motowidlo (1993) describe Contextual Performance as discretionary behaviors that apply across all jobs; are not necessarily role prescribed; and that contribute to the social and psychological environment of the organization. Borman and Motowidlo identify five types of contextual behaviors. A review of this list reveals that they can be grouped into three categories: helping others, helping the organizational environment and its image, and exerting effort and are comparable to Organ's, Brief and Motowidlo's, George and Brief's, and Borman and Motowidlo's conceptualizations.

Van Dyne, et al. (1995) defines Extra-role behaviors as "behavior which benefits the organization and/or is intended to benefit the organization, which is discretionary and which goes beyond existing role expectations". This definition requires that the behavior be non role-prescribed and not formally rewarded.

### 3.4. Comparison of POB, OCB and Contextual Performance

Borman and Motowidlo (1993) state that prosocial organizational behavior includes several elements of contextual performance. However, they consider only functional behaviors as being part of contextual performance, in contrast to functional and dysfunctional behaviors, which are considered part of prosocial behaviors. McNeely and Meglino (1994) concluded that prosocial behavior items reveal three different patterns of behavior: role-prescribed behavior, extra-role behavior directed at the organization, and extra-role behavior directed at specific individuals. According to Katz's (1964) classification, prosocial organizational behaviors include both prescribed and extra-role behaviors. In other words, the second and third patterns of behavior suggested by Katz are included in the prosocial behaviors. However, an important difference between POB and contextual performance taxonomy is that prosocial behavior includes activities that promote organizational goals as well as activities that detract from organizational goals (McNeely and Meglino, 1994).

Although the terms "contextual performance" and "OCB" refer to many of the same types of behaviors, they also connote differences that are arguably important enough to justify preserving a distinction between them. The concept of OCB was originally conceived out of an interest in behavioral consequences of job satisfaction that were presumed to have important implications for organizational effectiveness and was originally defined as behaviors that managers wanted their subordinates to perform but could not require them to perform. Ideas about contextual performance have a very different origin. Borman and Motowidlo (1993) suggested that the part that tended to be most frequently recognized and targeted by selection research and practice was what they called ``task performance," which consisted of activities like those that usually appear on formal job descriptions. They also suggested that these activities are organizationally important because they ``contribute to the organization's technical core either directly by implementing a part of its technological process, or indirectly by providing it with needed materials or services" (Borman and Motowidlo, 1993). In contrast, the part of the performance domain that Borman and Motowidlo believed was often ignored in selection research and practice includes activities such as volunteering, persisting, helping, following rules, and endorsing organizational objectives. Organ (1997) has proposed that Borman and Motowidlo’s (1993) term, contextual performance, may be the best one for describing such activities. Borman, Hanson, and Hedge (1997) stated that variables involved in organizational citizenship behaviors represented subsets of contextual performance. The term contextual performance, therefore, will be used to describe such activities during the rest of this study.

### 3.5. Task Performance versus Contextual Performance

Contextual performance includes such activities as volunteering to carry out actions that are not formally part of the job; helping others; following organizational rules/procedures when personally inconvenient; endorsing and supporting organizational objectives; and persisting with extra effort to successfully complete one’s task activities. Contextual performance activities differ from task performance activities in at least four important ways (Borman and Motowidlo, 1993). First, task activities contribute either directly or indirectly to the technical core of the organization. Contextual activities, however, support the organizational, social, and psychological environment in which task performance occurs. Second, task activities vary between different jobs within the same organization. Contextual activities, however, are common to many (or all) jobs. Third, task activities are role-prescribed and are behaviors that employees perform in exchange for pay. Contextual behaviors, however, are less role-prescribed. The final distinction between task and contextual performance is supported by evidence that they are differentially predicted

(Motowidlo and Van Scotter, 1994). Task performance is best predicted by measures of ability, knowledge, skills and job experience, while contextual performance is predicted best by personality-related measures (Motowidlo and Van Scotter, 1994). However, experienced supervisors weight task and contextual performance equally when appraising performance (Borman, White, and Dorsey 1995; Motowidlo and Van Scotter, 1994).

### 3.6. Counterproductive Behavior

Researchers have also written about non-task behaviors that have negative consequences for organizations and employees (Crino, 1994; Hollinger and Clark, 1982; Murphy, 1993; Raelin, 1994). As with the literature on organizational citizenship performance, there are numerous terms, definitions, and taxonomies that have been used to describe this group of behaviors. Robinson and Bennett (1995) defined deviant behavior as "voluntary behavior that violates significant organizational norms and in so doing threatens the well-being of an organization, its members, or both". In their study, they classified deviant workplace behaviors into four categories: Property deviance, Production deviance, Political deviance, and Personal aggression. Property deviance, borrowed from Hollinger and Clark (1982), represents serious acts committed at the level of the organization. It is defined as "those instances where employees acquire or damage the tangible property or assets of the work organization without authorization" (Hollinger and Clark). Production deviance represents less serious acts committed at the level of the organization. It is defined as "behaviors that violate the formally proscribed norms delineating the minimal quality and quantity of work to be accomplished" (Hollinger and Clark, 1982). Political deviance, represents minor and interpersonal acts. Robinson and Bennett defined it as social interaction that puts other individuals at a personal or political disadvantage. The fourth category, Personal aggression, represents serious and interpersonal acts. They defined it as behavior that was aggressive or hostile towards other individuals (Hollinger and Clark, 1982).

Researchers' interest in counterproductive behavior has been partially motivated by the desire to understand the underlying causes of this type of behavior. Research has shown that the determinants of deviant behavior include individual, social and interpersonal, and organizational factors (Robinson and Greenberg, 1998).

Concerning individual factors, a popular belief is that some people are more predisposed than others to engage in deviant acts. Rotundo (2000) notes that research on integrity tests as measures of one facet of personality provide some insight into individual difference variables as determinants of deviant acts. A large-scale meta-analysis of integrity test validities by Ones, Viswesvaran, and Schmidt's (1993) is one of the most significant contributions in this regard. Integrity tests measure honesty and moral character. This research showed that integrity tests predict a variety of counterproductive behaviors, providing support for individual differences as determinants of counterproductive behavior.

### 3.7. Prediction of Job Performance

Empirical evidence suggests that different facets of performance have different predictors. Murphy and Shiarella (1997) emphasized the need for a multivariate framework in evaluating the validity of selection tests. Performance is multifaceted in nature rather than being a unitary phenomenon, and multiple predictors are relevant for predicting job performance. For example, Motowidlo and Van Scotter (1994) findings indicate that both task performance and contextual performance contribute independently to overall job performance and that personality variables are more likely to predict contextual performance than task performance while task performance is best predicted by measures of ability, knowledge, skills and job experience.

The relationship between personality and job performance has received considerable attention and debate throughout the 20$^{th}$ century. Research conducted up until to the mid-1980s concluded that personality and job performance had no meaningful relationship across situations. In an influential review of the literature, Guion and Gottier (1965) concluded that, there is no generalizable evidence that personality measures can be recommended as good or practical tools for employee selection. However, this conclusion was reached without a thorough understanding of the personality construct. There was no classification system that could reduce the numerous personality traits into a useful framework, and each personality scale on every inventory was treated as a separate construct.

A new phase of research beginning in the mid-1980s and growing in the early 1990s revealed optimistic results for the personality-job performance relationship. By the

1990s however, methodological innovations in meta-analysis and the emergence of a widely accepted taxonomy of personality characteristics, the “Five Factor Model” (FFM) (i.e., extraversion, agreeableness, emotional stability, conscientiousness, and openness to experience), spurred a series of meta-analytic studies that have provided a much more optimistic view of the ability of personality measures to predict job performance.

### 3.8. The Five Factor Model/The Big Five

Costa and McCrae (1992) developed the FFM as a result of a cluster analytic study of Cattell’s Sixteen Personality Factor which has been developed by Catell et al. (1970) and known as 16PF. Their five factors were: Neuroticism, Extroversion, Openness, Agreeableness, and Conscientiousness. These have become the most commonly used implementation of the Big Five. The five factors are presented in Table 3.3.

Since Costa and McCrae’s original proposal of the FFM, there has been a vast amount of research using these five global traits for the purpose of personnel selection, which includes a large body of meta-analytic studies that support the relationship between the Big Five and job performance criteria (Barrick and Mount, 1991; Salgado 1997; Tett, Jackson and Rothstein, 1991; Vincher, Schippmann, Switzer and Roth, 1998).

Barrick and Mount (1991) found that the estimated true correlation between FFM dimensions of personality and performance across both occupational groups and criterion types ranged from .04 for Openness to Experience to .22 for Conscientiousness. Although correlations in this range may seem relatively modest, nevertheless these results provided a more optimistic view of the potential of personality for predicting job performance and this study had an enormous impact on researchers and practitioners (Mount and Barrick, 1998; Murphy, 1997, 2000). Moreover, correlations of this magnitude can still provide considerable utility to personnel selection decisions (e.g., Cascio, 1991), particularly because the prediction of job performance afforded by personality appears to be incremental to that of other major selection methods (e.g., Goffin, Rothstein and Johnson, 1996; Schmidt and Hunter, 1998). Barrick, Mount, and Judge (2001) also summarize 15 meta-analytic studies and conclude that conscientiousness is a valid predictor across performance measures in all areas, and that emotional stability appeared to be a generalizable predictor when overall work performance was the criterion, but its relationship to specific work criteria and occupations was less consistent than conscientiousness.

**Table 3.3:** The Big Five Taxonomy of Personality (McCrae and Costa, 1989).

| Big Five Factor | Alternate Names | Sample Associated Trait Descriptions - Positive Pole | Sample Associated Trait Descriptions - Negative Pole |
|---|---|---|---|
| Extroversion | Surgency, Assertiveness | Sociable, Gregarious, Assertive, Talkative, Active, Ambitious, Expressive, Energetic, Enthusiastic, Outgoing | Quiet, reserved, Shy, Retiring, Taciturn, Inhibited |
| Conscientiousness | Conformity, Dependability | Careful, Thorough, Responsible, Planful, Persevering, Achievement Oriented, Efficient, Selfdisciplined, Diligent | Inconsistent, Impulsive, Undisciplined, Unreliable |
| Emotional Stability | Neuroticism | Calm, Relaxed, Self-Confident, Steady, Easy-going | Anxious, Depressed, Angry, Worried, Insecure, Tense, Vulnerable, Highstrung |
| Agreeableness | Likeability, Friendliness | Courteous, Flexible, Cooperative, Tolerant, Caring, Trusting, Supportive, Altruistic, Sympathetic, Kind, Modest | Spiteful, Self-Centred, Self- Aggrandizing, Hostile, Indifferent, Cold, Coarse, Meanspirited |
| Openness to Experience | Culture, Intellectance, Inquiring Intellect | Imaginative, Creative, Curious, Cultured, Sharp-witted, Broadminded, Inventive, Insightful, Complex | Simple, Concrete, Narrow, Imitative, Unimaginative |

It should be noted that not all researchers agree that the construct of conscientiousness might be the best predictor of performance in most occupational areas. Robertson et al. (2000) conducted a study that examined the relationship between conscientiousness and managerial performance. They suggest that some of the qualities associated with the low-end of the conscientiousness scale (i.e., nonconforming, rebellious, and unconventional) are, at least some of the time, linked to managerial success.

Salgado (2003) reported that there are currently over fifteen inventories that have been specifically developed within the FFM framework and used in organizational settings. He urges the adaptation of these FFM-based instruments as opposed to non-FFM-based instruments. He found that conscientiousness and emotional stability (low end of neuroticism scale) showed higher operational validity when assessed by FFM-based instruments than by non-FFM-based inventories. Considering that the results of the meta-analytical studies mentioned above suggest that these two factors may be the strongest link between personality and performance, this is strong evidence to support the use of FFM-based instruments in personnel selection.

There is also a significant body of research linking the FFM to other work-related criteria such as absenteeism and counterproductive behaviors (Judge, Martochio and Thoresen, 1997; Salgado, 2002). Judge et al. (1997) found that in a sample of 89 non-academic university employees, the control variables and the Big Five traits accounted for 30% of the variance in absence. Conscientiousness and extroversion were the strongest predictors, but part of that relationship was mediated through absence history. Salgado conducted a meta-analysis that examined the relationship between the FFM and counterproductive behaviors. He did not find a strong relationship between any of the five factors and absenteeism ($r$ = -.06 to .08) or accident rates ($r$ = -.09 to -.08), but did find that conscientiousness ($r$ = .26), and agreeableness ($r$ = .20) were valid predictors of deviant behaviors (e.g., theft, drug and alcohol use). The data suggest that the FFM cannot only be used to predict performance, but also behaviors that are considered to be detrimental to productivity.

### 3.9. Personality and Contextual Performance

Historically, job performance has been conceptualized as mainly encompassing task performance. Recently, the domain of job performance has broadened to include contextual performance, which includes behaviors associated with helping coworkers perform their assigned tasks (Borman and Motowidlo, 1993). There is evidence that contextual performance also is correlated with personality. For example, Motowidlo and Van Scotter (1994) found that the personality dimensions “work orientation”, “dominance”, “dependability”, “adjustment”, “cooperativeness”, and “internal control” were all significantly correlated with contextual performance (correlations ranged from $r$ = .11 to $r$ = .36). In the same study, only the work orientation and dependability dimension scores significantly predicted task performance (correlations were $r$ = .23 and $r$ = .18, respectively).

Lyne, Sinclair and Gerhold (1997) found that four personality dimensions (adjustment, ambition, likeability, and prudence) were significantly related to contextual performance, whereas only the likeability dimension was significantly related to task performance (correlations ranged from $r = .16$ to $r = .36$). The results from McManus and Kelly's work (1997) revealed that three personality dimensions (sociable, analytical, and self-confident) were related to contextual performance and only two of the dimensions (sociable and self-confident) were significantly related to task performance (correlations ranged from $r = .20$ to $r = .31$). Van Scotter and Motowidlo (1996) took this research one step further in that they examined correlations between scores on personality measures and task performance, as well as two dimensions of contextual performance: interpersonal facilitation (cooperative behaviors that aid coworkers in completing their tasks) and job dedication (self-disciplined behaviors such as following rules, working hard, and taking the initiative to solve a problem). These researchers found that although conscientiousness was the only personality dimension that was significantly related to task performance, agreeableness, extroversion, conscientiousness, and positive affectivity were significantly related to interpersonal facilitation, and agreeableness, conscientiousness, and positive affectivity were significantly related to job dedication (correlations ranged from $r = .09$ to $r = .16$). Although this is only a small body of research, it suggests that four of the Big Five personality factors (conscientiousness, similar to dependability; extraversion, similar to sociable; emotional stability, similar to adjustment; and agreeableness, similar to likeability) are related to contextual performance in a variety of occupational settings.

### 3.10. Effects of Faking

Numerous studies conducted within simulated or actual personnel selection scenarios (e.g., Furnham, 1990; Goffin and Woods, 1995; Hough, 1998a,b; Jackson, Wroblewski and Ashton, 2000; Mueller-Hanson, Hegestad and Thornton, 2003; Rosse, Stecher, Miller and Levin, 1998; Zalinski and Abrahams, 1979), and a meta-analysis on faking in a variety of contexts (Viswesvaran and Ones, 1999), have converged on the conclusion that test-takers in laboratory situations as well as applicants in applied selection situations can, and do, deliberately increase their scores on desirable personality traits, and decrease their scores on undesirable traits when motivated to present themselves in a positive light.

If faking were uniform among applicants it would have the effect of merely adding (or subtracting) a constant to (or from) everyone's score, which would mean that candidate rank-ordering, criterion-related validity (i.e., the extent to which personality test scores are related to job performance), and hiring decisions based on personality scores would be unaffected. However, persons who have dissimulated the most may have an increased probability of being hired, resulting in less accurate and less equitable hiring decisions (Christiansen, Goffin, Johnston and Rothstein, 1994; Mueller-Hanson et al., 2003; Rosse et al., 1998).

There are also grounds for optimism that the usefulness of personality testing in personnel selection is not neutralized by faking. Barrick and Mount (1996) demonstrated that although self-deception and impression management response distortion of personality items occurred in their sample, validity of the responses was not adversely affected. Christiansen et al (1994) used the 16PF fake good and fake bad scales to correct the scores of assessment center candidates and found that criterion-related validity was unaffected. Although response distortion does not appear to have a major impact on personality inventory validity in a selection context (e.g. Barrick and Mount 1996), it is still of some concern because these measures are definitely fakeable. One approach to detecting faking when using computerized administration of personality tests is to measure response latencies. Holden and Hibbs (1995) have refined this strategy; the trick is to first correct latencies for both person effects (e.g. slow vs. fast readers) and item effects (e.g. longer vs. shorter to read). Holden and Hibbs find that these adjusted latency scores can correctly classify about 82% of the test-takers instructed to respond honestly and those told to try to maximize their chances of getting the job.

### 3.11. Team Performance and Selecting Personnel in Team Settings

Work teams and groups are composed of two or more individuals who (a) exist to perform organizationally relevant tasks, (b) share one or more common goals, (c) interact socially, (d) exhibit task interdependencies (i.e., work flow, goals, outcomes), (e) maintain and manage boundaries, and (f) are embedded in an organizational context that sets boundaries, constrains the team, and influences exchanges with other units in the broader entity (Alderfer, 1977; Hackman, 1987; Hollenbeck et al., 1995; Kozlowski, Gully, McHugh, Salas, and Cannon-Bowers, 1996; Kozlowski, Gully, Nason and Smith, 1999; Salas, Dickinson, Converse and Tannenbaum, 1992). Teams are often introduced with the objective of improving organizational performance as well as the outcomes of the individual worker. It is thought that teams are capable of increasing an organization's adaptability to dynamic environments, are able to handle more complex and variable products and production processes, and that team members can more easily mutually adjust and coordinate their efforts.

Research in the personnel selection literature indicates that if relevant personality factors are identified for a specific job or role, future performance can be predicted (Borman et al., 1980; Lord et al., 1986; Day and Silverman, 1989; Barrick and Mount, 1991; Tett et al., 1991). Extending this logic into the domain of teams, if relevant personality traits are identified for a specific team task, the personality profile of the team might be helpful in predicting future team performance (Driskell et al., 1987). The application of such knowledge would help organizations to maximize the effectiveness of the team simply by ensuring that the personality profile of the team (i.e., the combination of team member personality factors) matches the requirements of the task.

KSAOs needed for successful performance in team contexts might be somewhat different than the KSAOs needed in more traditional individually oriented jobs. For example, it has been suggested that the skills, knowledge, and motivation needed to function effectively in a team go well beyond the core technical skills often measured in traditional selection contexts (Barrick, Stewart, Neubert and Mount, 1998; Guion, 1998). Others have noted that selecting individuals for teams requires one to consider problems that are seldom considered when selecting individuals to work by themselves (Jones, Stevens and Fischer, 2000).

Compared to task performance, contextual performance is particularly important in team settings. For example, the interpersonal helping makes teams work effectively in organizational settings. Without this kind of contextual performance, the development and maintenance of teams will not be successful. LePine, Hanson, Borman, and Motowidlo (2000) have noted that, since individual task performance in teams requires cooperation among team members, acts of helpfulness could also be a required aspect of task performance. However, helpful actions in teams will still have contextual implications. Thus, actions that contribute only to contextual performance in many organizational settings can contribute to both task performance and contextual performance in team settings.

Not only must the personality profile of the team match the demands of the task, the people on the team (and hence, their personalities) must be compatible. There are not a vast number of studies relating team member personality to team performance. Most of the studies that do exist measure and relate specific personality traits (which compose a minute piece of one of the five factors) to team performance or team satisfaction. There is no replication of any of the results due to the task specificity and the situation nature of the experiments. There are therefore no specific conclusions relating personality, as classified within the Big Five framework, to team performance. However, the preliminary results from the studies in existence indicate that some personality traits may affect performance for certain tasks in certain situations (Driskell et al., 1987). A brief overview of the findings for each factor is described below.

Openness should be related to the success of teams involved in creative tasks, or tasks performed under conditions of high uncertainty, such as radical innovation. Openness may be less important for group performance on a routine mechanical or a social task than for a problem-solving task (e.g. Driskell et al., 1987; Gibb, 1969; Cattell and Stice, 1954), or may even have negative relationships with performance with highly structured tasks. Barry and Stewart (1997) found a significant relationship between openness and "open communication" within simulated self-managed teams, but a significant negative relationship with "task focus". Crutchfield (1955), who found intellectual competence to be negatively correlated with conformity, provides indirect support. In sum, the limited evidence supports the importance of openness for creative and imaginative tasks but suggests that openness is less important, or even detrimental, when the task is of a more routine nature.

Emotional stability should predict performance in team tasks regardless of the type of team (Driskell et al., 1987). Teams with a higher aggregate level of emotional stability should contribute to a relaxed atmosphere and promote team cooperation. On the other hand, "unstable teams" are more likely to engage in disruptive behaviors, lose focus and have difficulty in cooperating (e.g. Watson and Tellegen, 1985). For teams that work on tasks over a long period of time, emotional stability can contribute to team viability (e.g. their capability of working effectively together over time, as rated by observers). For example, Haythorn (1953), Hough (1992), and Barrick et al. (1998) found that emotional stability was positively related to the team's viability. Barrick et al. also found a positive relationship between emotional stability and performance. Mann (1959) and Heslin (1964) both found emotional stability to be one of the best predictors of team performance. Haythorn (1953) found that emotional stability was related to team effectiveness and orientation towards job completion. Finally, the findings of Hough (1992) provide evidence that emotional stability is positively related to teamwork. In sum, the evidence suggests that the team level of emotional stability should be positively related to team performance for a wide range of team tasks.

For team tasks that require interpersonal interaction, social competence and interpersonal tact, agreeableness is an important trait. One of the facets of agreeableness is the propensity for cooperative behavior. Since cooperation has been shown to be important for the long-term success of teams (Hackman, 1990) it is reasonable to expect that higher levels of team agreeableness will be associated with team success. Evidence for the relationship between agreeableness and team performance is provided by Hough (1992), Barrick et al. (1998), and Stevens et al. (1999). A more recent study by Neuman and Wright (1999) found agreeableness (as measured by the lowest scoring team member) to be a significant predictor of effectiveness of human resources teams. McCrae and Costa (1989) suggest that agreeableness should be associated with team cohesiveness, which under some conditions might lead to successful performance. On the other hand, high cohesiveness can also lead to "groupthink". According to Janis (1972) when teams are highly cohesive they are susceptible to "groupthink". Groupthink occurs when team members shut themselves off from the environment or from others that may have different views. Janis points out that this behavior reduces a team's effectiveness on problem solving tasks.

Of the FFM constructs, conscientiousness has been found to have the strongest and most reliable correlation with individual performance across job settings (Barrick and Mount, 1991; Mount and Barrick, 1995). Keller (1997) suggests that the achievement-striving facet of conscientiousness, because it taps an emphasis on high career investment and devotion to work, should be predictive of R&D performance in general for scientists and engineers. Hough's (1992) meta-analysis found conscientiousness to be related to teamwork. Barrick et al. (1998) reported a significant relationship between conscientiousness and team performance. Neuman and Wright (1999) found conscientiousness (as measured by the lowest scoring team member) to be a significant predictor of supervisor ratings and task accuracy for human resources teams. Zander and Forward (1968) found that team members, who score high on achievement motivation (a component of conscientiousness), show a greater concern for the successes of the team. Schneidner and Delaney (1972) found that teams composed of members with higher achievement motivation scores solved complex problems more efficiently. Given this evidence it seems reasonable to assume that higher levels of conscientiousness should result in better team performance. The research evidence suggests that conscientiousness should be positively related to team performance across a wide variety of tasks and settings.

In a team setting the higher scores on extraversion should be related to higher levels of social activity (Barrick and Mount, 1991). Bouchard (1969) found that extraversion was consistently related to performance on group creative and problem solving tasks. Greer (1955) found a positive relationship between social activeness (an indicator of extraversion) and group effectiveness. Barrick et al. (1998) found a positive relationship between extraversion and the viability of the team (as judged by supervisors). On the other hand, some tasks may tend to be disrupted by high levels of interaction; for example, tasks involving logic and precision. Gurnee (1937) found a positive relationship between group members' scores on extraversion and the number of errors that groups made as they collectively moved through an electric-contact maze. Barry and Stewart (1997) found a negative relationship between extraversion and task focus. Driskell et al. (1987) predict a negative relationship between extraversion and performance for such tasks. The research suggests that extraversion should be related to team performance when tasks involve imaginative or creative activity but may inhibit performance when tasks call for precise, sequential and logical behavior.

### 3.12. Personality and Leadership

Personality characteristics have been shown to predict overall leader effectiveness in terms of business outcomes, the ability of the leader to build an effective team, subordinate ratings of leader effectiveness, and executive derailment. Furthermore, personality is also predictive of emergent leadership - that is, early identification of leadership potential. In the following paragraphs, we describe the Big Five traits and their relationship to ratings of transformational and transactional leadership behaviors.

Watson and Clark (1997) suggested that positive emotionality is at the core of extraversion and extraverts experience and express positive emotions. Thus, it is likely that extraverts will tend to exhibit inspirational leadership (e.g., having an optimistic view of the future). Because they are positive, ambitious, and influential, they are likely to generate confidence and enthusiasm among followers. Extraverts also may score high on intellectual stimulation, as they tend to seek out and enjoy change.

Individuals high in neuroticism tend to view the world through a negative lens. According to Costa and McCrae (1992), at the core of neuroticism is the tendency to experience negative affects, such as fear, sadness, guilt, and anger. Individuals who score high in neuroticism tend to experience emotional distress, whereas those who score low on the trait are calm, even tempered, and relaxed. As Northouse (1997) noted, self-confidence is requisite to the initiation of leadership. Thus, individuals high in neuroticism should be less likely to attempt to lead and less likely to involve themselves in their subordinates' efforts (Bass, 1985), tending to avoid leadership responsibilities. Furthermore, they are not likely to be seen as role models, are unlikely to have a positive view of the future, and may be too anxious to undertake transformational change efforts. Hence, it is unlikely that they will exhibit transformational leadership behaviors, such as idealized influence, inspirational motivation, or intellectual stimulation.

Individuals high in openness to experience are emotionally responsive and intellectually curious (McCrae, 1996). They tend to have flexible attitudes and engage in divergent thinking (McCrae, 1994). Judge and Bono (2000) found that openness to experience was associated with transformational leadership. Because they are creative, individuals high in openness to experience are likely to score high in intellectual stimulation. However, individuals high in openness to experience may also exhibit inspirational leadership behaviors. Because they are imaginative and insightful, they are likely to be able to see a vision for the organization's future.

Individuals high in agreeableness value affiliation and avoid conflict (Graziano, Jensen-Cambell and Hair, 1996). They are modest, altruistic, and tend to be both trusting and trustworthy (Costa and McCrae, 1992). There are several leadership behaviors that might be exhibited by individuals high in agreeableness. First, because of their concern for others, they are likely to be concerned with individuals' growth and development needs (individualized consideration) and are likely to be sure that individuals are rewarded appropriately and praised "for work well done" (contingent reward; Bass, 1985). The modesty and kindness of agreeable individuals is not the most distinguishing characteristic of charismatic leaders. However, they may score high in idealized influence and be seen as role models because of their trustworthiness and consideration for others.

Conscientiousness has been one of the most commonly studied traits in work psychology. Conscientious individuals tend to have a strong sense of direction and work hard to achieve goals (Costa and McCrae, 1992). However, there is no particular reason to expect that conscientious individuals will exhibit vision, enthusiasm, or creativity. However, because conscientious individuals are goal and detail oriented (Hogan and Ones, 1997), they may be more likely to engage in management by exception–active, which involves both setting and monitoring goals (Bass, 1998). Also, because they are dependable and unlikely to evade their work responsibilities, they are unlikely to exhibit passive leadership behaviors, which involve lack of self-discipline and the default of leadership responsibilities (Bass, 1998).

### 3.13. Job Analysis

Job analysis is a broad term commonly used to describe a wide variety of systematic procedures for examining, documenting, and drawing inferences about work activities, worker attributes, and work context. In light of recent workplace changes that de-emphasize traditional conceptions of rigidly defined jobs, the broader term work analysis is sometimes advocated (Sanchez and Levine, 1999). Job analysis is believed to be the most central of all human resources management activities (Ghorpade, 1988). It is an effective tool in identifying the tasks performed by the job incumbents, the qualities required on the job, and the physical, technological, and social conditions under which the job gets done. Basically job analysis consists of two outputs: a job description and a job specification. A job description is a written description of the activities that have to be performed. Generally, a job description also contains information about tools and equipment used in the job and about the working conditions. The job specification indicates which specific skills, competences, knowledge, capabilities and other physical and personal attributes one must have to perform the job successfully.

### 3.13.1. Traditional methods of job analysis

Information about jobs can be collected in a number of ways. McCormick (1976) lists the following as potential sources: observation, individual interview, group interview, technical conference, questionnaire, diary, critical incidents, equipment design information, recording of job activities, or employee records.

Some method designed to study jobs include functional job analysis (Fine, 1974), critical incidents (Flanagan, 1954), job elements (Primoff, 1975) the Position Analysis Questionnaire (McCormick, Jeanneret, and Mecham, 1972), physical abilities requirement approach (Fleishman, 1975) and O*NET® Department of Labor Procedure.

#### 3.13.1.1. Functional job analysis

The rationale behind functional job analysis (FJA) is that jobs must be defined in terms of the interaction between the task, the individuals responsible for accomplishing the task, and the environment in which the task is to be performed. FJA relies on five components. First, the purpose, goals and objectives of a specific job need to be identified, and second, analysis must identify and describe the tasks necessary to accomplish a job. In the third component of functional job analysis, the analysts determine the specific abilities necessary to perform the job successfully. Fourth, from this information, performance standards are set and then, fifth, training needs are identified in the final stages of functional job analysis.

### 3.13.1.2. Critical incidents technique

In contrast to FJA, where experts make judgments about the content of job, the critical incidents technique (CIT) utilizes actual episodes of on-the-job behavior. The "critical incidents" were defined as "extreme behavior, either outstandingly effective or ineffective with respect to attaining the general aims of the activity" (Flanagan, 1954). In other words, CIT asks employees aims of the activity and specific examples of on-the-job behavior that demonstrate both high and low levels of performance (Flanagan, 1954).

Sources for critical incidents include workers, co-workers, supervisors, managers, and others. Typically, the job analyst will ask informant's to think of the most recent example of a worker performing at a very high level. Informants will describe what led to the incident, exactly what the employee did, the perceived consequences of the behaviour, and whether or not these consequences were within the control of the employee. After the incidents are collected, they are transferred to index cards, and job incumbents, supervisors, or analysts independently group similar incidents into broader categories. (Factor analysis is frequently used in this part of the analysis). These independent groupings are compared in order to establish categories may include "promptness of service," "accuracy of orders," or 'interaction with customers." Raters discuss any differences in categorization in order to ensure agreement and the reliability of the ratings. From this procedure, a detailed outline of the content of a specific job will emerge.

### 3.13.1.3. Job elements approach

Job elements include knowledge, skills, and abilities (KSAs), as well as willingness, interest, and personal characteristics (Primoff, 1975). Like the critical incidents approach, job elements approach relies on the knowledge and experiences of supervisors and job incumbents. In the first stop of a job elements approach to job analysis, SMEs participate in a brainstorming session in which they identify as many of the elements of a particular job as possible. Next, the identified elements are rated on each of four factors:

a) *Barely acceptable:* What relative portion of even barely acceptable workers is good in the element?

b) *Superior:* How important is the element in picking out the superior worker?

c) *Trouble:* How much trouble is likely if the element is ignored when choosing among applicants?

d) *Practical:* Is the element practical? To what extent can we fill our job openings if we demand it?

Using a statistical procedure developed by Primoff (1975), ratings on the above four factors are analyzed to determine what elements are most important in selecting superior workers.

**3.13.1.4. Position Analysis Questionnaire**

The Position Analysis Questionnaire (PAQ) was developed by McCormick et al. (1972) on the assumption that there is an underlying taxonomy to all jobs. That is, in contract to the other methods, the PAQ approach focuses on broad categories common to all jobs rather than on individual elements of specific jobs. Given the thousands of tasks for one job that the other methods may identify, PAQ attempts to put this data into a more manageable form. PAQ reduces all jobs to 194 elements, which are classified in terms of six broader dimensions. These six dimensions are information input (35 elements), mental processes (14 elements), work output (49 elements), interpersonal activities (36 elements), work situation and job context (19 elements), and miscellaneous aspects (41 elements).

**3.13.1.5. Physical abilities requirements approach**

One limitation of all the methods, with the exception of the PAQ, discussed is that they are not very useful for determining the physical requirements for job performance. Although these job analysis methods will identify those tasks that a worker is expected to accomplish, information about the physical requirements is usually inferred. For many jobs, qualities such as reaction time, manual dexterity, or trunk strength may be critical to successful job performance. Lack of knowledge about physical requirements can lead to problems in many areas, but particularly in personnel selection. Uncertainty about physical requirements can also result in turnover or attrition that can be quite costly to the employer. When an employer or a job applicant is uncertain about the levels of strengths or flexibility necessary to perform a job, then the likelihood of the candidate not performing successfully is much greater. Additionally, poor match between applicant abilities and physical requirements is likely to lead to a higher accident rate.

Fleishman (1975) & Fleishman and Quaintance (1984) had developed a taxonomy of physical and cognitive abilities that is designed to describe the performance standards of any job. According to Fleishman, abilities are the foundation on which skills are built. In contrast to the other methods, considering jobs from an abilities approach results is much greater generalizability of information across differently jobs. Levels of physical ability are obviously important in many occupations, but the analysis of jobs with regard to this area has not been widely explored in industrial and organizational psychology.

### 3.13.1.6. O*NET® Department of Labor procedure

Job analysis data has the potential to be analyzed so that information can be acquired about several jobs or job families and consequently multi-level decisions can be made. However, the data must be structured to accommodate such an analysis. The job data must have the capability for aggregation. This is especially true when a job analysis is needed across several jobs and job families as is the case in many large organizations including government and military. Without a method to aggregate the data, decisions made using the data across levels will not be valid (Harvey and Wilson, 2000). A solution to this problem of aggregation can be attained through the use of an online database called O*NET®. A significant part of the development and application of metrics uses standardized data from O*NET®. The Occupational Information Network replaced the Dictionary of Occupational Titles (U.S. Department of Labor, 1991) as a standardized, comprehensive, and online system available for performing worker and work-oriented job analysis and developing descriptions of jobs. The system is designed to present job information at both a general and an occupation-specific level (Peterson, Mumford, Borman, Jeanneret and Fleishman, 1999; Peterson et al., 2001).

O*NET® was designed to be hierarchical in nature allowing for the use of both broad descriptors that can be used across occupations such as generalized work activities skills and abilities, as well as more specific descriptors of a specific position such as tasks, occupational knowledge, occupationally specific skills, and tools, machines, and equipment. O*NET® uses standardized work activities and skill descriptions to provide a common language to describe and characterize various jobs and occupations (Borman, 1996; Mumford and Peterson, 1999).

In this study, the types of KSAOs and their definitions involved in the O*NET® Content Model are used in order to provide a common language in job analysis and personnel selection processes since O*NET® Content Model provides a synthesis of job analysis research, relying upon and reflecting the cumulative knowledge and research on job analysis (Campion, Morgeson and Mayfield, 1999).

### 3.13.2. Personality-based job analysis

Selection hypotheses must emerge from an understanding of jobs based on job analysis. Most job analysis inventories are quite clear in providing help for hypothesizing ability or aptitude variables that might make good predictors but are less clear for those traits more closely associated with personality variables. If a job analysis method emphasizes only cognitive or psychomotor aspects of jobs, it is likely that only cognitive or psychomotor predictors will be hypothesized. Therefore; an approach to job analysis explicitly directed to generating hypotheses about relevant personality variables would be helpful.

Although personality characteristics such as conscientiousness play an important role in job performance across jobs, personality characteristics are usually excluded from job analytic studies (Hogan, 1998). This oversight has led some researchers to propose using a personality-based job analysis (PBJA) instrument in conjunction with traditional job analysis instruments in order to obtain a comprehensive understanding of the requirements for a job. The earliest study, conducted by Arneson (1988), used a checklist called the Worker Characteristics Inventory (WCI) to identify the personality characteristics that are important for performing a job. The results of the WCI successfully identified the personality scales with the highest criterion-related validity. More recently, Sümer, Sümer, Demirutku, and Çiftçi (2001) used personality-based job analysis (PBJA) to identify personality traits required for Turkish armed forces officer job performance. Based on a content analysis of SME responses during a semi-structured interview, 79 personality traits were identified as relevant to successful job performance. In another study, Jenkins and Griffith (2002) found that a test developed to reflect the results of the Personal Requirements Survey (a PBJA technique) had higher criterion-related validity and positive applicant. Addressing the gap in the literature with respect to personality-based job analysis tools, Raymark, Schmit, and Guion (1997) have developed “Personality-Related Position Requirements Form” (PPRF) whereby job analysts can derive personality predictors of occupational success. Raymark et al. (1997) built their job analysis tool on the framework of the “Big Five” personality taxonomy. Within the broad-bandwidth factors of the “Big Five”, they constructed twelve narrowly defined facets. For each of the twelve facets, general task statements were created as behavioral indicators of that specific personality characteristic. The Personality-related Position Requirements Form (PPRF) is composed of 102 general task statements representing twelve personality facets within the “Big Five” personality framework. Subsequent analyses suggest that this personality-based job analysis tool meaningfully differentiates between various types of jobs (Raymark et al., 1997). All PPRF facets are given below in Table 3.4.

**Table 3.4:** Main and sub-categories involved in PPRF (Raymark et al., 1997)

| **Main category** | **Sub-categories** |
|---|---|
| Surgency | General Leadership, Interest in Negotiation, Achievement Striving |
| Agreeableness | Friendly Disposition, Sensitivity to interest of Others, Cooperative or Collaborative Work Tendency |
| Conscientiousness | General Trustworthiness, Adherence to a Work Ethic, Thoroughness and Attentiveness to Details |
| Emotional Stability | Emotional Stability |
| Intellectance | Desire to Generate Ideas, Tendency to Think Things Through |

As a result of previous discussions, O*NET® Content Model is integrated with major categories of PPRF and a hierarchical list of personnel characteristics (i.e. knowledge, skills, abilities, experience and personality) was formed in order to provide a common language so that variables used in the personnel selection process in this study is consistently understood and used in the same meaning across many jobs. The complete hierarchical model is seen in the Figure 3.1. A full description of these personnel characteristics is given in the Appendix A.

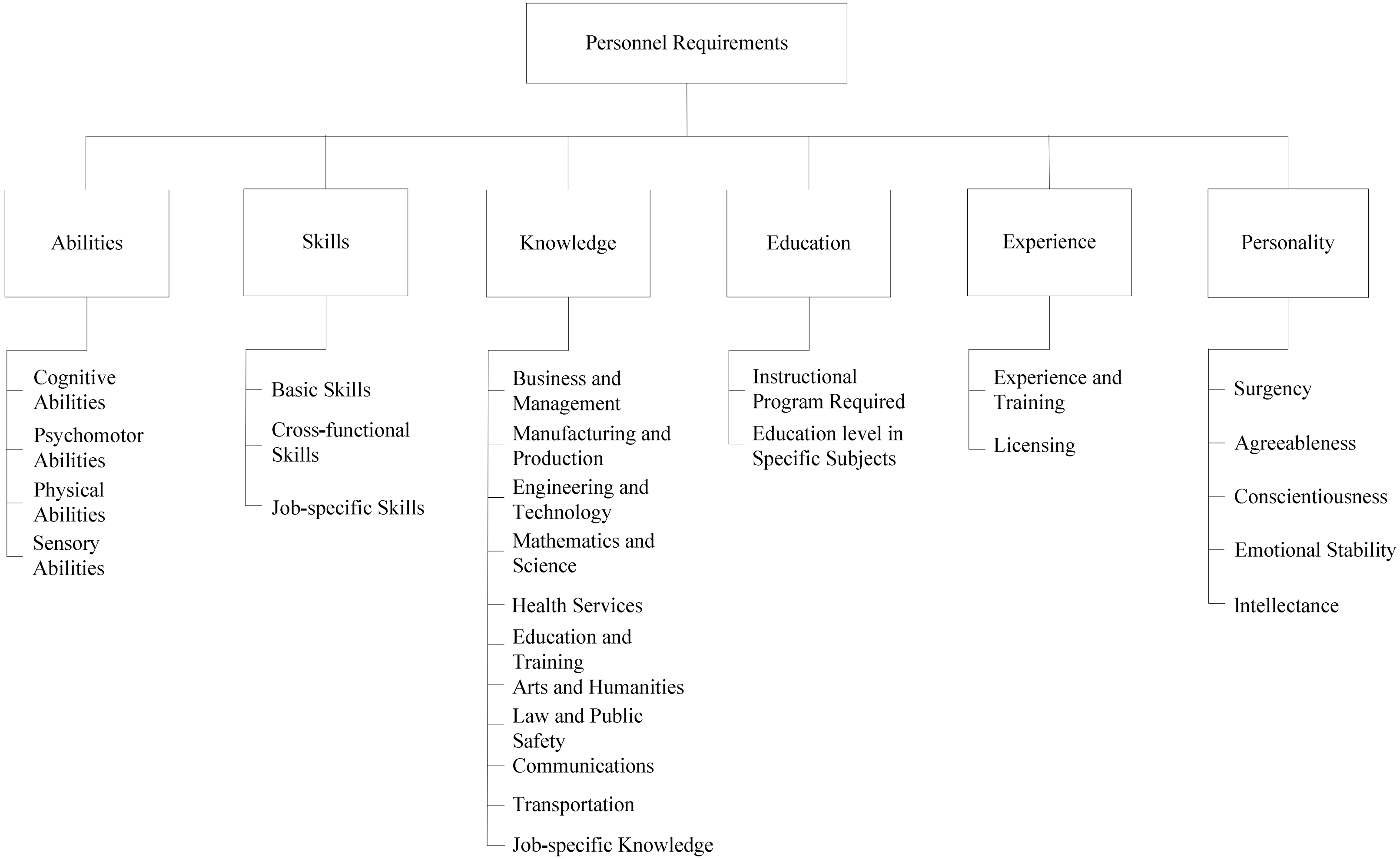


**Figure 3.1 :** Personnel characteristics.

### 3.14. Chapter Summary

In this chapter, the definition of "job perfomance" construct and its antecedents are given. More specifically, overall job performance has been categorized into two major categories, namely, task and contextual performance. Besides, other performance types such as counterproductive performance, team performance and leadership performance have been discussed in the literature. However, literature survey shows that task and contextual performance are the major individual performance categories which are generally used as the predictors of overall job performance.

Due to our findings in the literature survey, task performance is well predicted by KSAOs owned by the job incumbent; whereas, contextual performance can be predicted by personality variables. Thus, rather than thinking performance as a single construct, consideration of two performance dimensions separately will make easier to develop personnel selection hypotheses since each dimension contribute in a different way to the overall job performance.

Generally, the personnel selection decision is based on the knowledge, skills and abilities (KSAs) of the candidates which are developed as a result of education and previous experience. Literature survey reveals that these KSAs are generally developed by two ways: rules of thumb or know-how that exists in an organization at the moment when the personnel recruitment and selection is realized; or optimistically by job analysis to identify the KSAs required for performing the job. However, even though job analysis can be performed in medium-sized and large companies, information gathered from those studies are not used very effectively in other HR management activities. This is due to the lack of understanding of the benefits of performing job analysis during the time that it is performed in a particular organization. Even, the information gathered in the job analysis may be so far away from being true or at sufficient level or nor up-to-date since the purposes it may serve are not well-explained to the people in the organization.

In the beginning of the 1990s, even the traditional job analysis has been found to be lacking to define a good performer since traditional job analysis does not identify the personality characteristics required for the job. As a result of the many research studies in personality-performance relation, a "whole person" approach which supports the inclusion of personality characteristics in the job analysis and personnel selection processes has emerged. After many studies in different job contexts have been performed, today it is accepted that personality is an important variable to be measured for performance prediction and employment purposes. Thus, personality variables to be measured in the selection process should be identified by job analysis studies which consider personality characteristics required for performing the job in question. As a result, a few personality-based job analysis studies have been performed by the researchers.

By the inclusion of personality dimension in the job analysis and personnel recruitment and selection processes, different categorization approaches for personality traits have been used. Among these categorization approaches, Big Five or FFM has become the most popular one in the personnel selection research and practice. It has been tested for predicting job performance in many different organizational contexts and its wide-acceptance by researchers has triggered many other studies in the literature. As a result these studies "conscientiousness" component of FFM has been found to be the most important predictor of overall performance across many occupational areas. This component, even though is a personality trait, it does predict task performance even better than contextual performance of individuals.

Based on these results, the personnel selection model proposed in this study is based on a "whole person" approach in which KSAOs including personality are identified by performing job analysis. Therefore, personnel selection hypotheses will be developed in a more structured manner so that necessary KSAOs and their levels cover the whole job content. Although it may be time consuming, performing a specific job analysis in the course of recruitment process will help to determine up-to-date KSAOs due to the changing nature of jobs in today's work environments. Therefore specific hypotheses for specific personnel selection problems arising at different times can be developed and tested in the long run.

# 4. FUZZY PERSONNEL SELECTION MODELS: FUZZY QFD AND FUZZY MCDM

It has been widely recognized that most of the decisions made in the real world taken place in an environment in which the goals and constraints, due to their complexity, are not known precisely and thus; the problem cannot be exactly defined or precisely represented in a crisp value. To deal with the kind of qualitative, imprecise information or even ill-structured decision problems, Zadeh (1965) suggested employing fuzzy set theory as a modeling tool for complex systems that can be controlled by humans but are hard to define exactly. He noted that "Much of the decision making in the real world takes place in an environment in which the goals, the constraints and the consequences of possible actions are not known precisely" (Bellman and Zadeh 1970).

Fuzziness can be found in many areas in daily life, such as in engineering, in medicine, in meteorology, in manufacturing, and others, frequently in all area in which human judgment, evaluation or decision are important. Most of our daily communication uses natural language, which the meaning of words is very often vague. The meaning of a word itself maybe well defined, but when using the word as a label for a set, the boundaries within which objects belong to the set or do not become fuzzy or vague (Zimmermann, 1985). The following sections define fuzzy sets, fuzzy numbers and arithmetic used in the analysis of fuzzy decision making.

## 4.1. Basic Definition of Fuzzy Sets

Fuzzy set theory is a mathematical theory that is pioneered by Zadeh (1965) and designed to model the vagueness or imprecision of human cognitive processes. This theory is basically a theory of classes with uncertain boundaries. A fuzzy set allows intermediate values to be defined between conventional evaluations like true/false, yes/no, high/low, etc. Notions like rather tall or very fast can be formulated mathematically and processed by computers, in order to apply a more human-like way of thinking in the programming of computers (Zadeh, 1984).

A fuzzy set can be defined mathematically by assigning to each possible element in the universe of discourse a value representing its grade of membership to the fuzzy set. When A is a fuzzy set and x is a relevant object, the proposition "x is a member of A" is not necessarily either true or false, as required by classical dual logic, but it may be true only to some degree, the degree to which x is actually a member of A. Moreover, it is very often feasible to express degrees of membership in sets as well as degrees of truth of the associated propositions by real numbers in the closed unit interval of [0, 1]. This grade of membership corresponds to the degree to which an element is similar to or compatible with the concept represented by the respective fuzzy set (Klir and Yuan, 1995).

Following Zadeh (1965), let X = {x} denotes a collection of objects, with a generic element of X denoted by x. Then the fuzzy set A in X is characterized by a membership function $\mu_A(x)$ which associates with each point in X a real number in the interval [0,1].

$$A = \{(x, \mu_A(x))\}, \text{ for } x \in X \qquad \textbf{(4.1)}$$

where $\mu_A(x)$ represents the grade of membership of x in A, and $\mu_A: X \rightarrow M$ is a function from X to a space M called the membership space. When M contains only two points, 0 and 1, A is non-fuzzy and its membership function becomes identical with the characteristic function of a non-fuzzy set. In the case of a fuzzy set, there is a class of objects with a continuum membership grade. For the sake of simplicity, usually M is normalized and thus; it can be described in a closed interval of [0,1], with 0 and 1 representing the lowest and highest grades of membership respectively (Bellman and Zadeh 1970).

Fuzzy sets have imprecise boundaries that facilitate gradual transition from membership to non-membership and vice versa. This gradual transition provides a broad utility, mainly in enabling a meaningful and powerful representation of measurement uncertainties and representation of vague or ill-defined concepts expressed in natural language (Klir and Yuan, 1995).

## 4.2. Fuzzy Numbers

Among the various types of fuzzy sets, those fuzzy sets are of special significance that are defined on the set R of real numbers. In many situations, one is only able to characterize the numeric information imprecisely (Yager and Filev, 1994) such as “around 10”, “more than unity” or “nearly zero”, which can further be represented as a fuzzy subset of the set of real numbers. The membership function of these sets in a closed interval of $\mu_A(x)$: R $\in$ [0, 1] clearly has a quantitative meaning, which in certain conditions can be viewed as fuzzy numbers or fuzzy intervals. To qualify as a fuzzy number, a fuzzy set A on R must satisfy the condition of normality in which the membership value must be in a closed interval of [0, 1] and its support must be bounded (Klir and Yuan, 1995). Most common types of fuzzy numbers are triangular and trapezoidal. Other common types of fuzzy numbers are bell-shaped and Gaussian fuzzy numbers.

Triangular fuzzy numbers (TFNs) are used throughout this study since triangular fuzzy numbers have proven popular with fuzzy logic practitioners and been used extensively due to their simplicity and computational efficiency (Yen and Langari, 1999).

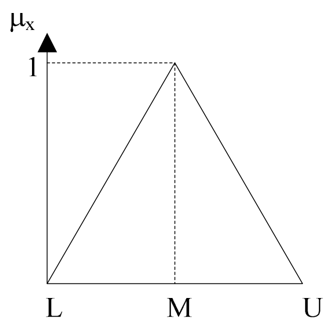


**Figure 4.1 :** Membership function for a TFN.

A triangular fuzzy number is the special class of fuzzy number whose membership defined by three real numbers, expressed as (L, M, U). The triangular fuzzy numbers, depicted in Figure 4.1, is represented as follows.

$$\mu_{\tilde{A}}(x) = \begin{cases} \dfrac{x-L}{M-L}, L \le x \le M \\ \dfrac{U-x}{U-M}, M \le x \le U \\ 0, otherwise \end{cases} \quad \textbf{(4.2)}$$

Let $\tilde{M} = (m_1, m_2, m_3)$ and $\tilde{N} = (n_1, n_2, n_3)$ be two triangular fuzzy numbers. The basic arithmetic operations on these two triangular fuzzy numbers are as follows (Dubois, Didier and Prade, 1980).

$$\tilde{M} \oplus \tilde{N} = (m_1 + n_1, m_2 + n_2, m_3 + n_3) \quad \textbf{(4.3)}$$

$$\tilde{M} \otimes \tilde{N} \cong (m_1 \times n_1, m_2 \times n_2, m_3 \times n_3) \quad \textbf{(4.4)}$$

$$\frac{\tilde{M}}{\tilde{N}} \cong (\frac{m_1}{n_3}, \frac{m_2}{n_2}, \frac{m_3}{n_1}) \quad \textbf{(4.5)}$$

$$k\tilde{M} = (km_1, km_2, km_3) \quad \forall k > 0, k \in R \quad \textbf{(4.6)}$$

Distance between $\tilde{M}$ and $\tilde{N}$ using vertex method:

$$d(\tilde{M}, \tilde{N}) = \sqrt{\frac{1}{3}\left[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2\right]} \quad \textbf{(4.7)}$$

## 4.3. Fuzzy Multi-criteria Decision Making

A decision making problem can generally be described as the process of searching for or finding a course of action from a given set of feasible alternatives which maximizes or satisfies certain criteria associated with the goals intended to be achieved (Zimmermann and Zysno, 1985). Multi-criteria decision making (MCDM) problems are shown by m x n matrix, where m is the number of the alternatives, n is the number of the criteria, containing elements ($x_{ij}$) of the matrix as an evaluation rating in attribute j with respect to alternative i (i=l,2,...,m, j=l,2,...,n). Accordingly, the processes involved in the multiple criteria decision making can be characterized as making preference decisions through evaluation, prioritization or selection of alternatives in the presence of multiple, usually conflicting criteria (Yoon and Hwang, 1995). They are concerned mainly with the question as to which alternative or course of action should be undertaken under a specific situation by considering many aspects, including the degree of importance of each criterion.

The classic MCDM methods generally assume that all criteria and their respective weights are expressed in crisp values and thus; the rating and the ranking of the alternatives can be carried out without any problem. In a real-world decision situation, the application of the classical MCDM method may face serious practical constraints, due to the criteria perhaps containing imprecision or vagueness inherent in the information. In many cases, performance of the criteria can only be expressed qualitatively or by using linguistic terms, which certainly demands a more appropriate method. The presence of fuzziness or imprecision in a MCDM problem will obviously increase the complexity of the decision situation in many ways. Fuzzy or qualitative data are operationally more difficult to manipulate than crisp data, and certainly increase the computational requirements in particular during the process of ranking when searching for the preferred alternatives (Chen and Hwang, 1992).

The attitude towards uncertainty and subjectivity inherent in human behavior during the process of decision making has led to the new area of study which applies fuzzy sets theory in the decision making area. This is known as Fuzzy Multi Criteria Decision Making (FMCDM). The main feature of this approach is that the imprecision inherent in the qualitative information can be formalized by applying fuzzy sets theory. The FMCDM methods have basically been developed along the same lines as conventional MCDM methods, but are designed with the help of fuzzy set theory to deal specifically with MCDM problems containing fuzzy data (Zimmermann, 1987, 1996). The introduction of fuzzy set theory to the field of decision making provides a consistent representation of qualitatively or linguistically formulated knowledge in such a way that still allows the use of precise operators and algorithms. The application of fuzzy set theory will facilitate the formulation of a complex, ill-defined and subjectively perceived decision problem in a more appropriate manner. It also enables the representation and adequate processing of the vagueness or imprecision into the formal decision model in such a way that there is no simplification, but an intellectually and scientifically acceptable manner (Carlsson and Fuller, 1996).

Based on the fuzzy concepts and operations on fuzzy numbers described above, the proposed model in this study uses fuzzy extensions of fuzzy multi-criteria decision making methods such as FAHP, FTOPSIS and FVIKOR under FQFD framework. FQFD is used as a framework for ensuring the development of job-related selection criteria such that the whole job-domain is covered in terms of performance and required KSAOs. Under the FQFD framework, FMCDM methods such as FAHP, FTOPSIS and FVIKOR are used in this study. In the following sections, an overview of QFD and multi-criteria decision making methods used in this study will be given.

### 4.4. QFD and FQFD

Quality function deployment (QFD) is a systematic method for translating the voice of customers into a final product through various product planning, engineering and manufacturing stages in order to achieve higher customer satisfaction. QFD was developed in Japan in the late 1960s by Professors Shigeru Mizuno and Yoji Akao. The purpose of Professors Mizuno and Akao was to develop a quality assurance method that would design customer satisfaction into a product before it was manufactured. Prior quality control methods were primarily aimed at fixing a problem during or after manufacturing.

The basic concept of QFD is to translate the desires of the customer into product design or engineering characteristics, and subsequently into parts characteristics, process plans, and production requirements associated with its manufacture. Ideally, each translation uses a chart, called ``House of Quality'' (HoQ) as seen in Figure 4.2. A house of quality typically contains information on performance characteristics or customer attributes (CASs), engineering characteristics (ECs), relationships between CAs and ECs and among the ECs and benchmarking data. The main objective of applying QFD is to determine the target values of the ECs for a new/improved product based upon the information contained in a HoQ. Currently, this is usually accomplished in a subjective, ad hoc manner, or using a heuristic approach, such as a prioritization-based method, with the view to yielding a feasible design, rather than an optimal one (Tang et al., 2002).

It is critically important to capture the customers' perspective in the corporate language. The customer information comes from a variety of sources, including surveys, focus groups, interviews, listening to salespeople, trade shows and journals, existing data on warranty and customer complaints (Bossert, 1991). Griffin and

Hauser (1993) address specific issues on identifying customer needs (how many customers, how many analysts, groups vs. depth interviews), structuring and sorting customer needs, and measuring or estimating relative importance. In practice, over 50% of the QFD effort is spent in capturing the CAs and relative importance of performance characteristics (Bosserman, 1992).

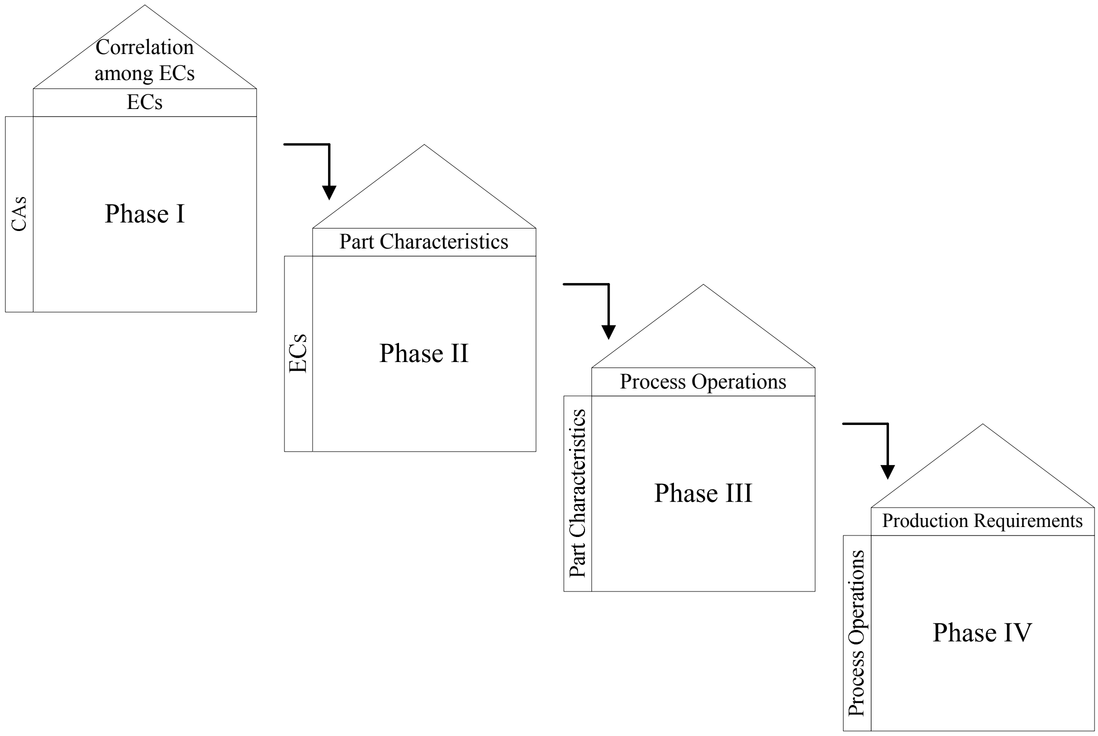


**Figure 4.2 :** Four phases of QFD.

Using all four matrices is a powerful concept, but in reality, it is often difficult to achieve due to the time and resource constraints involved in a project. The first matrix is generally considered as the most important matrix since it captures customer attributes and the benchmarking information for the product. The first matrix of QFD; and steps involved in the construction of that matrix are given in detail in Figure 4.3.

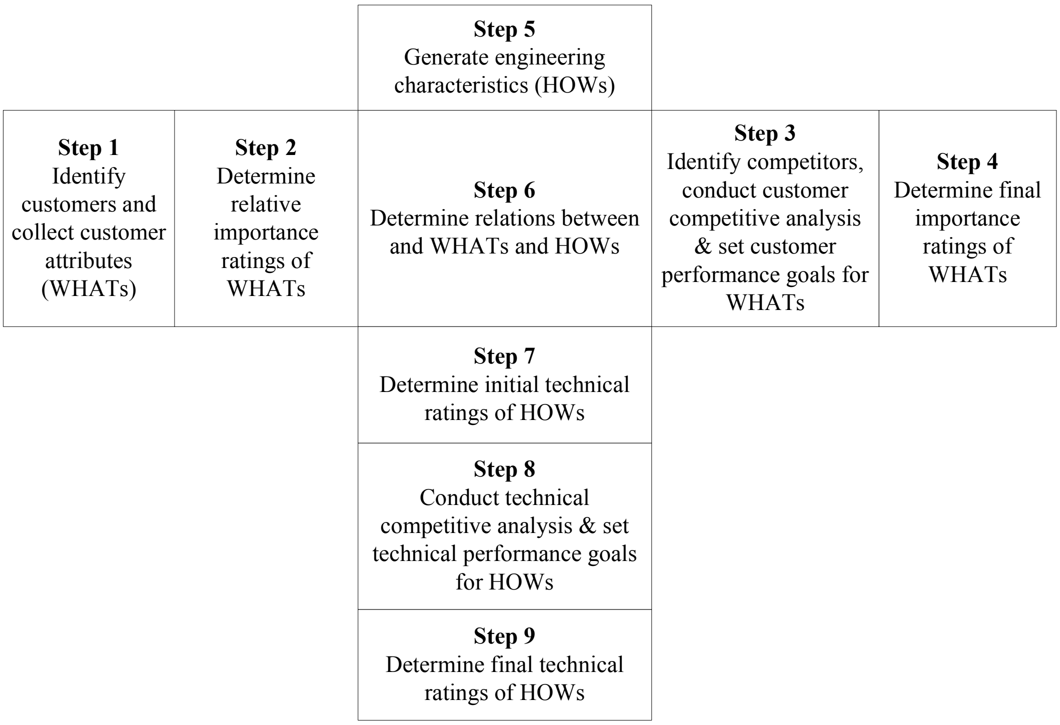


**Figure 4.3 :** First HOQ (Chan and Wu, 2005).

In practice, it is both difficult and unnecessary to include all the HoQ elements described above. In fact, different users build different HOQ models involving different elements from the Figure 4.3. The most simple but widely used HOQ model contains only the CAs (WHATs) and their relative importance, ECs (HOWs) and their relationships with the CAs, and the importance ratings of the ECs (Chan and Wu, 2005).

The technical priority is a key result of QFD since it guides the design team in decision-making, resource allocation, and the subsequent QFD analyses (Tang et al., 2002). Therefore, deriving the final importance rankings of ECs from input variables is a crucial step towards successful QFD. However, the inherent vagueness or impreciseness in QFD presents a special challenge to the effective calculation of the importance of ECs. The vagueness and impreciseness are due to a member of reasons:

(1) The QFD process involves various inputs in the form of linguistic data, e.g., human perception, judgment, evolution on importance of CAs or strengths of relationship between CAs and ECs, which are highly subjective, and vague (Chan and Wu, 2002);

(2) Formal mechanisms for translating CAs (which are generally qualitative) into ECs (which are usually quantitative) are lacking. There are normally many CAs for a product. Each CA can be translated into multiple ECs, and conversely a certain EC may affect multiple CAs. In general, these CAs tend to be translated into ECs in a subjective, qualitative and non-technical way, which should be expressed in more quantitative and technical terms. Hence, the relationships between CAs and ECs are often vague or imprecise (Kim et al., 2000);

(3) Owing to the uncertainties in the design process, the data available for product design is often limited and may be inaccurate, especially when an entirely new product is developed, and a certain degree of vagueness is often inevitable (Fung et al., 2002).

Simonson (1993) stated that customers' preferences are often fuzzy and imprecise, e.g., ``very important" and ``some important." In addition, relationships between CAs and ECs are identified qualitatively (Belhe and Kusiak, 1996). This is often ambiguous, e.g., ``strong relationship." Since linguistic data cannot be easily quantified, it may be more appropriate to treat them as fuzzy rather than precise.

Research on FQFD has received many attentions (Temponi, Yen and Tiao, 1999; Harding, Popplewell, Fung and Omar , 2001), and made substantial progress. Masud and Dean (1993) proposed the approach of prioritising ECs, weights of CAs, and the relationship between CAs and ECs using fuzzy numbers. The relationships between the ECs and the CAs are computed through the fuzzy weighted average (FWA) to calculate the priorities (Carnahan et al., 1994). Results (fuzzy numbers representing EC priorities) are defuzzified through the Centroid method, to obtain crisp numbers from fuzzy numbers. Khoo and Ho (1996) proposed an approach centered on the application of possibility theory and fuzzy arithmetic to address the ambiguity in QFD operation. Zhou (1998) proposed an approach that combines fuzzy set theory and mathematical programming. Triangular fuzzy numbers capture the influences that EC have on CA. The importance of each CA is considered as a real number. The priority of each EC is obtained by the fuzzy weighted average (FWA). Moskowitz and Kim (1997) presented an approach for determining EC targets, based on mathematical programming – the level of satisfaction produced by an EC value per CA is expressed as a function. Fung et al. (1998) used the analytic hierarchy process (AHP) to find targets. CA are categorised by using an “affinity diagram”, and prioritised by using the AHP. Wang (1999) used a fuzzy outranking model designed to achieve customer satisfaction and a balanced design of the product. Shen, Tan, and Xie (2001) proposed a fuzzy procedure to examine the sensitivity of the ranking of ECs to the defuzzification strategy and degree of fuzziness of fuzzy numbers.Vanegas and Labib (2001), proposed a FQFD approach, using new fuzzy weight approach. The new FWA calculated the corrected weights of the CAs based on the customer's level of importance and the company's perception on the customer's requirements. Sohn and Choi (2001) develop a FQFD model in order to convey fuzzy relationship between customers needs and design specification for reliability in the context of supply chain management. Kwong and Bai (2002) proposed a FAHP approach to determine importance weightings of ECs. However, those previous studies did not consider the impacts among ECs but one can recognize easily that an EC with much impact (positive or negative) on a number of other ECs normally is more significant than the one with little or even no impact on the other ECs. In recent years, Tang et al., (2002) and Fung et al. (2002) approached the relationship between customer satisfaction and enterprise satisfaction by optimizing fuzzy coefficients subject to crisp objective functions and constraints. Erol and Ferrell (2003) present a methodology to assist decision-makers in selecting from a finite number of alternatives when there is more than one objective and both qualitative and quantitative factors must be considered. Yang et al. (2003) presented the findings of a research effort to adapt HoQ to meet the needs of buildable designs in the construction industry and to develop a FQFD system for buildability evaluation. Kahraman et al. (2006) proposed an integrated framework based on fuzzy-QFD and a fuzzy optimization model is proposed to determine the product technical requirements to be considered in designing a product. The coefficients of the objective function are obtained from a fuzzy analytic network process approach. FAHP is also used in the proposed framework. An application in a Turkish company producing PVC window and door systems is presented to illustrate the proposed framework. Chen et al. (2004) formulated a new fuzzy regression-based mathematical programming approach for the QFD product planning. The authors claim that the approach can help determine a set of the level of attainment of engineering characteristics for the new/improved product to satisfy a budget constraint and match or exceed the customer expectation of all competitors in the target market. Büyüközkan et al. (2004) used an analytic network process, the general form of AHP, with the fuzzy triangular number to prioritize ECs by taking the degree of the interdependence between the customer needs and ECs, and their inner dependences into account. Karsak (2004) proposed a fuzzy multiple objective programming approach as an alternative to the classical mathematical programming formulations for prioritizing design requirements in QFD planning process. The relationships between customer needs and design requirements, importance of customer needs, sales point data, extendibility and technical difficulty of the design requirements are incorporated into the model using linguistic variables, and uncertain cost data are efficiently represented employing triangular fuzzy numbers. Büyüközkan et al. (2005) proposed a new fuzzy group decision-making to fuse multiple preference styles to respond customer needs in product development with QFD in a better way.

### 4.5. AHP and FAHP

To deal with a complex, hierarchical MADM problem, Saaty (1980) proposed a method for selecting the available alternatives by decomposing a complex MADM problem into a system of hierarchy. His method, well known as the analytic hierarchy process, structures the decision problem into levels corresponding to goals, criteria, sub-criteria and alternatives, making it possible for the decision maker to focus on a smaller set of decisions. Commonly, a hierarchy has at least three levels, comprising the global or overall goal of the problem at the top, multiple criteria that define alternatives in the middle and the competing alternatives at the bottom. Figure 4.4 shows a generic hierarchic structure.

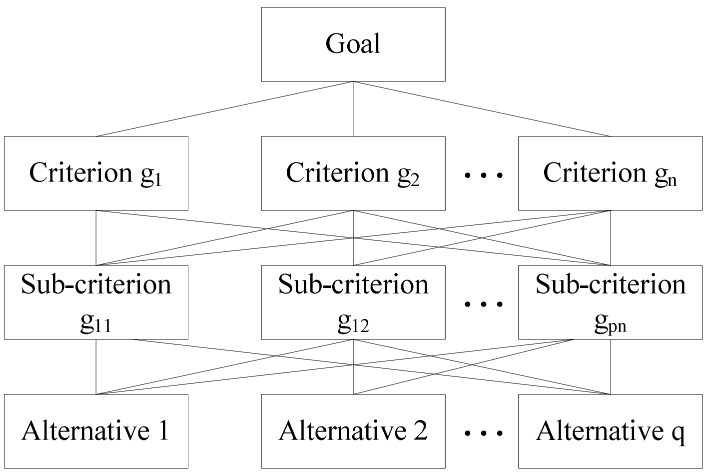


**Figure 4.4 :** Generic AHP structure.

The main feature of AHP is the utilization of pairwise comparison matrices to elicit the relative importance of the alternatives in terms of each criterion. It deals with the decision m x n matrix, which is constructed by using the relative importance of the alternatives with respect to each criterion. The vector ($a_{i1}$, $a_{i2}$, …, $a_{in}$) represents the principal eigenvector of an n x n reciprocal matrix which is determined by pairwise comparisons of the impact of the m alternatives on the $i^{th}$ criterion. The methodology of the AHP can be explained in following steps:

Step 1: The problem is decomposed into a hierarchy of goal, criteria, sub-criteria and alternatives. This is the most creative and important part of decision-making. Structuring the decision problem as a hierarchy is fundamental to the process of the AHP. At the root of the hierarchy is the goal or objective of the problem being studied and analyzed. The leaf nodes are the alternatives to be compared. In between these two levels are various criteria and sub-criteria. It is important to note that when comparing elements at each level a decision-maker has just to compare with respect to the contribution of the lower-level elements to the upper-level one. This local concentration of the decision-maker on only part of the whole problem is a powerful feature of the AHP.

Step 2: Data are collected from experts or decision-makers corresponding to the hierarchic structure, in the pairwise comparison of alternatives on a fundamental scale developed by Saaty (1994) as given in Table 4.1.

**Table 4.1 :** Pairwise comparison scale in AHP (Saaty, 1994).

| **Intensity of importance** | **Definition** | **Explanation** |
|---|---|---|
| **1** | Equal importance | Two activities contribute equally to the objective |
| **3** | Weak importance of one over another | Experience and judgment slightly favour one activity over another |
| **5** | Essential or strong importance | Experience and judgment strongly favour one activity over another |
| **7** | Demonstrated importance | An activity is strongly favored and its dominance is demonstrated in practice |
| **9** | Extreme importance | The evidence favoring one activity over another is of the highest possible order of affirmation. |
| **2, 4, 6, 8** | Intermediate value between the two adjacent judgments | When compromise is needed. |

Step 3: The pairwise comparisons of various criteria generated at step 2 are organized into a square matrix. The diagonal elements of the matrix are 1. The

criterion in the $i_{th}$ row is better than criterion in the $j^{th}$ column if the value of element (i, j) is more than 1; otherwise the criterion in the jth column is better than that in the *i*th row. The (j, i) element of the matrix is the reciprocal of the (i, j) element.

$$A = [a_{ij}] = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \qquad \textbf{(4.8)}$$

Step 4: The principal eigenvalue and the corresponding normalized right eigenvector of the comparison matrix give the relative importance of the various criteria being compared. The elements of the normalized eigenvector are termed weights with respect to the criteria or sub-criteria and ratings with respect to the alternatives.

Step 5: The consistency of the matrix of order *n* is evaluated. Comparisons made by this method are subjective and the AHP tolerates inconsistency through the amount of redundancy in the approach. If this consistency index fails to reach a required level then answers to comparisons may be re-examined. The consistency index, CI, is calculated as

$$CI = \frac{\lambda_{\max} - n}{n - 1} \qquad \textbf{(4.9)}$$

where $\lambda_{\max}$ is the maximum eigenvalue of the judgment matrix. This CI can be compared with that of a random matrix, RI given in Table 4.2. The ratio derived, CI/RI, is termed the consistency ratio, CR. The CR is acceptable if it does not exceed 0.10. The CR is > 0.10, the judgment matrix is inconsistent. To acquire a consistent matrix, judgments should be reviewed and improved.

**Table 4.2 :** Random consistency index values (Saaty, 2000).

| Size of matrix | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Random consistency Index | 0 | 0 | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

Step 6: The rating of each alternative is multiplied by the weights of the sub-criteria and aggregated to get local ratings with respect to each criterion. The local ratings are then multiplied by the weights of the criteria and aggregated to get global ratings.

The AHP produces weight values for each alternative based on the judged importance of one alternative over another with respect to a common criterion.

However, due to the uncertainty and vagueness of judgments of decision makers, the AHP seems insufficient and too imprecise to capture the decision makers' judgments correctly. However, this uncertainty in inputs can be modeled using the set of fuzzy theory by considering two more possible outcomes: smallest possible value and largest possible value. In the decision making environment of AHP, the relationship between criteria and alternatives are uncertain and imprecise as well as the input information. In order to improve these disadvantages of the AHP, a fuzzy extension of AHP, "FAHP", is applied to solve the hierarchical and MCDM problem.

The FAHP technique can be viewed as an advanced analytical method developed from the traditional AHP. Despite the convenience of AHP in handling both quantitative and qualitative criteria of multi-criteria decision making problems based on decision makers' judgments, fuzziness and vagueness existing in many decision-making problems may contribute to the imprecise judgments of decision makers in conventional AHP approaches (Bouyssou et al., 2000).

The essential step in the FAHP methodology is the prioritization procedure. There are several approaches for deriving priorities from the fuzzy pairwise comparison matrices. Among the conceptual papers, Buckley (1985) derived fuzzy comparison priorities from trapezoidal membership functions, Boender, De Grann, and Lootsma (1989) proposed an approach for local priority normalization, Deng (1999) presented an improved fuzzy approach to handle the multi-criteria problems in an uncomplicated manner, Leung and Cao (2000) discussed the consistency and ranking issues and contributed with a consistency definition. In view of the fact that FAHP method is applicable to many selection and evaluation type of problems, various application oriented papers appeared in the literature. Table 4.3 lists some of these approaches.

Many of the FAHP applications on various cases can be found in literature based on Chang's extent analysis. Kwong and Bai (2002) applied this method to prioritize customer requirements in the QFD. On the other hand, Bozdağ et al. (2003) utilized this approach in the evaluation of CIM alternatives. Kahraman et al. (2004) developed an analytical tool to select one of the catering firm alternatives in Turkey. Relationship between competitiveness and technology management was established by Erensal et al. (2006) using FAHP-based on Chang's extent analysis. Chan and Kumar (2007) proposed risk-based global supplier development model utilizing with fuzzy extended AHP-based approach. Kang and Lee (2007) structured FAHP-based ranking system for semiconductor fabrication. Göleç and Taşkın (2007) presented a comparative study to establish complex fuzzy methodologies in evaluating the performance of a manufacturing system and showed that FAHP leads to the best result. Also, this study uses Chang's FAHP method for determining the weights of the tasks In the following paragraphs, the outline of the extent analysis method on FAHP are given.

**Table 4.3 :** Comparison of different FAHP methods (Büyüközkan et al., 2004).

| **Sources** | **The main characteristics of the method** | **Advantages (A) / Disadvantages (D)** |
|---|---|---|
| **Van Laarhoven and Pedrycz (1983)** | • Direct extension of Saaty's AHP method with triangular fuzzy numbers<br>• Lootsma's logarithmic least square method is used to derive fuzzy weights and fuzzy performance scores | **(A)** The opinions of multiple decision makers can be modeled in the reciprocal matrix<br>**(D)** There is not always a solution to the linear equations<br>**(D)** The computational requirement is tremendous, even for a small problem<br>**(D)**It allows only triangular fuzzy numbers to be used |
| **Buckley (1985)** | • Extension of Saaty's AHP method with trapezoidal fuzzy numbers<br>• Uses the geometric mean method to derive fuzzy weights and performance scores | **(A)** It is easy to extend to the fuzzy case<br>**(A)** It guarantees a unique solution to the reciprocal comparison matrix<br>**(D)** The computational requirement is tremendous |
| **Boender et al. (1989)** | • Modifies Van Laarhoven and Pedrycz's method<br>• Presents a more robust approach to the normalization of the local priorities | **(A)** The opinions of multiple decision makers can be modeled<br>**(D)** The computational requirement is tremendous |
| **Chang (1996)** | • Synthetical degree values<br>• Layer simple sequencing<br>• Composite total sequencing | **(A)** The computational requirement is relatively low<br>**(A)** It follows the steps of crisp AHP. It does not involve additional operations<br>**(D)** It allows only triangular fuzzy numbers to be used |
| **Cheng (1996)** | • Builds fuzzy standards<br>• Represents performance scores by membership functions<br>• Uses entropy concepts to calculate aggregate weights | **(A)** The computational requirement is not tremendous<br>**(D)** Entropy is used when probability distribution is known. The method is based on both probability and possibility measures |

Let $O=\{o_1,o_2,...,o_n\}$ be an object set, and $U=\{g_1,g_2,...,g_m\}$ be a goal set. According to the Chang's extent analysis, each object is considered one by one, and for each object, the analysis is carried out for each of the possible goals, $g_i$. Therefore, m extent analysis values for each object are obtained and shown as follows:

$\tilde{M}_{g_i}^1,\tilde{M}_{g_i}^2,...,\tilde{M}_{g_i}^m \quad i=1,2,...,n$ where all the $\tilde{M}_{g_i}^j \quad (j=1,2,...,m)$ are triangular fuzzy numbers. The steps of the Chang's extent analysis can be summarized as follows:

Step 1: The value of fuzzy synthetic extent with respect to the i[th] object is defined as:

$$S_i=\sum_{j=1}^{m}M_{g_i}^j\otimes\left[\sum_{i=1}^{n}\sum_{j=1}^{m}M_{g_i}^j\right]^{-1} \qquad \textbf{(4.10)}$$

To obtain $\sum_{j=1}^{m}M_{g_i}^j$, we perform the fuzzy addition operation of *m* extent analysis values for a particular matrix such that

$$\sum_{j=1}^{m}\tilde{M}_{g_i}^j=\left(\sum_{j=1}^{m}l_j,\sum_{j=1}^{m}m_j,\sum_{j=1}^{m}u_j\right) \qquad \textbf{(4.11)}$$

and to obtain $\left[\sum_{i=1}^{n}\sum_{j=1}^{m}M_{g_i}^j\right]^{-1}$ we perform the fuzzy addition operation of $\tilde{M}_{g_i}^j \quad (j=1,2,...,m)$ values for a particular matrix such that,

$$\sum_{i=1}^{n}\sum_{j=1}^{m}\tilde{M}_{g_i}^j=\left(\sum_{i=1}^{n}l_i,\sum_{i=1}^{n}m_i,\sum_{i=1}^{n}u_i\right) \qquad \textbf{(4.12)}$$

Then, the inverse of the vector is computed as,

$$\left[\sum_{i=1}^{n}\sum_{j=}^{m}\tilde{M}_{g_i}^j\right]^{-1}=\left(\frac{1}{\sum_{i=1}^{n}u_i},\frac{1}{\sum_{i=1}^{n}m_i},\frac{1}{\sum_{i=1}^{n}l_i}\right) \text{ where } \forall\, u_i, m_i, l_i>0 \qquad \textbf{(4.13)}$$

Step 2: The degree of possibility of $\tilde{M}_2 = (l_2, m_2, u_2) \geq \tilde{M}_1 = (l_1, m_1, u_1)$ îs defined as $V\left(\tilde{M}_2 \geq \tilde{M}_1\right) = \sup_{y \geq x}\left[\min\left(\mu_{\tilde{M}_1}(x), \mu_{\tilde{M}_2}(y)\right)\right]$ which can be equivalently expressed as,

$$V\left(\tilde{M}_2 \geq \tilde{M}_1\right) = hgt(\tilde{M}_1 \cap \tilde{M}_2) = \begin{cases} 1 & if \quad m_2 \geq m_1 \\ 0 & if \quad l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & otherwise \end{cases} \qquad \textbf{(4.14)}$$

Figure 4.5 illustrates where d is the ordinate of the highest intersection point D between $\mu_{\tilde{M}_1}$ and $\mu_{\tilde{M}_2}$. To compare $M_1$ and $M_2$, we need both the values of $V\left(\tilde{M}_2 \geq \tilde{M}_1\right)$ and $V\left(\tilde{M}_1 \geq \tilde{M}_2\right)$.

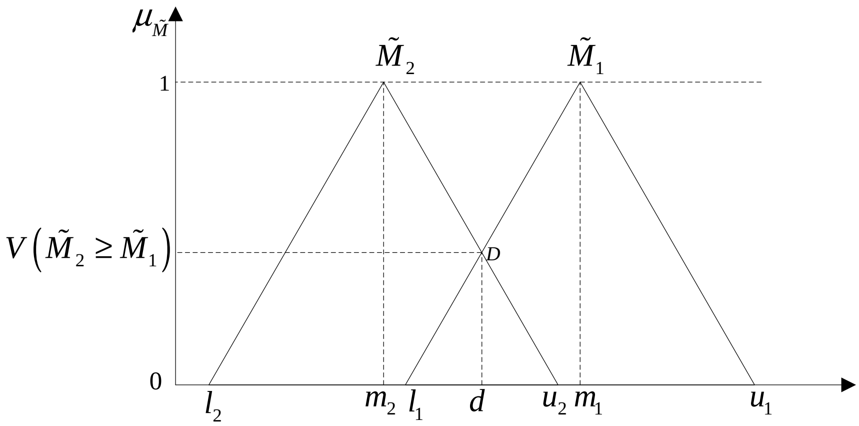


**Figure 4.5 :** Interaction between $M_1$ and $M_2$.

Step 3: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $\tilde{M}_i$ (i = 1, 2, ..., k) can be defined by

$$V\left(\tilde{M} \geq \tilde{M}_1, \tilde{M}_2, ..., \tilde{M}_k\right) = V\left(\tilde{M} \geq \tilde{M}_1\right) \cap V\left(\tilde{M} \geq \tilde{M}_2\right) \cap ... V\left(\tilde{M} \geq \tilde{M}_k\right)$$

$$= \min V\left(\tilde{M} \geq \tilde{M}_i\right) \quad i = 1, 2, ..., k \qquad \textbf{(4.15)}$$

Assume that $d(A_i) = \min \; V(S_i \leq S_k)$ for k = 1, 2, ..., n; k ≠ i. Then the weight vector is given by

$$W' = \left(d'(A_1), d'(A_2), \ldots, d'(A_n)\right)^T \qquad \textbf{(4.16)}$$

where $A_i \,(i = 1, 2, \ldots, n)$ are n elements.

Step 4: Via normalization, the normalized weight vectors are:

$$W = \left(d(A_1), d(A_2), \ldots, d(A_n)\right)^T \qquad \textbf{(4.17)}$$

where W is a non-fuzzy number.

Despite the intensive use of Chang's extent analysis method in the FAHP literature, Wang and Hua (2007) suggested that the Chang's extent analysis method cannot estimate the true weights from a fuzzy comparison matrix and has led to quite a number of misapplications in the literature. They have shown by examples that the priority vectors determined by the extent analysis method do not represent the relative importance of decision criteria or alternatives and that the misapplication of the extent analysis method to FAHP problems may lead to a wrong decision to be made and some useful decision information such as decision criteria and fuzzy comparison matrices not to be considered. They have also shown that the extent analysis method might assign an irrational zero weight to some useful decision criteria and sub-criteria, leading to them not to be considered in decision analysis, and hence the extent analysis method could not make full use of all the fuzzy comparison matrices information and might cause some useful fuzzy comparison matrices information to be wasted. Therefore in addition to Chang's extent analysis, two other prioritization methods in FAHP, namely, additive prioritization as proposed by Deng (1999) and prioritization by geometric means (Buckley, 1985) are proposed to be used comparatively in the course of FQFD process for ranking the tasks involved in the job in question.

### 4.6. TOPSIS and FTOPSIS

Technique for Order Performance by Similarity to Ideal Solution (TOPSIS), one of the known classical MCDM methods, also was first developed by Hwang and Yoon (1981). It bases upon the concept that the chosen alternative should have the shortest distance from the Positive Ideal Solution (PIS), i.e., the solution that maximizes the benefit criteria and minimizes the cost criteria; and the farthest from the Negative Ideal Solution (NIS), i.e., the solution that maximizes the cost criteria and minimizes the benefit criteria.

According to Kim et al. (1997) and Shih et al. (2006), four TOPSIS advantages are addressed: (i) a sound logic that represents the rationale of human choice; (ii) a scalar value that accounts for both the best and worst alternatives simultaneously; (iii) a simple computation process that can be easily programmed into a spreadsheet; and (iv) the performance measures of all alternatives on attributes can be visualized on a polyhedron, at least for any two dimensions.

To clarify its features, the characteristics of TOPSIS and AHP are compared in Table 4.4. We can see that the major weaknesses of TOPSIS are in not providing for weight elicitation, and consistency checking for judgments. However, AHP's employment has been significantly restrained by the human capacity for information processing, and thus; the number seven plus or minus two would be the ceiling in comparison (Saaty and Özdemir, 2003). From this viewpoint, TOPSIS alleviates the requirement of paired comparisons and the capacity limitation might not significantly dominate the process. Hence, it would be suitable for cases with a large number of attributes and alternatives, and especially handy for objective or quantitative data given.

**Table 4.4 :** Comparison of characteristics of AHP and TOPSIS, (Shih et al., 2006).

| **Characteristics** | **AHP** | **TOPSIS** |
|---|---|---|
| Category | Cardinal information, information on attribute, MADM | Cardinal information, information on attribute, MADM |
| Core process | Pairwise comparison (cardinal ratio measurement) | The distances from PIS and NIS (cardinal absolute measurement) |
| Attribute | Given | Given |
| Weight elicitation | Pairwise comparison | Given |
| Consistency check | Provided | None |
| No. of attributes accommodated | 7 ± 2 or hierarchical decomposition | Many more |
| No. of alternatives accommodated | 7 ± 2 | Many more |
| Others | Compensatory operation | Compensatory operation |

The TOPSIS procedure consists of the following steps:

Suppose there are J alternatives denoted as $a_1,\dots,a_j$. For alternative $a_j$, the rating of the i^th^ aspect is denoted by $f_{ij}$, i.e. $f_{ij}$ is the value of i^th^ criterion function for the alternative $a_j$.

Step 1: Calculate the normalized decision matrix. The normalized value $r_{ij}$ is calculated as

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{J} f_{ij}^2}} \text{ for i = 1,…, n j = 1,…, J.} \tag{4.18}$$

Step 2: Calculate the weighted normalized decision matrix. The weighted normalized value $v_{ij}$ is calculated as

$$v_{ij} = w_i r_{ij} \text{, for i = 1,…, n j = 1,…, J} \tag{4.19}$$

where $w_i$ is the weight of the i^th^ attribute or criterion, and $\sum_{i=1}^{n} w_i = 1$.

Step 3: Determine the ideal and negative-ideal solution.

$$A^* = \left\{v_1^*,\dots,v_n^*\right\} = \{(\max_j v_{ij} \mid i \in J_1),(\min_j v_{ij} \mid i \in J_2)\} \tag{4.20}$$

$$A^- = \left\{v_1^-,\dots,v_n^-\right\} = \{(\min_j v_{ij} \mid i \in J_1),(\max_j v_{ij} \mid i \in J_2)\} \tag{4.21}$$

where $J_1$ is associated with benefit criteria, and $J_2$ is associated with cost criteria.

Step 4: Calculate the separation measures, using the n-dimensional Euclidean distance. The separation of each alternative from the ideal solution is given as

$$d_j^* = \sqrt{\sum_{i=1}^{n} (v_{ij} - v_i^*)^2} \text{ , j=1,2,…,J} \tag{4.22}$$

Similarly, the separation from the negative ideal solution is given as

$$d_j^- = \sqrt{\sum_{i=1}^{n} (v_{ij} - v_j^-)^2} \text{ , j=1,2,…,J} \tag{4.23}$$

Step 5: Calculate the relative closeness to the ideal solution. The relative closeness of the alternative $a_j$ with respect to $A^*$ is defined as

$$C_j^* = \frac{d_j^-}{d_j^- + d_j^*}\text{ , j=1,2,…,J} \qquad \textbf{(4.24)}$$

Step 6: Rank the preference order.

Due to the similar reasons valid for AHP, TOPSIS has been extended to FTOPSIS in which the ratings and weights of the criteria in the problem are assessed by means of linguistic variables. These FTOPSIS applications differ from each other in terms of attribute weights, type of fuzzy numbers used, ranking methods and normalization methods. Kahraman et al. (2007) made a comparison of the FTOPSIS methods in the literature as given in Table 4.5.

**Table 4.5 :** Comparison of FTOPSIS methods (Kahraman et al., 2007).

| Source | Attribute weights | Type of fuzzy numbers | Ranking method | Normalizatio n method |
|---|---|---|---|---|
| Chen and Hwang (1992) | Fuzzy numbers | Trapezoidal | Lee and Li’s (1998) generalized mean method | Linear normalization |
| Liang (1999) | Fuzzy numbers | Trapezoidal | Chen’s (1985) ranking with maximizing set and minimizing set | Manhattan distance |
| Chen (2000) | Fuzzy numbers | Triangular | Chen (2000) assumes the fuzzy positive and negative ideal solutions as (1, 1, 1) and (0, 0, 0) respectively | Linear normalization |
| Chu (2002) | Fuzzy numbers | Triangular | Liou and Wang’s (1992) ranking method of total integral value with $\alpha = 1/2$ | Modified Manhattan distance |
| Tsaur et al. (2002) | Crisp values | Triangular | Zhao and Govind’s (1991) centre of area method | Vector normalization |
| Chu and Lin (2003) | Fuzzy numbers | Triangular | Kaufmann and Gupta’s (1988) mean of the removals method | Linear normalization |
| Zhang and Lu (2003) | Crisp values | Triangular | Chen’s (2000) fuzzy positive and negative ideal solutions: as (1, 1, 1) and (0, 0, 0) respectively | Manhattan distance |

A few significant studies employing FTOPSIS in the literature may be summarized as follows. Triantaphyllou and Lin (1996) developed a fuzzy version of the TOPSIS method based on fuzzy arithmetic operations, which leads to a fuzzy relative closeness for each alternative. Chen (2000) extends the TOPSIS method to fuzzy group decision making situations by defining a crisp Euclidean distance between any two fuzzy numbers. Chu (2002) presents a FTOPSIS model for solving the facility location selection problem. Tsaur, Chang and Yen (2002) first convert a fuzzy MCDM problem into a crisp one via centroid defuzzification and then solve the nonfuzzy MCDM problem using the TOPSIS method. Zhang and Lu (2003) present an integrated fuzzy group decision-making method in order to deal with the fuzziness of preferences of the decision-makers. Chu and Lin (2003) propose a FTOPSIS approach for robot selection where the ratings of various alternatives under different subjective attributes and the importance weights of all attributes are assessed in linguistic terms represented by fuzzy numbers.

### 4.7. VIKOR

The VIKOR (the Serbian name, VlseKriterijumska Optimizacija iKompromisno Resenje, means Multi-criteria Optimization and Compromise Solution) method was introduced as one applicable technique to implement within MCDM (Opricovic, 1998). It determines the compromise ranking-list, the compromise solution, and the weight stability intervals for preference stability of the compromise solution obtained with the initial (given) weights. This method focuses on ranking and selecting from a set of alternatives in the presence of conflicting criteria. The VIKOR method introduces an aggregating function, representing the distance from the ideal solution. This ranking index is an aggregation of all criteria, the relative importance of the criteria, and a balance between total and individual satisfaction.

VIKOR is a helpful tool in multi-criteria decision making, particularly in a situation where the decision maker is not able, or does not know to express his/her preference at the beginning of system design. The obtained compromise solution could be accepted by the decision makers because it provides a maximum ‘‘group utility’’ of the ‘‘majority’’, and a minimum of the individual regret of the ‘‘opponent’’. The compromise solutions could be the basis for negotiations, involving the decision makers’ preference by criteria weights. The compromise ranking algorithm VIKOR has the following steps:

Step 1: Determine the best solution ( $f_i^*$) and the worst solution ( $f_i^-$ ) for all assessment criteria. $I_1$ and $I_2$ in equations (4.25) and (4.26) represent benefit criteria set and cost criteria set respectively.

$$f_i^* = [(\max_j f_{ij} \mid i \in I_1) \ , (\min_j f_{ij} \mid i \in I_2)] \ , \forall_i \tag{4.25}$$

$$f_i^- = [ (\min_j f_{ij} \mid i \in I_1 ) , (\max_j f_{ij} \mid i \in I_2 ) ] \ , \forall_i \tag{4.26}$$

Step 2: Calculate the $S_j$ and $R_j$ values where $(f_i^*-f_{ij})/(f_i^*-f_i^-)$ in Equations (4.27) and (4.28) is the distance ratio of the i criterion of j to the ideal solution. $w_i$ is the weight obtained by using the i criterion. By adding all criteria in j together, we can get the maximum "collective" benefit ($S_j$). $R_j$ is the ratio criterion selected from j and is farthest from the ideal solution. The smaller $S_j$ and $R_j$ are, the better j will be.

$$S_j = \sum_{i=1}^{n} w_i ( f_i^* - f_{ij} ) / ( f_i^* - f_i^- ) \tag{4.27}$$

$$R_j = \max_i \left[ w_i ( f_i^* - f_{ij} ) / ( f_i^* - f_i^- ) \right], \ \ j = 1,2,\ldots.J \tag{4.28}$$

Step 3: Calculate the Q value where $Q_j$ is the benefit value of j combining collective ($S_j$) and individual ($R_j$). Its calculation is shown in Equation (4.29). The parameter *v* is the coefficient for decision-making mechanism. When it is larger than 0.5, *v* will represent the decision of the majority of the people. When it is equal to 0.5, *v* represents the decision that is passed reluctantly. When it is smaller than 0.5, v means that the decision is not approved.

$$Q_j = v(S_j - S^*)/(S^- - S^*) + (1-v)(R_j - R^*)/(R^- - R^*) \tag{4.29}$$

where $S^* = \min_j S_j$ , $S^- = \max_j S_j$ , $R^* = \min_j R_j$ , $R^- \max_j R_j$

Step 4: Rank the alternatives, sorting by the values S, R and Q, in decreasing order. The results are three ranking lists.

Step 5: Propose as a compromise solution the alternative a′ which is ranked the best by the measure Q (minimum) if the following two conditions are satisfied:

Condition 1: The alternative a′ has an acceptable advantage, in other words Q(a″)-Q(a′)≥DQ where $DQ = 1/(m-1)$ and m is the number of alternatives (DQ = 0.25 if m ≤ 4) and; a′ and a″ are the optimum and second optimum solution respectively according to ranking of Q values.

Condition 2: The alternative a′ is stable within the decision-making process, in other words it is also the best ranked in S and/or R. This compromise solution is stable within a decision making process, which could be: ‘‘voting by majority rule’’ (when *v* > 0:5 is needed), or ‘‘by consensus’’ *v* ≈ 0:5, or ‘‘with veto’’ (*v* < 0:5). Here, v is the weight of the decision making strategy ‘‘the majority of criteria’’ (or ‘‘the maximum group utility’’).

If either one of the above two requirements fails to be satisfied, we can work out a compromised solution by the following means: (1) If the first requirement fails to be satisfied, and shall be taken as the compromised solution. (2) If the second requirement fails to be satisfied, $a', a'', \ldots, a^{(M)}$ shall be taken as the compromised solution.

If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consists of:

• Alternatives a′ and a″ if only condition 2 is not satisfied, or

• Alternatives $a', a'', \ldots, a^{(M)}$ if condition 1 is not satisfied; and $a^{(M)}$ is determined by the relation $Q\left(a^{(M)}\right) - Q(a') < DQ$ for maximum M (the positions of these alternatives are ‘‘in closeness’’).

The best alternative, ranked by Q, is the one with the minimum value of Q. The main ranking result is the compromise ranking list of alternatives, and the compromise solution with the ‘‘advantage rate’’.

Due to the similar reasons mentioned for AHP and TOPSIS; VIKOR also has been extended to FVIKOR in which the ratings and weights of the criteria in the problem are assessed by means of linguistic variables. There is not an intensive study about FVIKOR in the literature. The FVIKOR method applied in this study is based on Büyüközkan and Ruan (2008) which will be explained in Chapter 5.

### 4.8. Previous Research about Fuzzy Personnel Selection and Allocation Models

There is not much work in the literature about personnel selection or allocation which uses fuzzy sets, fuzzy arithmetics or any MCDM method which is extended for including vague and subjective information by using fuzzy concepts and linguistic variables.

Liang and Wang (1994) present a fuzzy multi-criteria decision making algorithm for personnel selection. Their approach makes use of fuzzy ranking methods to determine the most suitable candidate. Shaout and Al-Shammari (1998) presents a proposed application of the fuzzy set theory to a personnel performance evaluation system. An application to the performance evaluation in a higher educational setting is proposed. Their study is intended to provide an illustrative example that would encourage the application of fuzzy set theory in the domain of the multi-attribute performance appraisal of faculty members.

Shipley et al. (1999), applies fuzzy logic to multi-attribute decision making problem where the project manager must select project team members from candidates, none of whom may exactly satisfy the ideal level of skills needed at any point in time. The decision mechanism is constrained by the uncertainty inherent in the determination of the relative importance of each skill and the classification of potential team members. This latter uncertainty of potential team membership is addressed through expert evaluation of the degree to which each potential team member possesses each skill. Then the belief and plausibility that a candidate will satisfy the decision maker's ideal skill levels are calculated and combined to rank order the available candidates. The changing skill requirements are addressed through an iterative process for each project phase.

Yaakob and Kawata (1999) presented a new proposal to solve the problem of placement of workers in a production line. The authors focused on the group evaluation among the workers assigned to a group via using triangular fuzzy numbers and fuzzy arithmetics. In their paper, not only the individual evaluation but also the group evaluation are performed and included to find a better combination based on the relationship among workers to assigned to groups. The objective is the maximization of a composite function obtained by summing the workers suitability and the relationship among the team members for each job.

Karsak (2000) proposed a fuzzy multiple objective programming approach for personnel selection. The proposed method integrates the decision-maker's linguistic assessments about subjective factors such as excellence in oral communication skills, personality, leadership, and quantitative factors such as aptitude test score within the multiple objective programming framework. The importance degree of each objective is considered by applying the composition operator to the objective's membership function and the membership function corresponding to its fuzzy priority defined by linguistic variables.

Shen et al. (2002) proposed a multi-criteria assessment model that considers the relationships between human resources. They underline the fact that several workers, with different skills and expertise, may share the same role in the organization but the selection of appropriate individuals, based merely on the relationship between a role and a task, is not very effective. They also take into account the social relationships among workers and the learning process to evaluate worker performance. They use linguistic variables and fuzzy numbers to evaluate worker suitability for each task.

Kwak et al. (2003) adopts a fuzzy set approach to solve human resource allocation problems. A solution procedure based on a fuzzy set approach is proposed to systematically identify a satisfying selection of possible staffing solutions that can reach the best compromise value for the multiple objectives and multiple constraint levels associated with risk or ambiguity in audit planning problem. The study deals with the risk or the ambiguity in an audit planning and staffing problem so that certified public accountants firm can make a realistic decision regarding its human resource allocation problems as well as the firm's overall strategic resource management when environmental factors are uncertain.

Tseng et al. (2003) proposed a solution to assist a company to form project teams through grouping system characteristics and selecting qualified members. The methodology is based on fuzzy sets theory and grey decision theory. Fuzzy sets theory is applied to deal with problems involving ambiguities, which are normally confronted in multi-functional teams formation practice and form groups, when there is no clear boundary for relationship between customers' requirements and project characteristics. The fuzzy planning matrix was used to collect and represent the data for the multifunctional team selection model. Also, a grey decision making approach was formulated to determine the required composition of teams.

Golec and Kahya (2006) utilizes the theory of fuzzy sets to demonstrate the applicability of fuzzy logic for expressing the inherent imprecision in the way that people think and make decisions about the employee evaluation and selection process. Their study proposes an approach to minimizing subjective judgment in the effective employee evaluation and selection in the existence of the multi-factor competency-based measures in a hierarchical structure.

Canos and Viern (2006) developed a flexible decision support system to help managers in their decision-making functions. This decision support system simulates experts' evaluations using ordered weighted average aggregation operators, which assign different weights to different selection criteria. They also show an aggregation model based on efficiency analysis to put the candidates into an order. Their proposal is to evaluate the candidates by means of a fuzzy weighted mean of their competences and to sort the candidates using a ranking method for fuzzy quantities.

Baran and Kılağız (2006) developed a multi-criteria and multi-experts academician selection system developed for universities using fuzzy weighting and fuzzy ranking. In the proposed system, effects of many criteria and views of many experts are evaluated for selection. Number of criteria, number of linguistic variables of criteria, names of linguistic variables, membership functions of linguistic variables, number of experts and alternatives is flexible in the proposed system. Experts can determine importance levels of criteria and performance of each alternative for each criterion as linguistic or numerical. The system weights the alternatives using standard fuzzy arithmetic and ranks as fuzzy. Maximizing set and minimizing set method has been used for ranking alternatives.

Güngör et al. (2008) proposed a personnel selection system based on FAHP. The FAHP is applied to evaluate the best adequate personnel dealing with the rating of both qualitative and quantitative criteria. The result obtained by FAHP is compared with results produced by Yager's weighted goals method. In addition to above mentioned methods, a practical computer-based decision support system is introduced to provide more information and help managers make better decisions under fuzzy circumstances.

Huang et al. (2008) proposed a systematic approach with a feedback mechanism in which the interdependences among positions and the differences among the selected employees are considered simultaneously. The purpose of their study is to obtain the best matching of candidates and positions in order to organize a collaboratively cross-functional team. In the proposed approach, a bi-objective binary integer programming model is formulated. Based on the weighted composite scores determined in the third step of the proposed procedure, the binary integer programming model is transformed into a fuzzy bi-objective goal programming model. An elaborately designed heuristic algorithm is developed to determine the appropriate values of several important parameters in the fuzzy bi-objective goal programming model, which is solved using LINDO 8.0.

The common point in these research papers mentioned above is that they do not take content-validity and criterion-validity into account. They do not use FQFD and/or job analysis as a basis for identifying necessary knowledge, skills, abilities and other qualifications required for performing the job. The selection or allocation criteria are chosen arbitrarily for the sake of emphasizing the usage of fuzzy concepts in the field of personnel selection research.

### 4.9. Chapter Summary

In this chapter, basic information about the fuzzy decision making techniques used in this study and rationale of using these techniques have been explained. The proposed model in this study uses FAHP to determine the weights of the tasks and; FTOPSIS, and FVIKOR methods have been used in the final selection process. The types of fuzzy decision making methods used in the final selection phase could be extended to other methods such as Fuzzy PROMETHEE, or Fuzzy ELECTRE III and etc. However, not to diverge from the main point, this study is limited to using FTOPSIS and FVIKOR methods in the final selection phase.

In the last section of this chapter, the personnel selection research which is based on fuzzy sets has been explained. As it has been mentioned above, FQFD has not been used in any of these studies and KSAOs used in these studies are identified arbitrarily without performing a job analysis and considering performance-predictor relationships. Thus, these studies are not based on performance theories and personnel selection research. The main focus in these studies is generally the delineation of the analytical methods used. Different from them, this study bases the proposed model on previous personnel selection and performance research as well as it uses fuzzy decision making approaches. The framework of the proposed model and the computational procedures of these fuzzy decision making methods will be explained in the following chapter.

# 5. PROPOSED PERSONNEL SELECTION MODEL BASED ON FUZZY QUALITY FUNCTION DEPLOYMENT

The proposed model in this study uses FQFD as a framework to translate the content of the job into personnel characteristics and personnel characteristics into the candidates. The translation of job content into personnel characteristics, which are stated in terms of KSAOs, is performed at the task level because in hiring an employee for a certain position, what the employer is really interested in the first place is the performance of personnel in the tasks or activities involved in the job in question rather than the characteristics of the personnel.

A task refers to a specific action being applied to a specific object, and must be observable, have a definite beginning and end, and result in a completed work action or measurable product (Gael, 1990). However, task statements solely do not explain all aspects of the job in order to cover the whole job content. Therefore, these task statements should also include, tools and technology used, organizational and work context descriptors. Tools and technology involve machines, equipment, tools, software, and information technology which employees may use for optimal functioning in a high performance workplace. Organizational context involves characteristics of the organization that influence how people do their work. Work context descriptors are conditions under which job activities must be carried out including physical conditions (e.g., temperature and noise) and social-psychological conditions (e.g., time pressure and dependence on others) that have the potential to influence how people perform certain work activities. In the following sections, an overview of the proposed model, its computational details and its application for two real-life cases are presented.

## 5.1. Model Overview

The proposed FQFD process for personnel selection has two phases as seen in Figure 5.1. In Phase I of the FQFD process, tasks correspond to the CAs; and similarly, personnel characteristics correspond to the ECs of the traditional HoQ process performed in the product design applications where statements of tasks and personnel characteristics required to perform the job are the outcomes of the work-oriented and worker-oriented job analysis processes respectively.

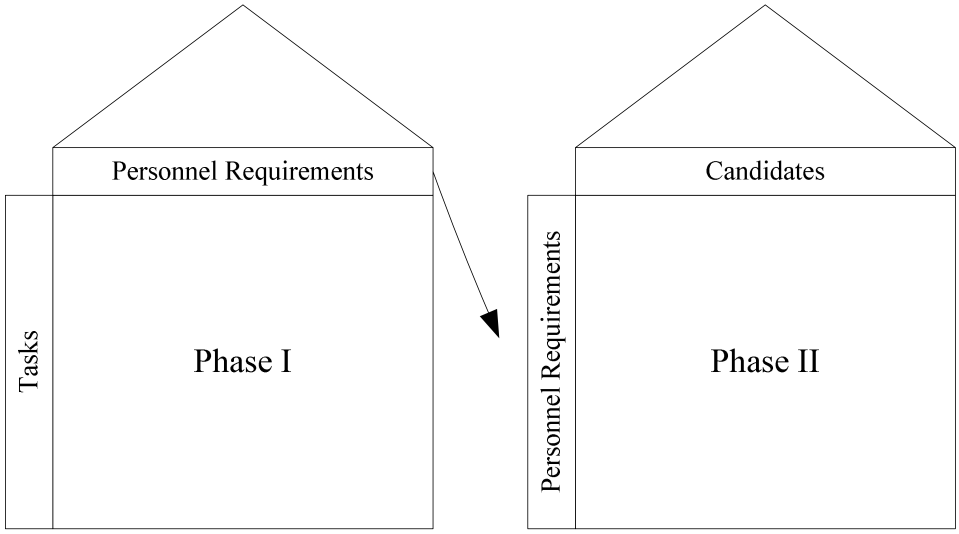


**Figure 5.1 :** FQFD process in personnel selection context.

In Phase I, first the relative weights of the tasks are determined by FAHP. Next, the level of relationship between each task and each personnel characteristic are identified (if there exists) by the SMEs and/or job incumbents. The importance weights of the characteristics are obtained by fuzzy weighted sum as the final outcome of this phase. Thus, statements of tasks involved in the job in question are translated into the personnel characteristics and their levels, which are required to perform the job with the desired performance level.

In Phase II, a matrix of personnel characteristics vs. candidates is constructed and each candidate is evaluated based on each personnel characteristic. By using the personnel characteristics' weights obtained in Phase I, FMCDM methods (FTOPSIS and FVIKOR) are applied to rank the candidates with respect to required personnel characteristics. The computational procedures of the proposed model are explained in the following sections.

### 5.2. The Proposed Personnel Selection Model

The proposed model described in Figure 5.1 has three major stages as seen in Figure 5.2. The first two stages are involved in the Phase I and; Stage 3 is involved in the Phase II of the FQFD process as described above. These three stages are as follows:

1. Determination of tasks' importance ratings by using FAHP

2. Tasks - (KSAOs) Linkages

3. Final selection

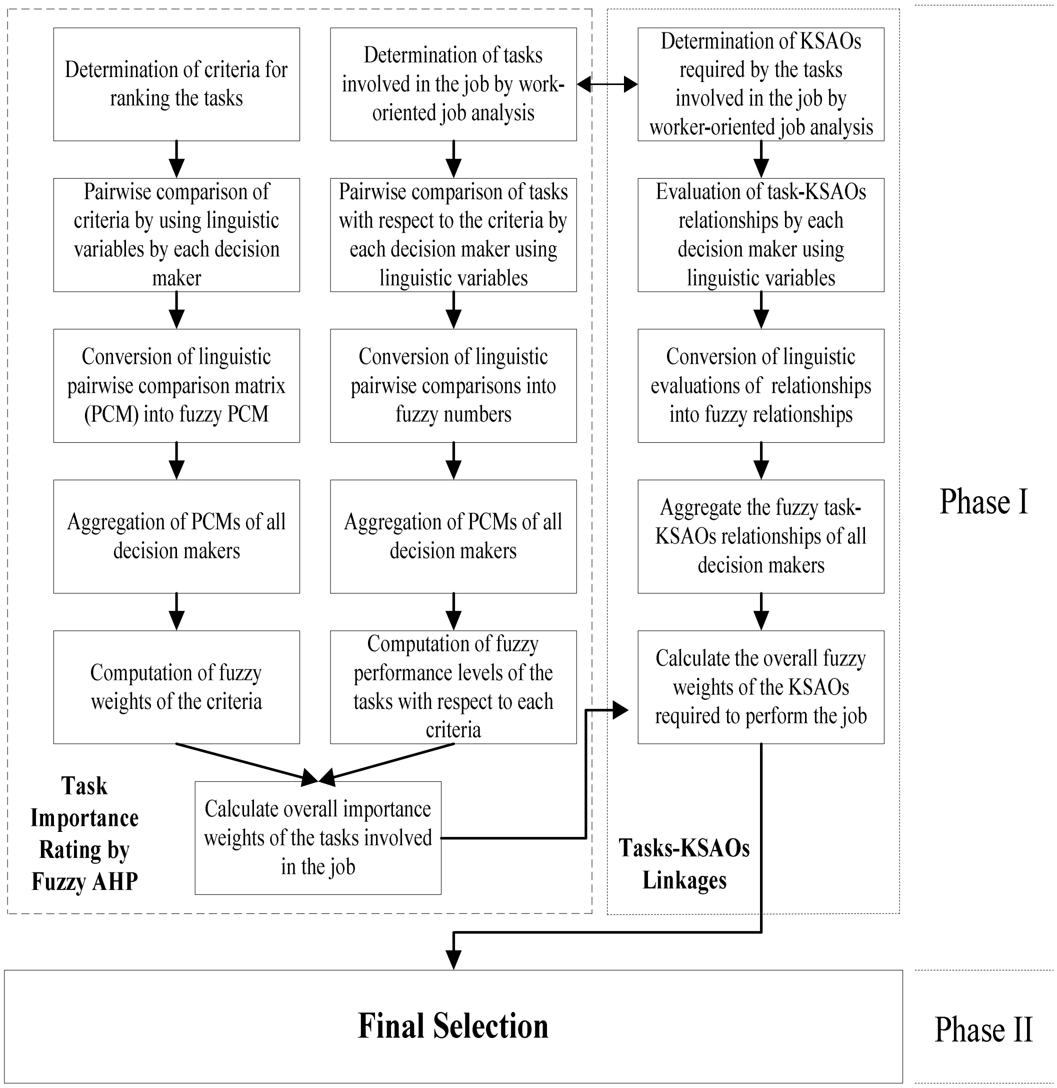


**Figure 5.2 :** Steps of the proposed personnel selection model.

In the following sections, the steps involved in the three stages of the model are given in detail.

### 5.2.1. Determination of tasks' importance ratings by using FAHP

The Phase I of FQFD aims to translate the tasks involved in the job in question to personnel characteristics required to perform the job and their levels. In order to perform this translation, the importance ratings of the tasks must be determined. The importance weights of the tasks are determined by a FAHP that is a quite popular method in determining the importance ratings in QFD applications. In the following sub-sections the steps of performing FAHP are explained in detail.

Step 1: Determination of criteria for ranking the tasks:

Overall task importance is complex, multidimensional, and often subjective (Harvey, 1991; Raymond, 2001; Sanchez & Levine, 1989). It is recommended that two or more one-dimensional scales be statistically combined into an overall composite of task importance. For example, a criticality scale when combined with a frequency scale would provide a very meaningful estimate of overall importance. Kane et al. (1989) found that indices of task importance derived from linear combinations of two other scales were generally more reliable than holistic judgments of task importance made on a single scale. Instead of linear combination different scales, this study proposes FAHP for determination of tasks' importance weights and overall task importance is operationalized by task criticality (TC), task frequency (TF) and time spent (TS) for the task where TC represents how much difference it makes in terms of client outcomes if the activity is performed well or badly and TF expresses how often the activity occurs. The decision hierarchy in the proposed is seen in Figure 5.3.

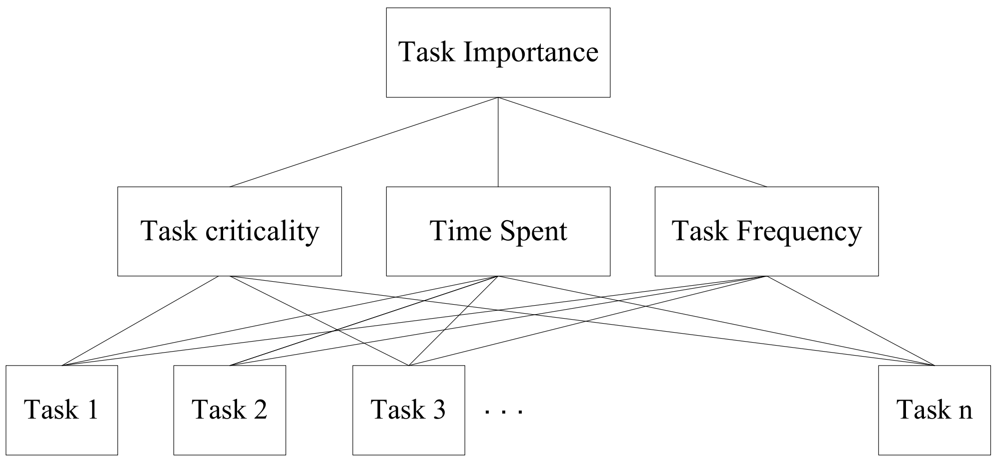


**Figure 5.3 :** Task importance hierarchy.

Step 2: Pairwise comparison of criteria by using linguistic variables by each decision maker:

The proposed model suggests the involvement of multiple decision makers in the personnel selection process since they may have different views about the contents and requirements of the jobs. In this step, three criteria, namely task criteria, task frequency and time spent, are compared with each other by each decision maker using the linguistic variables given in Table 5.1. It should be noted that the elements in the diagonal of the fuzzy pairwise comparison matrices are always “Just Equal” instead of “Equally Important”.

Step 3: Conversion of linguistic pairwise comparison matrix (PCM) into fuzzy PCM:

In fuzzifying the linguistic PCM into the fuzzy PCM, the linguistic variables and corresponding scales given in Table 5.1 have been used.

**Table 5.1 :** Triangular fuzzy conversion scale (Tüysüz and Kahraman, 2006).

| **Linguistic scale** | **Triangular fuzzy scale** | **Triangular fuzzy reciprocal scale** |
|---|---|---|
| Just Equal | (1, 1, 1) | (1, 1, 1) |
| Equally important | (1/2, 1, 3/2) | (2/3, 1, 2) |
| Weakly more important | (1, 3/2, 2) | (1/2, 2/3, 1) |
| Strongly more important | (3/2, 2, 5/2) | (2/5, 1/2, 2/3) |
| Very strongly more important | (2, 5/2, 3) | (1/3, 2/5, 1/2) |
| Absolutely more important | (5/2, 3, 7/2) | (2/7, 1/3, 2/5) |

As a result of this conversion, the fuzzy PCM ($\tilde{B}^k$) given below is obtained for each decision maker.

$$\tilde{B}^k = \begin{array}{c} \\ TC \\ TF \\ TS \end{array} \begin{array}{c} \begin{array}{ccc} TC & TF & TS \end{array} \\ \begin{bmatrix} \tilde{x}_{11}^k & \tilde{x}_{12}^k & \tilde{x}_{13}^k \\ \tilde{x}_{21}^k & \tilde{x}_{22}^k & \tilde{x}_{23}^k \\ \tilde{x}_{31}^k & \tilde{x}_{32}^k & \tilde{x}_{33}^k \end{bmatrix} \end{array} \qquad \textbf{(5.1)}$$

where $\tilde{x}_{ij}^k$ represents the fuzzy pairwise comparison of criteria *i* versus criteria *j* by decision maker *k*.

Step 4: Aggregation of PCMs of all decision makers:

If the decision group has *K* persons, then the pairwise comparison values in fuzzy PCM ($\tilde{B}^k$) can be aggregated by using geometric mean of the parameters of triangular numbers assigned by each decision maker. If we denote $ij^{th}$ value in aggregated fuzzy PCM as $\tilde{x}_{ij} = (L_{ij}, M_{ij}, R_{ij})$, then $L_{ij}$, $M_{ij}$ and $U_{ij}$ can be calculated as follows:

$$L_{ij} = \sqrt[K]{L_{ij}^1 \otimes L_{ij}^2 \otimes ... \otimes L_{ij}^K}\ ,\ i = 1,2,\ldots,m \text{ and } j = 1,2,\ldots,m \quad \textbf{(5.2)}$$

$$M_{ij} = \sqrt[K]{M_{ij}^1 \otimes M_{ij}^2 \otimes ... \otimes M_{ij}^K}\ ,\ i = 1,2,\ldots,m \text{ and } j = 1,2,\ldots,m \quad \textbf{(5.3)}$$

$$U_{ij} = \sqrt[K]{U_{ij}^1 \otimes U_{ij}^2 \otimes ... \otimes U_{ij}^K}\ ,\ i = 1,2,\ldots,m \text{ and } j = 1,2,\ldots,m \quad \textbf{(5.4)}$$

where $K$ is the number of decision makers.

Step 5: Computation of fuzzy weights of the criteria:

The fuzzy weights of the criteria can be calculated by additive prioritization method as used by Deng (1999) as follows:

$$\tilde{w}_i = \frac{\sum_{j=1}^{m} \tilde{x}_{ij}}{\sum_{j=1}^{m} \sum_{i=1}^{m} \tilde{x}_{ij}} \quad \textbf{(5.5)}$$

where $i$ = *TC, TF and TS* and $j$ = *TC, TF and TS*.

Based on the fuzzy weights we have obtained by equation (5.5), we can perform Chang's extent analysis which is explained in section 4.5. At this step, we can calculate the degree of possibility of $V(\tilde{w}_i \geq \tilde{w}_k)\ \forall i,k,\ i \neq k$ by using equation (4.14). Assuming that $d(A_i) = \min\ V(\tilde{w}_i \leq \tilde{w}_k)\ \forall k$, the weight vector of the task importance criteria is found as $W' = (d'(A_{TC}), d'(A_{TF}), d'(A_{TS}))^T$. Finally, we normalize the vector $W'$, and obtain the normalized weight vector $W = (d(A_{TC}), d(A_{TF}), d(A_{TS}))^T$ which is a non-fuzzy vector of task importance criteria weights.

In addition to additive prioritization and Chang's extent analysis, fuzzy weights of the criteria can be obtained also by using fuzzy geometric means in prioritization (Buckley, 1985). Assuming $n$ is the size of the PCM, the computation procedure is as follows:

$$\tilde{Z}_i = \left( \prod_j \tilde{x}_{ij} \right)^{\frac{1}{n}}, \; i = 1, \ldots, n \qquad \textbf{(5.6)}$$

$$\tilde{W}_i = \tilde{Z}_i \otimes \left( \sum_i \tilde{Z}_i \right)^{-1}, \; i = 1, \ldots, n \qquad \textbf{(5.7)}$$

As a result of either of the prioritization methods, we obtain fuzzy weight vector for the criteria $\tilde{W} = (\tilde{w}_{TC}, \tilde{w}_{TS}, \tilde{w}_{TF})^T$

Step 6: Determination of tasks involved in the job by work-oriented job analysis:

In this step, work-oriented job analysis is performed for the job for which the personnel selection will be performed. Work-oriented approaches to job analysis describe work in technological and behaviorally explicit terms. Using these methods, job analysts describe work in terms of tasks, the most specific level of job behavior describing performance of a meaningful job function. These task statements must also include other occupationally specific information such as tools and technology, organizational context and work context descriptors.

Step 7: Pairwise comparison of tasks with respect to the criteria by each decision maker using linguistic variables:

In this step, tasks involved in the job in question are compared with each other by each decision maker with respect to the criteria, namely task criteria, task frequency and time spent, using linguistic variables. For this purpose, same linguistic variables given in Step 2 will be used.

Step 8: Conversion of linguistic pairwise comparisons into fuzzy numbers:

In fuzzifying the linguistic PCM into the fuzzy PCM, the linguistic variables and corresponding scales given in Step 3 will be used. As a result, the following three matrices with triangular fuzzy elements are obtained for each decision maker associated with TC, TS and TF as seen below.

$$\widetilde{TC} = \begin{array}{c} \\ T_1 \\ \\ T_s \end{array} \overset{\begin{array}{ccc} T_1 & & T_s \end{array}}{\begin{pmatrix} \tilde{a}_{11}^k & \cdots & \tilde{a}_{1n}^k \\ \vdots & \ddots & \vdots \\ \tilde{a}_{m1}^k & \cdots & \tilde{a}_{mn}^k \end{pmatrix}} \tag{5.8}$$

$$\widetilde{TF} = \begin{array}{c} \\ T_1 \\ \\ T_s \end{array} \overset{\begin{array}{ccc} T_1 & & T_s \end{array}}{\begin{pmatrix} \tilde{b}_{11}^k & \cdots & \tilde{b}_{1n}^k \\ \vdots & \ddots & \vdots \\ \tilde{b}_{m1}^k & \cdots & \tilde{b}_{mn}^k \end{pmatrix}} \tag{5.9}$$

$$\widetilde{TS} = \begin{array}{c} \\ T_1 \\ \\ T_s \end{array} \overset{\begin{array}{ccc} T_1 & & T_s \end{array}}{\begin{pmatrix} \tilde{c}_{11}^k & \cdots & \tilde{c}_{1n}^k \\ \vdots & \ddots & \vdots \\ \tilde{c}_{m1}^k & \cdots & \tilde{c}_{mn}^k \end{pmatrix}} \tag{5.10}$$

where $T_i$ represents tasks involved in the job ($i = 1, 2,\ldots, s$).

At this step, consistency ratio is computed for each PCM which is calculated by $CR = CI / RI$ In this formula, consistency index is calculated as $CI = (\tilde{\lambda}_{\max} - \mathrm{n}) / (\mathrm{n} - 1)$ where $\tilde{\lambda}_{\max}$ is estimated by the mean of $\tilde{\lambda}$ values for each row ($\tilde{\lambda}_i$) of the comparison matrix and $\tilde{\lambda}_i$ is calculated by $A_i\omega/\omega_i$ where $\boldsymbol{A_i}$ is the $i^{th}$ row of PCM and $\omega$ is the weight vector. Since fuzzy PCM and weight vector are composed of triangular fuzzy numbers, $\tilde{\lambda}_i$ is also a triangular fuzzy number represented by $(\lambda_1,\ \lambda_\mathrm{m},\ \lambda_\mathrm{u})$. Thus, $\tilde{\lambda}_i$ values are defuzzified by $\sqrt[3]{\lambda_l \times \lambda_m \times \lambda_u}$ (Mete, 2007). If $CR < 0.1$ for a certain PCM, the consistency of the PCM is ensured; otherwise, decision makers must revise their judgments.

Step 9: Aggregation of PCMs of all decision makers:

Aggregation process is performed in the same way that has been described in Step 4. Fuzzy PCMs of the decision makers are aggregated by calculating the geometric means of the same elements of same matrices of different decision makers. Therefore the number of matrices is reduced in this stage to three, namely; task criticality, time spent and task frequency, as seen below.

$$\widetilde{TC} = \begin{array}{c} \\ T_1 \\ \\ T_s \end{array} \begin{array}{c} \begin{array}{ccc} T_1 & & T_s \end{array} \\ \begin{pmatrix} \tilde{a}_{11} & \dots & \tilde{a}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{m1} & \cdots & \tilde{a}_{mn} \end{pmatrix} \end{array} \qquad \textbf{(5.11)}$$

$$\widetilde{TF} = \begin{array}{c} \\ T_1 \\ \\ T_s \end{array} \begin{array}{c} \begin{array}{ccc} T_1 & & T_s \end{array} \\ \begin{pmatrix} \tilde{b}_{11} & \dots & \tilde{b}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{b}_{m1} & \cdots & \tilde{b}_{mn} \end{pmatrix} \end{array} \qquad \textbf{(5.12)}$$

$$\widetilde{TS} = \begin{array}{c} \\ T_1 \\ \\ T_s \end{array} \begin{array}{c} \begin{array}{ccc} T_1 & & T_s \end{array} \\ \begin{pmatrix} \tilde{c}_{11} & \dots & \tilde{c}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{c}_{m1} & \cdots & \tilde{c}_{mn} \end{pmatrix} \end{array} \qquad \textbf{(5.13)}$$

Step 10. Computation of fuzzy importance weights of the tasks with respect to each criterion:

In this step, we use the same formula given in Step 5 to calculate the tasks' fuzzy performance on three criteria. The performance of the tasks with respect to task criticality, task frequency and time spent are calculated as follows.

$$\tilde{w}_i^{TC} = \frac{\sum_{i=1}^{s} \tilde{a}_{ij}}{\sum_{i=1}^{s} \sum_{j=1}^{s} \tilde{a}_{ij}}, \ i = 1, 2,\dots, s, j = 1, 2,\dots, s \qquad \textbf{(5.14)}$$

$$\tilde{w}_i^{TF} = \frac{\sum_{i=1}^{s} \tilde{b}_{ij}}{\sum_{i=1}^{s} \sum_{j=1}^{s} \tilde{b}_{ij}}, \ i = 1, 2,\dots, s, j = 1, 2,\dots, s \qquad \textbf{(5.15)}$$

$$\tilde{w}_i^{TS} = \frac{\sum_{i=1}^{s} \tilde{c}_{ij}}{\sum_{i=1}^{s} \sum_{j=1}^{s} \underset{\sim}{c}_{ij}}, \ i = 1, 2,\dots, s, j = 1, 2,\dots, s \qquad \textbf{(5.16)}$$

Based on the fuzzy weights we have obtained by equations (5.14), (5.15) and (5.16), we can perform Chang's extent analysis to find crisp weights of the tasks by following the same procedure that has been explained in Step 5. In addition to additive prioritization and Chang's extent analysis, fuzzy weights of the criteria can be obtained also by using fuzzy geometric means in prioritization (Buckley, 1985) with respect to each importance criterion by using equations (5.6) and (5.7). At this stage, it should be noted that the prioritization method used in this step must be same as the prioritization method used in Step 5, in which the weights of the task importance criteria are calculated. As a result of these computations, we obtain fuzzy performance matrices of tasks in terms of task criticality, task frequency and time spent as seen below.

$$\tilde{w}^{TC} = \begin{bmatrix} \tilde{w}_1^{TC} \\ \vdots \\ \tilde{w}_s^{TC} \end{bmatrix}, \ \tilde{w}^{TF} = \begin{bmatrix} \tilde{w}_1^{TF} \\ \vdots \\ \tilde{w}_s^{TF} \end{bmatrix}, \ \tilde{w}^{TS} = \begin{bmatrix} \tilde{w}_1^{TS} \\ \vdots \\ \tilde{w}_s^{TS} \end{bmatrix} \tag{5.17}$$

Step 11. Calculation of overall importance weights of the tasks involved in the job:

In Step 5, the relative weights of the criteria, TC, TF and TS, have been calculated. In Step 10, the performance levels of tasks in terms of these criteria have been found. Based on the outputs of Step 5 and Step 10, the overall importance weights of the tasks represented by a column vector ($\tilde{P}$) can be computed by a weighted sum formula as shown below.

$$\tilde{P} = \begin{bmatrix} \tilde{w}_1 \\ \vdots \\ \tilde{w}_s \end{bmatrix} = \tilde{w}_{TC} \times \begin{bmatrix} \tilde{w}_1^{TC} \\ \vdots \\ \tilde{w}_s^{TC} \end{bmatrix} + \tilde{w}_{TF} \times \begin{bmatrix} \tilde{w}_1^{TF} \\ \vdots \\ \tilde{w}_s^{TF} \end{bmatrix} + \tilde{w}_{TS} \times \begin{bmatrix} \tilde{w}_1^{TS} \\ \vdots \\ \tilde{w}_s^{TS} \end{bmatrix} \tag{5.18}$$

### 5.2.2. Tasks-KSAOs linkages

In the second stage of the personnel selection process, the relative fuzzy importance weights of the KSAOs with respect to tasks are evaluated by the decision makers and their fuzzy values are calculated.

Step 1: Determination of KSAOs required by the tasks involved in the job by worker-oriented job analysis:

This step is based on work-oriented job analysis which identifies the personnel characteristics required for performing the job. However, the purpose of the selection is important in terms of overall level of KSAOs expected from new personnel at the entry. If the intended purpose of the selection procedure is to hire or promote individuals into jobs for which no advanced training is provided, the researcher should design the selection procedure in terms of the work behaviors, activities, and/or KSAOs an employee is expected to have before placement on the job. If the intent of the content-based procedure is to select individuals for a training program, the work behaviors, activities, and/or employee KSAOs would be those needed to succeed in a training program.

Step 2: Evaluation of task-KSAOs relationships by each decision maker using linguistic variables:

After computing the importance of each task involved in the job, next step is to map these tasks to the KSAOs. Linguistic variables are used for the purpose of translating the task statements into personnel characteristics by using the matrix shown in Table 5.2.

**Table 5.2 :** Tasks - KSAOs linkage matrix.

| | | **KSAOs** | | | | | |
|---|---|---|---|---|---|---|---|
| | **Task Importance** | **KSAO 1** | **KSAO 2** | **.** | **.** | **.** | **KSAO t** |
| **Task 1** | $\tilde{w}_1$ | | | | | | |
| **Task 2** | $\tilde{w}_2$ | | | | | | |
| **Task 3** | $\tilde{w}_3$ | | | | | | |
| **.** | | | | | | | |
| **.** | | | | | | | |
| **.** | | | | | | | |
| **Task s** | $\tilde{w}_s$ | | | | | | |

Each relationship denotes the relative contribution of the corresponding KSAOs to the task in question represented by $r_{ij}$. This step may be performed by the contribution of human resource specialists, job incumbents and SMEs in a company where the model is applied. Thus, multiple decision makers may be involved in this stage. For this purpose, linguistic variables given in Table 5.3 can be used.

Step 3: Conversion of linguistic evaluations of relationships into fuzzy relationships:

In converting the task-KSAO relationships expressed as linguistic variables into the fuzzy relationships, corresponding scales given in Table 5.3 have been used.

**Table 5.3 :** Fuzzy scale for tasks-KSAOs linkages.

| **Linguistic variables** | **Fuzzy scale** |
|---|---|
| Very Low | (0,0,1) |
| Low | (0, 0.1, 0.3) |
| Medium Low | (0.1, 0.3, 0.5) |
| Medium | (0.3, 0.5, 0.7) |
| Medium High | (0.5, 0.7, 0.9) |
| High | (0.7, 0.9, 1) |
| Very High | (0.9, 1, 1) |

As a result, matrices in the form given below are obtained.

$$\tilde{R}^k = \begin{matrix} & \text{KSAO}_1 & & \text{KSAO}_t \\ \text{T}_1 & \tilde{r}_{11}^k & \cdots & \tilde{r}_{1t}^k \\ & \vdots & \ddots & \vdots \\ \text{T}_s & \tilde{r}_{s1}^k & \cdots & \tilde{r}_{st}^k \end{matrix} \quad \textbf{(5.19)}$$

Step 4: Aggregation of fuzzy task-KSAOs relationships of all decision makers:

After all decision makers have evaluated task-KSAOs relationships, the task-KSAOs matrices, $\tilde{R}^k$ for $k = 1, 2, \ldots, K$, are aggregated into a single task-KSAOs matrix, $\tilde{R}$ by the following formula:

$$\tilde{r}_{ij} = \frac{\tilde{r}_{ij}^1 \oplus \tilde{r}_{ij}^2 \oplus \ldots \oplus \tilde{r}_{ij}^K}{K} \quad \textbf{(5.20)}$$

where $\tilde{r}_{ij}^k$ is the $ij^{th}$ element of task-KSAOs matrix of decision maker $k$, $k = 1,2,\ldots,K$ and $K$ is the number of decision makers. Thus, we obtain the following aggregated task-KSAOs matrix.

$$\tilde{R} = \begin{matrix} & \text{KSAO}_1 & & \text{KSAO}_t \\ \text{T}_1 & \tilde{r}_{11} & \cdots & \tilde{r}_{1t} \\ & \vdots & \ddots & \vdots \\ \text{T}_s & \tilde{r}_{s1} & \cdots & \tilde{r}_{st} \end{matrix} \quad \textbf{(5.21)}$$

Step 5: Calculation of overall fuzzy weights of the KSAOs required to perform the job

In this step, the overall fuzzy weights of KSAOs, which represent the overall requirements of KSAOs for performing the job, is calculated based on the importance weights of the tasks and task-KSAO relationships by using the following formula.

$$\tilde{z}_j = \sum_{i}^{s} \left( \tilde{w}_i \otimes \tilde{r}_{ij} \right), \quad \forall j, \quad j = 1, \ldots, t \qquad \textbf{(5.22)}$$

where $\tilde{z}_j = \left( a_j, b_j, c_j \right)$ represents a fuzzy weights of the $j^{th}$ KSAOs and $\tilde{w}_i$ represents the importance weight of the $i^{th}$ task involved in the job.

Step 6: Normalization of overall fuzzy weights of the KSAOs

Normalization ensures a more meaningful representation of the KSAOs weights. Hence, a linear scale transformation enabling the scale of measurement to vary precisely in the [0,1] interval is employed to normalize the resulting KSAOs weights (Karsak, 2004). The formulation is as follows:

$$\tilde{s}_j = \left( \frac{a_j}{c^*}, \frac{b_j}{c^*}, \frac{c_j}{c^*} \right) \qquad \textbf{(5.23)}$$

where $c^* = \max c_j$ and; $a_j$, $b_j$ and $c_j$ represents the left, middle and right parameters of the triangular fuzzy number $\tilde{z}_j = \left( a_j, b_j, c_j \right)$ which has been obtained Step 5. In the final selection, $\tilde{s}_j$ values will be used as a column vector as seen in Table 5.4 and will be represented by $\tilde{s}_i = (\alpha_i, \beta_i, \delta_i)$.

### 5.2.3. Final selection

Final selection is the phase where we combine weights of the KSAOs with candidate information in order to select the most suitable candidate for the job. Various multi-criteria techniques can be used for this purpose. In this study, FTOPSIS and FVIKOR techniques are proposed for final selection process.

#### 5.2.3.1. Final selection by FTOPSIS

The FTOPSIS methods used in this study are based on the studies of Chen (2000), Kahraman et al. (2007) and Karsak (2002). In this section, FTOPSIS methods developed by Chen (2000), Kahraman et al. (2007) and Karsak (2002) are adapted for personnel selection problem. The generic steps of final selection phase may be seen in Figure 5.4.

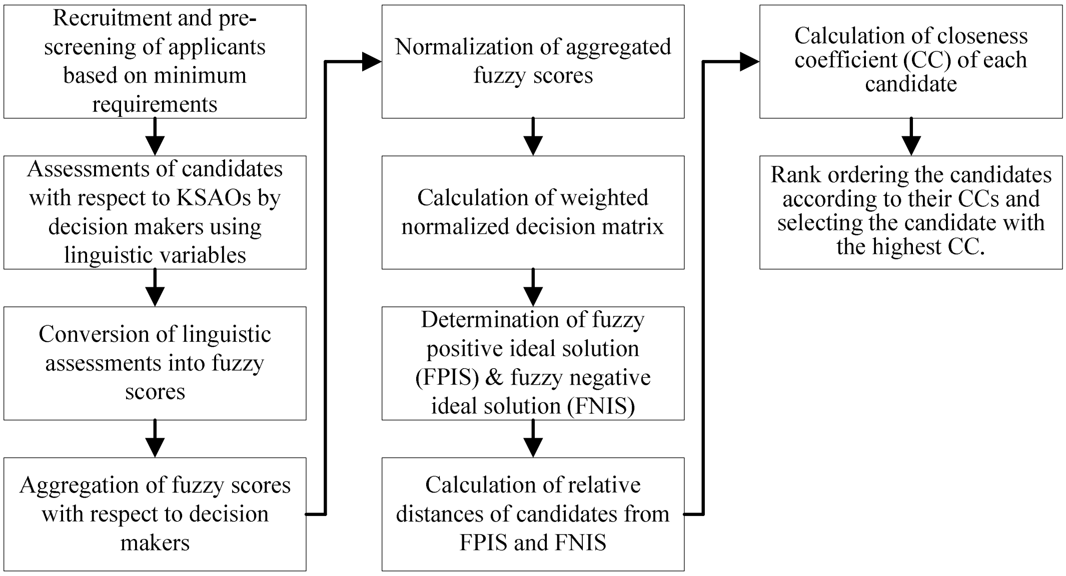


**Figure 5.4 :** Steps of FTOPSIS.

Step 1: Recruitment and pre-screening of applicants based on minimum requirements

This step must in fact be readily performed before the final selection. However, alternative generation is a general step in all problem solving approaches. Thus, by recruitment process, candidates are attracted to work in a specific position in the organization and then pre-screening process reduces a potentially large candidate pool to a more manageable number that can be progressed to more rigorous assessment phases. If the selection ratio for a personnel selection problem is small, pre-screening process becomes more important and utility of the selection method increases.

Step 2: Assessments of candidates with respect to KSAOs by decision makers using linguistic variables

In this step, personnel candidates are evaluated by the decision makers with respect to each KSAO determined in the previous steps. The performance of a candidate can be evaluated by using linguistic variables given in Table 5.5. As a result, *K* (number of decision makers) tables in the format given in Table 5.4 is obtained.

**Table 5.4 :** KSAOs vs. candidates matrix.

| | KSAOs' weights | Cand. 1 | Cand. 2 | Cand. 3 | | | Cand. m |
|---|---|---|---|---|---|---|---|
| KSAO 1 | $\tilde{s}_1$ | | | | | | |
| KSAO 2 | $\tilde{s}_2$ | | | | | | |
| KSAO 3 | $\tilde{s}_3$ | | | | | | |
| | | | | | | | |
| KSAO t | $\tilde{s}_t$ | | | | | | |

Step 3: Conversion of linguistic assessments into fuzzy scores

The linguistic scale in Table 5.5 is used for converting linguistic assessments of candidates into fuzzy scores.

**Table 5.5 :** Fuzzy conversion scale for candidate assessments.

| Linguistic variables | Fuzzy scale |
|---|---|
| Very Poor | (0,0,1) |
| Poor | (0,1,3) |
| Fair-Poor | (1,3,5) |
| Fair | (3,5,7) |
| Fair-Good | (5,7,9) |
| Good | (7,9,10) |
| Very Good | (9,10,10) |

Step 4: Aggregation of fuzzy scores with respect to decision makers

The fuzzy matrices (KSAOs vs. candidates) may be aggregated with respect to decision makers by using the following formula:

$$\tilde{x}_{ij} = \frac{1}{K}\left[\tilde{x}_{ij}^{1} \oplus \tilde{x}_{ij}^{2} \oplus \ldots \oplus \tilde{x}_{ij}^{K}\right] \qquad \textbf{(5.24)}$$

where $\tilde{x}_{ij}^{k}$ is the $j^{th}$ candidate's fuzzy performance score in $i^{th}$ KSAO, $i = 1, \ldots, t$, $j = 1, \ldots, m$, $k = 1, \ldots, K$.

Step 5: Normalization of aggregated fuzzy scores

The normalization is required for preserving the property that the ranges of normalized triangular fuzzy numbers belong to [0, 1]. To avoid the complicated normalization formula used in classical TOPSIS, the linear scale transformation is proposed by Chen (2000) to transform the various criteria scales into a comparable scale. Therefore, we can obtain the normalized fuzzy decision matrix denoted by D**.**

$$\tilde{\mathbf{D}} = \left[\tilde{\mathrm{d}}_{\mathrm{ij}}\right]_{m\times n} \quad \textbf{(5.25)}$$

where B and C are the set of benefit criteria and cost criteria, respectively, and

$$\tilde{d}_{ij} = \left(\frac{a_{ij}}{c_i^*}, \frac{b_{ij}}{c_i^*}, \frac{c_{ij}}{c_i^*}\right), \quad i \in B \quad \textbf{(5.26)}$$

$$\tilde{d}_{ij} = \left(\frac{a_i^-}{c_{ij}}, \frac{a_i^-}{b_{ij}}, \frac{a_i^-}{a_{ij}}\right), \quad i \in C \quad \textbf{(5.27)}$$

where

$$c_i^* = \max_j c_{ij}, \quad if \quad i \in B \quad \textbf{(5.28)}$$

$$a_i^- = \min_j a_{ij}, \quad if \quad i \in C \quad \textbf{(5.29)}$$

and *a*, *b* and *c* represent the left, middle and right parameters of the triangular fuzzy number $\tilde{x}_{ij}$ .

In addition to the FTOPSIS method proposed by Chen (2000), FTOPSIS methods proposed by Kahraman et al. (2007) and Karsak (2002) also have been used in this study for comparing the outcomes of the personnel selection process. Normalization is one of the steps that these three methods differ from each other. Kahraman et al. (2007) uses Lee and Li's (1998) ranking method for the purpose of normalization and determination of positive and negative ideal solutions in order to calculate the distances. Kahraman et al. (2007) apply the generalized mean formula for ranking the triangular fuzzy numbers. The generalized mean formula is as follows:

$$M(x_{ij}) = \frac{-a_{ij}^2 + c_{ij}^2 - a_{ij}b_{ij} + b_{ij}c_{ij}}{\left[3\left(-a_{ij} + c_{ij}\right)\right]} \quad \textbf{(5.30)}$$

where $x_{ij}$ is the $ij^{th}$ fuzzy rating of personnel *j (j = 1,2, …, m)* with respect to criteria *i* (*i = 1,2, …, t*). After determining the generalized mean of all $x_{ij}$, following normalization procedure is applied by Kahraman et al. (2007).

$$\tilde{d}_{ij} = \begin{cases} \tilde{x}_{ij}(\div)x_i^* = \left(\dfrac{a_{ij}}{c_i^*}, \dfrac{b_{ij}}{b_i^*}, \dfrac{c_{ij}}{a_i^*}\right), & \forall i, \ x_j \ \text{is a benefit attribute} \\ x_i^-(\div)\tilde{x}_{ij} = \left(\dfrac{a_j^-}{c_{ij}}, \dfrac{b_j^-}{b_{ij}}, \dfrac{c_j^-}{a_{ij}}\right), & \forall i, \ x_j \ \text{is a cost attribute} \end{cases} \tag{5.31}$$

where $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$, $x_i^* = (a_i^*, b_i^*, c_i^*)$ and $x_i^- = (a_i^-, b_i^-, c_i^-)$. $x_i^*$ and $x_i^-$ represent the fuzzy rating with the largest generalized mean and the smallest generalized mean respectively.

Karsak (2002) applied a different normalization procedure. For fuzzy data denoted as $(a_{ij}, b_{ij}, c_{ij})$, the normalized values for benefit-related criteria, $i \in B$, and cost-related criteria, $i \in C$, are:

$$\tilde{d}_{ij} = \begin{cases} \left(\dfrac{a_{ij} - a_i^-}{c_i^* - a_i^-}, \dfrac{b_{ij} - a_i^-}{c_i^* - a_i^-}, \dfrac{c_{ij} - a_i^-}{c_i^* - a_i^-}\right), & i \in B \\ \left(\dfrac{c_i^* - c_{ij}^-}{c_i^* - a_i^-}, \dfrac{c_i^* - b_{ij}^-}{c_i^* - a_i^-}, \dfrac{c_i^* - a_{ij}^-}{c_i^* - a_i^-}\right), & i \in C \end{cases} \tag{5.32}$$

where $c_i^* = \max_j c_{ij}$ and $a_i^- = \min_j a_{ij}$

Step 6: Calculation of weighted normalized decision matrix

Considering the different importance of each criterion, the weighted normalized fuzzy decision matrix is calculated in FTOPSIS methods proposed by Chen (2000) and Kahraman et al. (2007) as given below.

$$\tilde{\mathbf{V}} = \left[\tilde{v}_{ij}\right]_{t \times m}, \quad i = 1, 2, ..., t, \quad j = 1, 2, ..., m \tag{5.33}$$

where $\tilde{v}_{ij} = \tilde{s}_i \otimes \tilde{d}_{ij}$ and $\tilde{s}_i = (\alpha_i, \beta_i, \delta_i)$ is the fuzzy weight of the KSAO *i*. Different from these two FTOPSIS methods, Karsak (2002) uses the weights of the KSAOs in the following step.

Step 7: Determination of fuzzy positive ideal solution (FPIS) & fuzzy negative ideal solution (FNIS)

We can define the fuzzy positive-ideal solution (FPIS), $A^*$ and fuzzy negative-ideal solution (FNIS), $A^-$ as

$$A^* = \left(\tilde{v}_1^*, \tilde{v}_2^*, ..., \tilde{v}_n^*\right) \quad \textbf{(5.34)}$$

$$A^- = \left(\tilde{v}_1^-, \tilde{v}_2^-, ..., \tilde{v}_n^-\right) \quad \textbf{(5.35)}$$

where $\tilde{v}_i^* = (1,1,1)$ and $\tilde{v}_i^- = (0,0,0)$, $i = 1; 2, \ldots, t$.

Step 8: Calculation of relative distances of candidates from FPIS and FNIS

The distance of each candidate from FPIS and FNIS can be currently calculated as given below.

$$d_j^* = \sum_{i=1}^{t} d\left(\tilde{v}_{ij}, \tilde{v}_i^*\right), \quad j = 1, 2, ..., m \quad \textbf{(5.36)}$$

$$d_j^- = \sum_{i=1}^{t} d\left(\tilde{v}_{ij}, \tilde{v}_i^-\right), \quad j = 1, 2, ..., m \quad \textbf{(5.37)}$$

where $d(\cdot,\cdot)$ is the distance measurement between two fuzzy numbers. Chen (2000) proposes using vertex method given in equation (4.7) and assumes FPIS and FNIS as (1, 1, 1) and (0, 0, 0) respectively. The FTOPSIS methods proposed by Kahraman et al. (2007) and Karsak (2002) also differ in distance calculation. Kahraman et al. (2007) calculates the distances in two steps as follows.

$$d_{ij}^* = \begin{cases} 1 - \dfrac{c_{ij} - a^*}{b^* + c_{ij} - a^* - b_{ij}} & for \quad b_{ij} < b^* \\ 1 - \dfrac{c^* - a_{ij}}{b_{ij} + c^* - a_{ij} - b^*} & for \quad b^* < b_{ij} \end{cases} \quad \textbf{(5.38)}$$

$$d_{ij}^{-} = \begin{cases} 1 - \dfrac{c^{-} - a_{ij}}{b_{ij} + c^{-} - a_{ij} - b^{-}} & \textit{for} \quad b^{-} < b_{ij} \\ 1 - \dfrac{c_{ij} - a^{-}}{b^{-} + c_{ij} - a^{-} - b_{ij}} & \textit{for} \quad b_{ij} < b^{-} \end{cases} \qquad \textbf{(5.39)}$$

where $d_{ij}^{*}$ and $d_{ij}^{-}$ are the distance of $\tilde{v}_{ij}$ (the *ij* element of weighted normalized matrix) from $\tilde{v}_i^{*} = \left(a^{*}, b^{*}, c^{*}\right)$ and $\tilde{v}_i^{-} = \left(a^{-}, b^{-}, c^{-}\right)$ respectively. Then, the distance of each alternative from FPIS and FNIS is calculated respectively as follows:

$$d_j^{*} = \sum_{i=1}^{t} D_{ij}^{*} \qquad \textbf{(5.40)}$$

$$d_j^{-} = \sum_{i=1}^{t} D_{ij}^{-} \qquad \textbf{(5.41)}$$

Karsak (2002) also assumes FPIS and FNIS as (1, 1, 1) and (0, 0, 0) respectively and uses the distance measure based on the study of Bojadziev and Bojadziev (1995). The weighted distances from the FPIS solution and the FNIS are calculated respectively by the following formula (Karsak, 2002).

$$d_j^{*} = \sum_{i=1}^{t} \left( \frac{1}{2} \left\{ \max\left( \alpha_i \left| a_{ij} - 1 \right|, \delta_i \left| c_{ij} - 1 \right| \right) + \beta_i \left| b_{ij} - 1 \right| \right\} \right) \qquad \textbf{(5.42)}$$

$$d_j^{-} = \sum_{j=1}^{n} \left( \frac{1}{2} \left\{ \max\left( \alpha_i \left| a_{ij} - 0 \right|, \delta_i \left| c_{ij} - 0 \right| \right) + \beta_i \left| b_{ij} - 0 \right| \right\} \right) \qquad \textbf{(5.43)}$$

where $(\alpha_i, \beta_i, \delta_i)$ are the parameters of $\tilde{s}_i$, which denotes the fuzzy weight of the KSAO *i*.

Step 9: Calculation of closeness coefficient (CC) of each candidate

A closeness coefficient is defined to determine the ranking order of all alternatives once $d_j^{*}$ and $d_j^{-}$ of each alternative $A_j$, $(j = 1, 2, \ldots, m)$ have been calculated. The closeness coefficient of each alternative is calculated as

$$CC_j = \frac{d_j^-}{d_j^* + d_j^-}, \quad j = 1, 2, ..., m \tag{5.44}$$

which is a crisp value.

Step 10: Rank ordering the candidates according to their CCs and selecting the candidate with the highest CC

Obviously, an alternative $A_j$ is closer to the FPIS ($A^*$) and farther from FNIS ($A^-$) as $CC_j$ approaches to 1. Since closeness coefficients are crisp values, we can determine the ranking order of all candidates and select the best one from among a set of personnel candidates.

#### 5.2.3.2. Final selection by FVIKOR

In addition to these three FTOPSIS methods, FVIKOR also has been used in this study for comparing the outcomes. The FVIKOR method applied in this study is based on Büyüközkan and Ruan (2008). The summary of the method is as follows.

Denote *m* candidates under consideration as $a_1, a_2, ..., a_m$, the *t* evaluation criteria (KSAOs) and the rating of each candidate $a_j$, *j = 1, 2, ..., m* versus criteria $c_i$, $i = 1, \cdots, t$ as $\tilde{f}_{ij} = (f_{ij}^1, f_{ij}^2, f_{ij}^3)$. Then, the fuzzy compromise ranking algorithm FVIKOR consists of the following steps.

Step 1: If the supports of triangular fuzzy numbers expressing linguistic variables do not belong to the interval [0,1], then a scaling is needed to transform them back in this interval. Here, we use a linear scale transformation to have a comparable number. As an example, if we transform the rating of candidates, we have

$$\tilde{r}_{ij} = \left( \frac{f_{ij}^1}{f_i^{\max}}, \frac{f_{ij}^2}{f_i^{\max}}, \frac{f_{ij}^3}{f_i^{\max}} \right) \text{where } f_i^{\max} = \max_j f_{ij}^3, \ i = 1, 2, ..., n. \tag{5.45}$$

Step 2: Compute the values of $\tilde{S}_j$ and $\tilde{R}_j$, j = 1, 2, ..., m by the relations

$$\tilde{S}_j = \sum_{i=1}^{t} \tilde{s}_i \otimes d\left(\tilde{1}, \tilde{r}_{ij}\right) \tag{5.46}$$

$$\tilde{R}_j = \max_i \tilde{s}_i \otimes d\left(\tilde{1}, \tilde{r}_{ij}\right) \quad \textbf{(5.47)}$$

where $\tilde{S}_j$ and $\tilde{R}_j$ are used for formulating the ranking measure of "group utility" and the "individual regret" respectively. Here, $d\left(\tilde{1}, \tilde{r}_{ij}\right)$ represents the distance of a candidate rating to the positive ideal solution $\tilde{1} = (1,1,1)$ calculated by vertex method in eq. (4.7) and $\tilde{s}_i = (\alpha_i, \beta_i, \delta_i)$ denotes the fuzzy weight of the KSAO *i*. Note that the maximum among $\tilde{s}_i \otimes d\left(\tilde{1}, \tilde{r}_{ij}\right)$ values is the one that is the most distant from $\tilde{1}$.

Step 3: Compute the values $\tilde{Q}_j$, *j = 1, 2, ..., m* by the relation

$$\tilde{Q}_j = v\left(\tilde{S}_j^{'}\right) \oplus (1-v)\left(\tilde{R}_j^{'}\right), \quad \textbf{(5.48)}$$

where $\tilde{S}_j^{'}$ and $\tilde{R}_j^{'}$ are normalized $\tilde{S}_j$ and $\tilde{R}_j$ values using the linear scale transformation. Here, *v* is introduced as a weight of the strategy of "the majority of criteria" as proposed in the original VIKOR method. The compromise can be selected with "voting by majority" $v > 0.5$, with "consensus" $v \approx 0.5$, or with "veto" $v < 0.5$.

Step 4: The ranking order of candidates is determined with the help of generalized mean given in eq. (5.30). First, $\tilde{S}_j^{'}$, $\tilde{R}_j^{'}$ and $\tilde{Q}_j^{'}$ values are defuzzified into crisp $S_j^{'}$, $R_j^{'}$ and $Q_j^{'}$ values. Then, candidates are ranked by sorting each $S_j^{'}$, $R_j^{'}$ and $Q_j^{'}$ values in an ascending order as in the original VIKOR. The result is a set of three ranking lists denoted as $S_{[.]}^{'}, R_{[.]}^{'}$ and $Q_{[.]}$. The candidate $j_1$ corresponding to $Q_{[1]}$ (the smallest among $Q_j$ values) is proposed as a compromise solution if

Condition 1: The candidate $j_1$ has an *acceptable advantage,* in other words $Q_{[2]} - Q_{[1]} \geq DQ$ where $DQ = 1/(m-1)$ and m is the number of alternatives (DQ = 0.25 if $m \leq 4$).

Condition 2: The candidate $j_1$ is *stable within the decision-making process,* in other words it is also the best ranked in $S_{[.]}^{'}$ or $R_{[.]}^{'}$.

If one of the above conditions is not satisfied, then a set of compromise solutions is proposed, which consists of:

• The candidate s $j_1$ and $j_2$ where $Q_{j2} = Q_{[2]}$ if only the condition **C2** is not satisfied, or

• The candidate s $j_1, j_2, \ldots, j_k$ if the condition **C1** is not satisfied; and $j_k$ is determined by the relation $Q_{[k]} - Q_{[1]} < DQ$ for the maximum $k$ where $Q_{jk} = Q_{[k]}$ (the positions of these alternatives are in closeness).

### 5.3. Application of the Proposed Model

The model has been applied in of the leading companies in our country in the milk and milk products sector. The interview with the Human Resource Specialist (HRS) of the company has shown that currently, there is no formal and structured test used in personnel selection processes in the company. The recruitment decision is based on the pre-screening based on some attributes (minimum qualifications like education and experience) and interview performance of the candidates. In determining the personnel attributes required for the job, human resources specialists benefit from ideas and recommendations of immediate supervisor of the position in question. Combining with his/her thoughts and previous experiences, HRS determines the personnel attributes required for the position, their relative importance weights and ways of measuring those attributes through the interviews. This procedure is totally based on a mental process depending on the information input by the immediate supervisor and HRS's own judgment which is unstructured and quite subjective. After this mental process, HRS and immediate supervisor interview with the candidates separately, even sometimes at different dates. At a later time, HRS and immediate supervisor discuss in a meeting about the information gathered in the interviews and they reach a final decision.

Briefly, the selection process is totally based on judgmental processes, in which no analytical methods are applied and the information in all stages is vague and subjective. When we think about the costs of the complicated selection tools and the time consumed for them, selection based upon the minimum qualifications and interviewing may be acceptable. However, the method followed in personnel selection does not promise reliable results and its validity can be discussed in terms of its predictive efficiency and its relation with the job content. Employee turnover in some positions is high and hence, it signals a mismatch of people and jobs.

Since the data input process and computations require significant effort and time, fuzzy personnel selection software (FPSS) has been developed by using Microsoft Visual C#. It enables data input by multiple decision makers and performs FAHP computations to determine the weights of tasks, perform task-KSAOs linkages and FTOPSIS computations in order to determine the best candidate. Therefore, the decision makers involved in personnel selection processes can enter their assessments using an interface which uses linguistic variables with predefined fuzzy scales. The assessments of decision makers and predefined fuzzy scales can be later modified for performing further sensitivity analysis. As a result, without using many spreadsheet tables, multiple decision makers can reach the final aggregated decision by spending less effort and time. A sample screen shot of the software is seen in Figure 5.5.

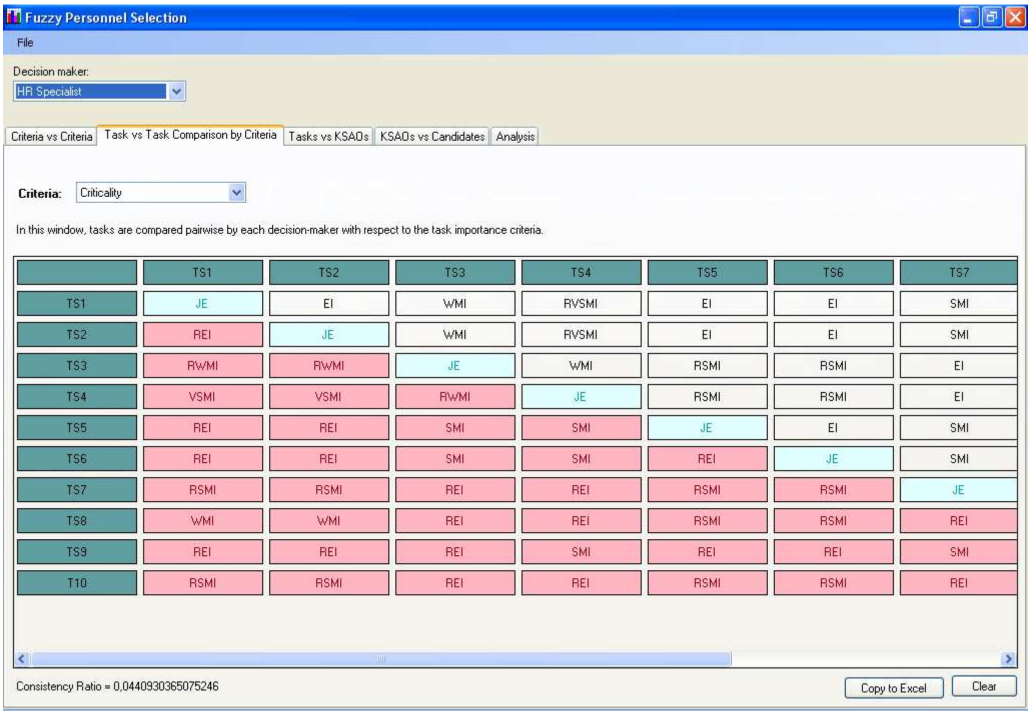


**Figure 5.5 :** A screen shot of FPSS.

Two positions, namely “Shift Engineer” (SE) and “Chief Maintenance Engineer” (CME), were determined to perform the application due to high turnover rates of these positions. In the following sections, these two applications will be presented.

### 5.3.1. Application for SE position

In the beginning of the application, a job analysis study has been carried out for determining the job description and personnel characteristics for the SE position so that tasks performed may be linked to the KSAOs. This job analysis has been performed based on the previous documentation about the job description and job specification of the SE title. However, these documents were not suitable for use in terms of interdependencies among tasks, unclear statements and repeated expressions. This was due to the reason that the outcomes of job analysis studies performed in the company have not been considered to be used effectively in other human resources management activities. Therefore, by making interviews with the HRS and SMEs, list of the tasks involved in these positions were clarified, re-organized, linked to the main responsibilities of the job; and interdependencies and similarities of task statements in the task lists were removed so that they could be considered independent of each other in mapping the tasks to KSAOs. The lists of tasks for SE position can be seen in Table 5.6. The tables showing all the information gathered and used in this application can be seen in Appendix B.

**Table 5.6 :** The list of tasks involved in SE position.

| Task | Description |
|---|---|
| **1.** | Controls the appearance, quality and hygiene parameters of the products in the production stage. |
| **2.** | Controls the order of the products which are saved in the open area and takes initiatives against humidity, dampening or any other kind of abrasion during his shift. |
| **3.** | Controls the milk distribution according to strategic targets during his shift. |
| **4.** | Operates UHT and milk powder units during the meal breaks. |
| **5.** | Informs the Production Chief and Head of Production Department about the problems associated with staff, missing material, production problems, managerial problems that were met during his shift and applies the resultant decisions against these problems. |
| **6.** | Controls the production systems, units, accuracy of the measurement devices, temperature in the refrigerating warehouse and contacts with the Machine Maintenance Department when a problem occurs and ensures the solution of the problem as soon as possible. |

**Table 5.6 :** The list of tasks involved in SE position (contd.)

| Task | Description |
|---|---|
| **7.** | Transfers staff between different units when needed during his shift. |
| **8.** | Informs about and discusses the problems which he met during his shift in the production meetings and ensures their solution as soon as possible. |
| **9.** | Controls and ensures that activities during his shift are performed according to the predetermined instructions and procedures and controls the production portfolios at regular intervals. |
| **10.** | Controls the timely arrival of production staff at the beginning and at the end of the shift. |

For the determination of the personnel characteristics, KSAOs and their definitions listed in Appendix A has been used. A subset of these KSAOs was selected which are hypothesized to be predicting the future performance of SEs. Cooperating with the job incumbents and a HR specialist, 21 KSAOs were determined to be necessary for performing the tasks of SEs. The required KSAOs are given in Table 5.7.

**Table 5.7 :** The list of KSAOs required for SE position.

| **Categories** | **Required KSAOs** |
|---|---|
| Verbal Abilities | Oral Comprehension |
| | Written Comprehension |
| | Oral Expression |
| | Written Expression |
| | Active Listening |
| Technical Skills | Operation Monitoring & Control |
| | Troubleshooting |
| | Quality Control Analysis |
| Knowledge | Milk Production and Processing |
| Surgency | General Leadership |
| | Interest in Negotiation |
| | Achievement Striving |
| Agreeableness | Friendly Disposition |
| | Sensitivity to interest of others |
| | Cooperative or Collaborative Work Tendency |

**Table 5.7 :** The list of KSAOs required for SE position (contd.)

| **Categories** | **Required KSAOs** |
|---|---|
| Conscientiousness | General Trustworthiness |
| | Adherence to a Work Ethic |
| | Thoroughness and Attentiveness to Details |
| Emotional Stability | Emotional Stability |
| Intellectance | Desire to Generate Ideas |
| | Tendency to Think Things Through |

By identifying the KSAOs listed in Table 5.7, the decision makers involved in the personnel selection problem hypothesize that these KSAOs are the most significant characteristics that may be used in predicting the job performance of the new SE. Second step of the application is the determination of the weights of the tasks. Pairwise comparison process was performed by two SEs, each of who evaluate the tasks individually in terms of task criticality for the overall performance, tasks' frequencies and time spent for each task. Then, their individual PCMs are aggregated by calculating their geometric means. These evaluations are given in Appendix B. FAHP by additive prioritization based on Deng's method (1999), Chang's extent analysis technique (1996) and Buckley's method (1985) has been applied. As a result of FAHP, the weights of the tasks given in Table 5.8 are obtained.

**Table 5.8 :** Weights of the tasks performed by SE.

| | | **CHANG** | **DENG** | | | **BUCKLEY** | | |
|---|---|---|---|---|---|---|---|---|
| | | **Crisp** | **L** | **M** | **U** | **L** | **M** | **U** |
| **1** | Controls the appearance, quality and hygiene parameters of the products in the production stage. | 0.118 | 0.039 | 0.118 | 0.326 | 0.038 | 0.117 | 0.318 |
| **2** | Controls the order of the products which are saved in the open area and takes initiatives against humidity, dampening or any other kind of abrasion during his shift. | 0.116 | 0.040 | 0.118 | 0.334 | 0.040 | 0.116 | 0.324 |
| **3** | Controls the milk distribution according to strategic targets during his shift. | 0.082 | 0.026 | 0.079 | 0.227 | 0.027 | 0.078 | 0.215 |
| **4** | Operates UHT and milk powder units during the meal breaks. | 0.071 | 0.029 | 0.082 | 0.236 | 0.029 | 0.081 | 0.229 |

**Table 5.8 :** Weights of the tasks performed by SE (contd.)

| | | CHANG | DENG | | | BUCKLEY | | |
|---|---|---|---|---|---|---|---|---|
| | | **Crisp** | **L** | **M** | **U** | **L** | **M** | **U** |
| **5** | Informs the Production Chief and Head of Production Department about the problems associated with staff, missing material, production problems, managerial problems that were met during his shift and applies the resultant decisions against these problems. | 0.146 | 0.049 | 0.141 | 0.389 | 0.051 | 0.144 | 0.387 |
| **6** | Controls the production systems, units, accuracy of the measurement devices, temperature in the refrigerating warehouse and contacts with the Machine Maintenance Department when a problem occurs and ensures the solution of the problem as soon as possible. | 0.144 | 0.049 | 0.140 | 0.401 | 0.051 | 0.142 | 0.400 |
| **7** | Transfers staff between different units when needed during his shift. | 0.062 | 0.023 | 0.065 | 0.197 | 0.024 | 0.065 | 0.184 |
| **8** | Informs about and discusses the problems which he met during his shift in the production meetings and ensures their solution as soon as possible. | 0.071 | 0.023 | 0.066 | 0.191 | 0.025 | 0.066 | 0.183 |
| **9** | Controls and ensures that activities during his shift are performed according to the predetermined instructions and procedures and controls the production portfolios at regular intervals. | 0.126 | 0.043 | 0.122 | 0.371 | 0.044 | 0.122 | 0.369 |
| **10** | Controls the timely arrival of production staff at the beginning and at the end of the shift. | 0.063 | 0.025 | 0.068 | 0.227 | 0.026 | 0.069 | 0.213 |

Third step is to map the tasks involved in SE position to the required KSAOs. This step has been performed by the HRS, and two SEs in consensus. Therefore, tasks-KSAOs linkages were performed by two different parties by using linguistic variables so that relative contribution of each KSAO for performing each task has been identified. Next, these linguistic evaluations were converted to triangular fuzzy numbers by using the scale given in Table 5.3 and aggregated into a single tasks vs. KSAOs matrix by calculating their arithmetic means. Then, by using the fuzzy weights of the tasks calculated before by FAHP methods, the total weight of each skill is calculated by fuzzy weighted sum formula. Therefore, in this stage, the tasks involved in SE position and their relative weights were translated into required KSAOs and their relative weights (see Table 5.9).

**Table 5.9 :** Weights of the KSAOs required for SE position.

| | | CHANG | | | DENG | | | BUCKLEY | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **L** | **M** | **U** | **L** | **M** | **U** | **L** | **M** | **U** |
| **1** | Oral Comprehension | 0.235 | 0.398 | 0.568 | 0.028 | 0.135 | 0.557 | 0.029 | 0.139 | 0.560 |
| **2** | Written Comprehension | 0.235 | 0.398 | 0.568 | 0.028 | 0.135 | 0.557 | 0.029 | 0.139 | 0.560 |
| **3** | Oral Expression | 0.197 | 0.329 | 0.461 | 0.023 | 0.112 | 0.444 | 0.024 | 0.115 | 0.445 |
| **4** | Written Expression | 0.197 | 0.329 | 0.461 | 0.023 | 0.112 | 0.444 | 0.024 | 0.115 | 0.445 |
| **5** | Active Listening | 0.235 | 0.392 | 0.549 | 0.028 | 0.133 | 0.533 | 0.029 | 0.137 | 0.537 |
| **6** | Operation Monitoring & Control | 0.460 | 0.540 | 0.571 | 0.055 | 0.185 | 0.561 | 0.058 | 0.191 | 0.570 |
| **7** | Troubleshooting | 0.347 | 0.414 | 0.445 | 0.041 | 0.143 | 0.433 | 0.044 | 0.148 | 0.439 |
| **8** | Quality Control Analysis | 0.531 | 0.599 | 0.606 | 0.063 | 0.205 | 0.594 | 0.066 | 0.212 | 0.603 |
| **9** | Milk Production and Processing | 0.600 | 0.800 | 0.950 | 0.071 | 0.276 | 0.950 | 0.075 | 0.283 | 0.950 |
| **10** | General Leadership | 0.165 | 0.298 | 0.453 | 0.019 | 0.102 | 0.444 | 0.020 | 0.105 | 0.444 |
| **11** | Interest in Negotiation | 0.127 | 0.212 | 0.296 | 0.015 | 0.071 | 0.284 | 0.016 | 0.074 | 0.286 |
| **12** | Achievement Striving | 0.800 | 0.950 | 1.000 | 0.095 | 0.328 | 1.000 | 0.100 | 0.337 | 1.000 |
| **13** | Friendly Disposition | 0.347 | 0.547 | 0.747 | 0.041 | 0.189 | 0.747 | 0.044 | 0.194 | 0.747 |
| **14** | Sensitivity to interest of others | 0.021 | 0.036 | 0.050 | 0.003 | 0.014 | 0.057 | 0.003 | 0.014 | 0.057 |
| **15** | Cooperative or Collaborative Work Tendency | 0.473 | 0.608 | 0.707 | 0.056 | 0.207 | 0.692 | 0.059 | 0.213 | 0.697 |
| **16** | General Trustworthiness | 0.832 | 0.966 | 1.000 | 0.099 | 0.333 | 1.000 | 0.104 | 0.342 | 1.000 |
| **17** | Adherence to a Work Ethic | 0.900 | 1.000 | 1.000 | 0.107 | 0.345 | 1.000 | 0.113 | 0.354 | 1.000 |
| **18** | Thoroughness and Attentiveness to Details | 0.728 | 0.828 | 0.847 | 0.084 | 0.280 | 0.820 | 0.089 | 0.287 | 0.824 |
| **19** | Emotional Stability | 0.700 | 0.900 | 1.000 | 0.083 | 0.311 | 1.000 | 0.088 | 0.319 | 1.000 |
| **20** | Desire to Generate Ideas | 0.120 | 0.181 | 0.235 | 0.014 | 0.061 | 0.225 | 0.014 | 0.062 | 0.224 |
| **21** | Tendency to Think Things Through | 0.453 | 0.618 | 0.739 | 0.052 | 0.208 | 0.713 | 0.055 | 0.214 | 0.716 |

After obtaining the weights of the required KSAOs, next step is the final selection. The final selection process was performed among four candidates who were pre-screened out of seven applicants based on their education and experience. These four candidates are new graduated food engineers with different levels of KSAOs. Since only one of the candidates is to be selected for employment, the selection ratio is 1/4 = 0.25 which is a fairly high value.

The candidates are evaluated by both Head of Production Department (HoPD), who is the immediate supervisor of SE and the HRS individually by using linguistic variables and fuzzy scales given in Table 5.5. The individual evaluations of two decision makers are given in Table 5.10. VP, P, FP, F, FG, G, VG represent "very poor", "poor", "fair poor", "fair", "fair good", "good" and "very good" respectively.

**Table 5.10 :** Evaluation of the candidates.

| | | HoPD | | | | HRS | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **C1** | **C2** | **C3** | **C4** | **C1** | **C2** | **C3** | **C4** |
| Verbal Abilities | Oral Comprehension | G | G | G | G | G | G | G | G |
| | Written Comprehension | G | G | G | G | G | G | G | G |
| | Oral Expression | F | FP | F | FG | FP | FG | FG | G |
| | Written Expression | G | G | G | G | G | G | G | G |
| | Active Listening | F | G | FG | G | FG | G | G | G |
| Technical Skills | Operation Monitoring & Control | F | F | F | F | F | F | F | F |
| | Troubleshooting | F | F | F | F | F | F | F | F |
| | Quality Control Analysis | F | F | F | F | F | F | F | F |
| Knowledge | Milk Production and Processing | VP | G | G | VP | VP | FG | F | VP |
| Surgency | General Leadership | F | F | FP | FP | FP | FG | FP | FP |
| | Interest in Negotiation | F | FG | FG | FG | F | FG | F | FG |
| | Achievement Striving | G | FG | F | F | VG | FG | FG | G |
| Agreeableness | Friendly Disposition | G | F | FG | FG | FG | G | FG | FG |
| | Sensitivity to interest of others | G | F | FG | FG | FG | FG | FG | F |
| | Cooperative or Collaborative Work Tendency | G | FG | FG | G | F | F | F | G |
| Conscientiousness | General Trustworthiness | VG | G | G | VG | FG | G | G | G |
| | Adherence to a Work Ethic | VG | VG | VG | VG | VG | VG | VG | VG |
| | Thoroughness and Attentiveness to Details | G | G | G | G | G | G | G | G |
| Emotional Stability | Emotional Stability | F | FG | F | G | FG | F | FG | G |
| Intellectance | Desire to Generate Ideas | G | G | G | G | G | G | G | G |
| | Tendency to Think Things Through | G | G | G | G | G | G | G | G |

These linguistic evaluations are converted to triangular fuzzy numbers and aggregated by computing their arithmetic means; and this aggregated performance matrix of candidates is used for applying FTOPSIS and FVIKOR methods.

#### 5.3.1.1. Final selection by FTOPSIS

FTOPSIS has been applied for the personnel selection problem by using the fuzzy weights of the skills which were computed based on the tasks' weights determination by three different FAHP methods. In the final selection process, three FTOPSIS methods, namely, Chen (2000), Kahraman et al. (2007) and Karsak (2002), were applied. Thus, nine FAHP-FTOPSIS combinations have been performed to see the effects of variations in different FAHP and FTOPSIS methods and ensure that their outcomes are same. The results of these methods can be summarized in Table 5.11 and Table 5.12.

**Table 5.11 :** CCs of the candidates.

| **FTOPSIS Method** | **Chen (2000)** | | | **Kahraman et al. (2007)** | | | **Karsak (2002)** | | |
|---|---|---|---|---|---|---|---|---|---|
| **FAHP Method** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** |
| **Cand. 1** | 0.4022 | 0.2865 | 0.2883 | 0.2375 | 0.1725 | 0.1735 | 0.5693 | 0.7491 | 0.7471 |
| **Cand. 2** | 0.4296 | 0.3075 | 0.3094 | 0.6080 | 0.7098 | 0.7081 | 0.6089 | 0.8175 | 0.8150 |
| **Cand. 3** | 0.4173 | 0.3005 | 0.3023 | 0.4886 | 0.6068 | 0.6045 | 0.5842 | 0.7895 | 0.7872 |
| **Cand. 4** | 0.4190 | 0.2961 | 0.2980 | 0.4234 | 0.3336 | 0.3355 | 0.6170 | 0.8031 | 0.8010 |

**Table 5.12 :** Ranking of candidates by FTOPSIS.

| **FTOPSIS Method** | **Chen (2000)** | | | **Kahraman et al. (2007)** | | | **Karsak (2002)** | | |
|---|---|---|---|---|---|---|---|---|---|
| **FAHP Method** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** |
| | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 4 | Cand. 2 | Cand. 2 |
| | Cand. 4 | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 2 | Cand. 4 | Cand. 4 |
| | Cand. 3 | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 3 | Cand. 3 | Cand. 3 |
| | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 1 |

In Table 5.12, we can see that, in only one of the nine different FAHP and FTOPSIS combinations, candidate 4 was in the first candidate to be selected. According to the remaining eight FAHP and FTOPSIS combinations, candidate 2 must be selected.

We have also analyzed the case of single decision maker. In other words, if solely HoPD or HRS would evaluate the candidates and make the final decision what the outcome of the final selection process would be has been analyzed. This analysis has been performed by re-applying the FTOPSIS methods based on the evaluations of candidates which were performed individually by HoPD or HRS. The results of this analysis are seen in Table 5.13 and Table 5.14. If HoPD performs the candidate evaluation and final selection process alone, the FTOPSIS results show that candidate 2 would be selected according to all FAHP and FTOPSIS combinations. If HRS performs the candidate evaluation and final selection process alone, according to the nine of the eight FAHP and FTOPSIS combinations, candidate 2 must be selected as seen in Table 5.15 and Table 5.16.

**Table 5.13 :** CCs of the candidates based on assessments of HoPD.

| **FTOPSIS Method** | **Chen (2000)** | | | **Kahraman et al. (2007)** | | | **Karsak (2002)** | | |
|---|---|---|---|---|---|---|---|---|---|
| **FAHP Method** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** |
| **Cand. 1** | 0.3354 | 0.2660 | 0.2924 | 0.4179 | 0.3332 | 0.3349 | 0.6170 | 0.7851 | 0.7831 |
| **Cand. 2** | 0.3425 | 0.2731 | 0.3080 | 0.5944 | 0.6765 | 0.6749 | 0.6224 | 0.8261 | 0.8236 |
| **Cand. 3** | 0.3389 | 0.2710 | 0.3012 | 0.5398 | 0.6441 | 0.6421 | 0.5938 | 0.7917 | 0.7895 |
| **Cand. 4** | 0.3393 | 0.2691 | 0.2949 | 0.4462 | 0.3670 | 0.3688 | 0.6222 | 0.7965 | 0.7946 |

**Table 5.14 :** Ranking of the candidates based on assessments of HoPD.

| **FTOPSIS Method** | **Chen (2000)** | | | **Kahraman et al. (2007)** | | | **Karsak (2002)** | | |
|---|---|---|---|---|---|---|---|---|---|
| **FAHP Method** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** |
| | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 |
| | Cand. 4 | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 4 | Cand. 4 | Cand. 4 |
| | Cand. 3 | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 1 | Cand. 3 | Cand. 3 |
| | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 3 | Cand. 1 | Cand. 1 |

**Table 5.15 :** CCs of the candidates based on assessments of HRS.

| **FTOPSIS Method** | **Chen (2000)** | | | **Kahraman et al. (2007)** | | | **Karsak (2002)** | | |
|---|---|---|---|---|---|---|---|---|---|
| **FAHP Method** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** |
| **Cand. 1** | 0.3926 | 0.2556 | 0.2571 | 0.2093 | 0.1381 | 0.1388 | 0.5633 | 0.7387 | 0.7368 |
| **Cand. 2** | 0.4282 | 0.2798 | 0.2815 | 0.6463 | 0.7457 | 0.7444 | 0.6233 | 0.8266 | 0.8241 |
| **Cand. 3** | 0.4165 | 0.2701 | 0.2717 | 0.5118 | 0.6057 | 0.6040 | 0.6017 | 0.8008 | 0.7986 |
| **Cand. 4** | 0.4225 | 0.2696 | 0.2712 | 0.5221 | 0.4278 | 0.4297 | 0.6337 | 0.8152 | 0.8130 |

**Table 5.16 :** Ranking of the candidates based on assessments of HRS.

| **FTOPSIS Method** | **Chen (2000)** | | | **Kahraman et al. (2007)** | | | **Karsak (2002)** | | |
|---|---|---|---|---|---|---|---|---|---|
| **FAHP Method** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** |
| | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 4 | Cand. 2 | Cand. 2 |
| | Cand. 4 | Cand. 3 | Cand. 3 | Cand. 4 | Cand. 3 | Cand. 3 | Cand. 2 | Cand. 4 | Cand. 4 |
| | Cand. 3 | Cand. 4 | Cand. 4 | Cand. 3 | Cand. 4 | Cand. 4 | Cand. 3 | Cand. 3 | Cand. 3 |
| | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 1 |

### 5.3.1.2. Final selection by FVIKOR

For the comparison of the outcomes with the FTOPSIS results, FVIKOR method has also been applied. As it was done in FTOPSIS application, the method has been applied based on the fuzzy weights from three FAHP methods. Therefore, three different combinations were analyzed. Also, different weights of the strategy ($v$) between 0.5 and 1.0 have been tried for sensitivity analysis since the values of $v >$

0.5 show that the best candidate is selected by satisfying majority of the criteria. The ranking of candidates and values of $Q_{[k]} - Q_{[1]}$ can be seen in Table 5.17 and Table 5.18 respectively. The shaded cells in Table 5.18 show $Q_{[2]} - Q_{[1]}$ values in which $Q_{[1]}$ does not have an acceptable advantage over $Q_{[2]}$ (i.e. $Q_{[2]} - Q_{[1]} \leq DQ$). Thus, in the shaded cells, candidates in the first position to $k^{th}$ position form a compromise set of solutions; and the candidate in the first position set can not be exactly distinguished from the other candidates involved in the compromise solution by the decision maker(s).

**Table 5.17 :** Ranking of the candidates by FVIKOR.

| | ***v* = 0.50** | ***v* = 0.75** | ***v* = 1.00** |
|---|---|---|---|
| Chang (1996) | Cand. 2 | Cand. 2 | Cand. 2 |
| | Cand. 3 | Cand. 3 | Cand. 4 |
| | Cand. 4 | Cand. 4 | Cand. 3 |
| | Cand. 1 | Cand. 1 | Cand. 1 |
| Deng (1999) | Cand. 2 | Cand. 2 | Cand. 2 |
| | Cand. 3 | Cand. 3 | Cand. 4 |
| | Cand. 4 | Cand. 4 | Cand. 3 |
| | Cand. 1 | Cand. 1 | Cand. 1 |
| Buckley (1985) | Cand. 2 | Cand. 2 | Cand. 2 |
| | Cand. 3 | Cand. 3 | Cand. 4 |
| | Cand. 4 | Cand. 4 | Cand. 3 |
| | Cand. 1 | Cand. 1 | Cand. 1 |

**Table 5.18 :** Levels of advantage provided by selecting first-ranked candidate

| | ***v* = 0.50** | | ***v* = 0.75** | | ***v* = 1.00** | |
|---|---|---|---|---|---|---|
| Chang (1996) | Q3-Q2 | 0.054 | Q3-Q2 | 0.068 | Q4-Q2 | 0.053 |
| | Q4-Q2 | 0.299 | Q4-Q2 | 0.176 | Q3-Q2 | 0.082 |
| | Q1-Q2 | 0.354 | Q1-Q2 | 0.258 | Q1-Q2 | 0.162 |
| Deng (1999) | Q3-Q2 | 0.197 | Q3-Q2 | 0.291 | Q4-Q2 | 0.273 |
| | Q4-Q2 | 1.398 | Q4-Q2 | 0.836 | Q3-Q2 | 0.384 |
| | Q1-Q2 | 1.649 | Q1-Q2 | 1.212 | Q1-Q2 | 0.775 |
| Buckley (1985) | Q3-Q2 | 0.189 | Q3-Q2 | 0.277 | Q4-Q2 | 0.258 |
| | Q4-Q2 | 1.331 | Q4-Q2 | 0.794 | Q3-Q2 | 0.366 |
| | Q1-Q2 | 1.571 | Q1-Q2 | 1.155 | Q1-Q2 | 0.739 |
| **DQ = 0.250** | | | | | | |

In all cases candidate 2 was in the first position according to the $Q$ values and it was stable also in $S'_{[.]}$ and $R'_{[.]}$. Although candidate 2 is in the first position when tasks involved in the job are ranked by Chang's extent analysis (1996), candidate 2 does not have an acceptable advantage since $Q_{[2]} - Q_{[1]} \leq DQ$ for any strategy weight.

When Deng's FAHP method (1999) is applied, $Q_{[2]} - Q_{[1]} \geq DQ$ for $v$ > 0.641 and thus; candidate 2 has an acceptable advantage only when $v$ > 0.641. Similarly, critical strategy weight for candidate 2 to have an acceptable advantage is 0.673 when Buckley's FAHP method (1985) is applied for determining the task importance ratings. For strategy weights greater than this value, candidate 2 will have an acceptable advantage.

As it was applied in FTOPSIS, the cases where HoPD and HRS make the final selection individually are analyzed also in the FVIKOR application. The results for the case where HoPD individually evaluates the candidates are given in Table 5.19 and Table 5.20. In all cases candidate 2 was in the first position according to the $Q$ values and it was stable also in $S'_{[.]}$ and $R'_{[.]}$. When tasks involved in the job are ranked by Chang's extent analysis (1996), candidate 2 does not have an acceptable advantage since $Q_{[2]} - Q_{[1]} \leq DQ$ for any strategy weight. When Deng's FAHP method (1999) is applied, $Q_{[2]} - Q_{[1]} \geq DQ$ for all strategy weights; and thus candidate 2 has an acceptable advantage for all strategy weights. Similarly, $Q_{[2]} - Q_{[1]} \geq DQ$ for all strategy weights; and therefore candidate 2 has an acceptable advantage for all strategy weights when Buckley's FAHP method (1985) is applied for determining the task importance ratings.

**Table 5.19 :** Ranking of the candidates by FVIKOR based on assessments of HoPD.

| | **v = 0.50** | **v = 0.75** | **v = 1.00** |
|---|---|---|---|
| Chang (1996) | Cand. 2 | Cand. 2 | Cand. 2 |
| | Cand. 3 | Cand. 3 | Cand. 4 |
| | Cand. 4 | Cand. 4 | Cand. 3 |
| | Cand. 1 | Cand. 1 | Cand. 1 |
| Deng (1999) | Cand. 2 | Cand. 2 | Cand. 2 |
| | Cand. 3 | Cand. 3 | Cand. 4 |
| | Cand. 4 | Cand. 4 | Cand. 3 |
| | Cand. 1 | Cand. 1 | Cand. 1 |
| Buckley (1985) | Cand. 2 | Cand. 2 | Cand. 2 |
| | Cand. 3 | Cand. 3 | Cand. 4 |
| | Cand. 4 | Cand. 4 | Cand. 3 |
| | Cand. 1 | Cand. 1 | Cand. 1 |

**Table 5.20 :** Levels of advantage provided by selecting first-ranked candidate based on assessments of HoPD.

| | ***V* = 0.50** | | ***v* = 0.75** | | ***v* = 1.00** | |
|---|---|---|---|---|---|---|
| Chang (1996) | Q3-Q2 | 0.163 | Q3-Q2 | 0.128 | Q4-Q2 | 0.086 |
| | Q4-Q2 | 0.362 | Q4-Q2 | 0.224 | Q3-Q2 | 0.092 |
| | Q1-Q2 | 0.371 | Q1-Q2 | 0.238 | Q1-Q2 | 0.105 |
| Deng (1999) | Q3-Q2 | 0.566 | Q3-Q2 | 0.478 | Q4-Q2 | 0.383 |
| | Q4-Q2 | 1.574 | Q4-Q2 | 0.979 | Q3-Q2 | 0.389 |
| | Q1-Q2 | 1.624 | Q1-Q2 | 1.054 | Q1-Q2 | 0.484 |
| Buckley (1985) | Q3-Q2 | 0.541 | Q3-Q2 | 0.456 | Q4-Q2 | 0.364 |
| | Q4-Q2 | 1.499 | Q4-Q2 | 0.932 | Q3-Q2 | 0.371 |
| | Q1-Q2 | 1.548 | Q1-Q2 | 1.004 | Q1-Q2 | 0.461 |
| **DQ = 0.250** | | | | | | |

The results for the case where HRS individually evaluates the candidates are given in Table 5.21 and Table 5.22. As seen in these tables, candidate 2 and candidate 3 compete for the first position depending on the strategy weight and in all cases candidate in the first position according to the $Q$ values and was also stable in $S'_{[.]}$ and $R'_{[.]}$.

When tasks involved in the job are ranked by Chang's extent analysis (1996), candidate 2 and candidate 3 do not have an acceptable advantage since $Q_{[2]} - Q_{[1]} \geq DQ$ for any strategy weight and the critical strategy weight that candidate 2 first passes candidate 3 is 0.597. If strategy weight is greater than 0.597, then candidate 2 is the winner.

When Deng's FAHP method (1999) is applied, candidate 2 or candidate 3 does not have an acceptable advantage since $Q_{[2]} - Q_{[1]} \leq DQ$ for any strategy weight $v \geq 0.5$. The critical strategy weight that candidate 2 first passes candidate 3 is 0.504. Similarly, candidate 2 or candidate 3 does not have an acceptable advantage since $Q_{[2]} - Q_{[1]} \leq DQ$ for any strategy weight $v \geq 0.5$ when Buckley's FAHP method (1985) is applied for determining the task importance ratings. The critical strategy weight that candidate 2 first passes candidate 3 is 0.505.

**Table 5.21 :** Ranking of the candidates by FVIKOR based on assessments of HRS.

| | v = 0.50 | v = 0.75 | v = 1.00 |
|---|---|---|---|
| Chang (1996) | Cand. 3 | Cand. 2 | Cand. 2 |
| | Cand. 2 | Cand. 3 | Cand. 4 |
| | Cand. 4 | Cand. 4 | Cand. 3 |
| | Cand. 1 | Cand. 1 | Cand. 1 |
| Deng (1999) | Cand. 3 | Cand. 2 | Cand. 2 |
| | Cand. 2 | Cand. 3 | Cand. 4 |
| | Cand. 4 | Cand. 4 | Cand. 3 |
| | Cand. 1 | Cand. 1 | Cand. 1 |
| Buckley (1985) | Cand. 3 | Cand. 2 | Cand. 2 |
| | Cand. 2 | Cand. 3 | Cand. 4 |
| | Cand. 4 | Cand. 4 | Cand. 3 |
| | Cand. 1 | Cand. 1 | Cand. 1 |

**Table 5.22 :** Levels of advantage provided by selecting first-ranked candidate based on assessments of HRS.

| | *v* = 0.50 | | *v* = 0.75 | | *v* = 1.00 | |
|---|---|---|---|---|---|---|
| Chang (1996) | Q2-Q3 | 0.018 | Q3-Q2 | 0.028 | Q4-Q2 | 0.017 |
| | Q4-Q3 | 0.241 | Q4-Q2 | 0.120 | Q3-Q2 | 0.073 |
| | Q1-Q3 | 0.336 | Q1-Q2 | 0.262 | Q1-Q2 | 0.206 |
| Deng (1999) | Q2-Q3 | 0.004 | Q3-Q2 | 0.185 | Q4-Q2 | 0.145 |
| | Q4-Q3 | 1.089 | Q4-Q2 | 0.615 | Q3-Q2 | 0.373 |
| | Q1-Q3 | 1.517 | Q1-Q2 | 1.258 | Q1-Q2 | 1.002 |
| Buckley (1985) | Q2-Q3 | 0.004 | Q3-Q2 | 0.176 | Q4-Q2 | 0.136 |
| | Q4-Q3 | 1.036 | Q4-Q2 | 0.584 | Q3-Q2 | 0.356 |
| | Q1-Q3 | 1.446 | Q1-Q2 | 1.199 | Q1-Q2 | 0.956 |
| **DQ = 0.250** | | | | | | |

### 5.3.2. Application for CME position

Application for CME position was based on an internal recruitment scenario in which one of the maintenance engineers employed in the company is promoted to the CME position in the case that the current CME leaves the company. The decision makers involved in the job analysis phase is current CME and a maintenance engineer (ME) who determine the task statements and personnel characteristics involved in the position, perform pairwise comparison of tasks in consensus and assess tasks-KSAOs linkages individually to find the overall KSAOs weights.

In this step, 10 task statements have been determined to cover the job content; and considering each of these tasks seperately, 31 KSAOs were hypothesized to be predicting the future performance of a CME. As in the SE application, tasks involved in CME position have been ranked by using three different FAHP methods. The outcomes of phase I of FQFD process can be seen in Table 5.23 and Table 5.24. The tables showing all the information gathered and used in this application can be seen in Appendix C.

**Table 5.23 :** Weights of the tasks performed by CME.

| | | OVERALL TASK WEIGHTS | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **CHANG** | **DENG** | | | **BUCKLEY** | | |
| | | **Crisp** | **L** | **M** | **U** | **L** | **M** | **U** |
| **1** | Performs the annual maintenance plans for the process machines in agreement with production chiefs and ensures that these plans are applied. | 0,201 | 0,058 | 0,151 | 0,376 | 0,061 | 0,151 | 0,360 |
| **2** | Controls the monthly shift plans of his staff, plans the annual vacation of his staff and ensures that these plans are obeyed. | 0,008 | 0,024 | 0,062 | 0,168 | 0,026 | 0,063 | 0,163 |
| **3** | Solves the problems associated with unplanned interruptions in production as soon as possible by coordinating related organizational units. | 0,133 | 0,042 | 0,118 | 0,309 | 0,043 | 0,116 | 0,294 |
| **4** | Researches alternative solutions for repetitive problems and applies these solutions. | 0,105 | 0,038 | 0,105 | 0,280 | 0,039 | 0,105 | 0,270 |
| **5** | Controls the inventory costs associated with spare parts of the machines which are in his responsibility and takes initiatives for achieving the targets. | 0,078 | 0,032 | 0,084 | 0,225 | 0,032 | 0,079 | 0,203 |
| **6** | Procures the spare parts which do not exist in the spare parts inventories from external suppliers in urgent cases. | 0,115 | 0,030 | 0,085 | 0,242 | 0,031 | 0,085 | 0,228 |
| **7** | Supports his staff by considering their educational, personal and equipment requirements. | 0,126 | 0,037 | 0,101 | 0,288 | 0,038 | 0,100 | 0,272 |
| **8** | Ensures the realization of quality management activities (calibration and procedures etc.). | 0,139 | 0,046 | 0,122 | 0,336 | 0,049 | 0,124 | 0,324 |
| **9** | Coordinates the assembly and launching of the new machines. | 0,044 | 0,032 | 0,086 | 0,223 | 0,034 | 0,089 | 0,223 |
| **10** | Formation of the planned maintenance control lists of the new machines, determination of spare parts inventories for the new machines and provides the education of the machines about the new machines. | 0,050 | 0,033 | 0,086 | 0,232 | 0,035 | 0,089 | 0,229 |

**Table 5.24 :** Weights of the KSAOs required for CME position.

| | | Chang (1996) | | | Deng (1999) | | | Buckley (1985) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **L** | **M** | **U** | **L** | **M** | **U** | **L** | **M** | **U** |
| **1** | Oral Comprehension | 0.472 | 0.703 | 0.902 | 0.063 | 0.253 | 0.871 | 0.068 | 0.264 | 0.870 |
| **2** | Written Comprehension | 0.257 | 0.417 | 0.567 | 0.041 | 0.171 | 0.605 | 0.044 | 0.179 | 0.607 |
| **3** | Oral Expression | 0.511 | 0.725 | 0.909 | 0.067 | 0.258 | 0.870 | 0.072 | 0.268 | 0.868 |
| **4** | Written Expression | 0.237 | 0.443 | 0.649 | 0.034 | 0.165 | 0.643 | 0.038 | 0.172 | 0.642 |
| **5** | Active Listening | 0.479 | 0.676 | 0.838 | 0.062 | 0.241 | 0.801 | 0.068 | 0.251 | 0.802 |
| **6** | Critical Thinking & Decision Making | 0.339 | 0.532 | 0.723 | 0.047 | 0.196 | 0.713 | 0.050 | 0.205 | 0.714 |
| **7** | Complex Problem Solving | 0.237 | 0.373 | 0.538 | 0.037 | 0.150 | 0.563 | 0.040 | 0.157 | 0.566 |
| **8** | Systems Analysis & Evaluation | 0.310 | 0.370 | 0.414 | 0.047 | 0.154 | 0.456 | 0.051 | 0.162 | 0.461 |
| **9** | Time Management | 0.517 | 0.653 | 0.744 | 0.070 | 0.240 | 0.725 | 0.077 | 0.251 | 0.727 |
| **10** | Management of Material Resources | 0.468 | 0.586 | 0.676 | 0.063 | 0.212 | 0.657 | 0.068 | 0.220 | 0.653 |
| **11** | Management of Personnel Resources | 0.486 | 0.646 | 0.763 | 0.066 | 0.236 | 0.750 | 0.071 | 0.246 | 0.748 |
| **12** | Milk Production and Processing | 0.481 | 0.631 | 0.744 | 0.060 | 0.211 | 0.661 | 0.065 | 0.221 | 0.662 |
| **13** | Knowledge of Basic Electricity | 0.466 | 0.633 | 0.787 | 0.061 | 0.222 | 0.732 | 0.066 | 0.232 | 0.734 |
| **14** | Knowledge of Pneumatics | 0.665 | 0.819 | 0.917 | 0.087 | 0.286 | 0.850 | 0.094 | 0.299 | 0.853 |
| **15** | Knowledge of Hydraulics | 0.665 | 0.819 | 0.917 | 0.087 | 0.286 | 0.850 | 0.094 | 0.299 | 0.853 |
| **16** | Knowledge of Automation | 0.665 | 0.819 | 0.917 | 0.087 | 0.286 | 0.850 | 0.094 | 0.299 | 0.853 |
| **17** | Computer Skills (SAP R/3) | 0.318 | 0.505 | 0.704 | 0.047 | 0.187 | 0.675 | 0.051 | 0.194 | 0.672 |
| **18** | Computer Skills (MS-Office) | 0.332 | 0.534 | 0.735 | 0.048 | 0.205 | 0.749 | 0.052 | 0.214 | 0.747 |
| **19** | Computer Skills (AutoCAD) | 0.451 | 0.565 | 0.624 | 0.059 | 0.203 | 0.603 | 0.065 | 0.212 | 0.604 |
| **20** | General Leadership | 0.519 | 0.718 | 0.886 | 0.074 | 0.272 | 0.887 | 0.081 | 0.284 | 0.886 |
| **21** | Interest in Negotiation | 0.169 | 0.284 | 0.398 | 0.021 | 0.098 | 0.371 | 0.023 | 0.102 | 0.371 |
| **22** | Achievement Striving | 0.541 | 0.728 | 0.888 | 0.073 | 0.266 | 0.868 | 0.079 | 0.277 | 0.868 |
| **23** | Friendly Disposition | 0.212 | 0.334 | 0.449 | 0.028 | 0.118 | 0.423 | 0.030 | 0.123 | 0.421 |
| **24** | Sensitivity to interest of others | 0.167 | 0.273 | 0.378 | 0.023 | 0.100 | 0.371 | 0.025 | 0.105 | 0.370 |
| **25** | Cooperative or Collaborative Work Tendency | 0.542 | 0.746 | 0.889 | 0.076 | 0.280 | 0.888 | 0.082 | 0.293 | 0.889 |
| **26** | General Trustworthiness | 0.450 | 0.592 | 0.674 | 0.064 | 0.227 | 0.687 | 0.069 | 0.236 | 0.686 |
| **27** | Adherence to a Work Ethic | 0.740 | 0.909 | 1.000 | 0.107 | 0.346 | 1.000 | 0.116 | 0.361 | 1.000 |
| **28** | Thoroughness and Attentiveness to Details | 0.517 | 0.677 | 0.800 | 0.073 | 0.257 | 0.807 | 0.079 | 0.269 | 0.809 |
| **29** | Emotional Stability | 0.270 | 0.451 | 0.631 | 0.038 | 0.170 | 0.635 | 0.041 | 0.178 | 0.635 |
| **30** | Desire to Generate Ideas | 0.286 | 0.363 | 0.410 | 0.039 | 0.135 | 0.402 | 0.042 | 0.141 | 0.403 |
| **31** | Tendency to Think Things Through | 0.439 | 0.578 | 0.675 | 0.066 | 0.230 | 0.701 | 0.072 | 0.242 | 0.708 |

There were six candidates who are currently employed as Maintenance Engineers (MEs) in the company and general recruitment practice for CME position is to promote one of the MEs currently employed in the company. Since there is only one open position, the selection ratio is 1/6 ≈ 0.17, which is a fairly high value. The candidates are evaluated by Plant Manager (PM), who is the immediate supervisor of CME position, and HRS (see Table 5.25).

**Table 5.25 :** Evaluation of the candidates.

| | PM | | | | | | HRS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **C1** | **C2** | **C3** | **C4** | **C5** | **C6** | **C1** | **C2** | **C3** | **C4** | **C5** | **C6** |
| Oral Comprehension | VG | VG | VG | VG | VG | VG | VG | VG | VG | VG | VG | VG |
| Written Comprehension | VG | VG | VG | VG | VG | VG | VG | VG | VG | VG | VG | VG |
| Oral Expression | F | FG | VG | G | FG | F | F | FG | G | G | FG | F |
| Written Expression | VG | VG | VG | VG | VG | VG | VG | VG | VG | VG | VG | VG |
| Active Listening | G | FG | G | VG | FG | FG | G | FG | VG | G | FG | FG |
| Critical Thinking & Decision Making | FG | FG | G | G | F | FG | G | G | G | G | G | G |
| Complex Problem Solving | FG | FG | VG | G | G | FG | F | FG | G | FG | G | FG |
| Systems Analysis & Evaluation | G | VG | G | VG | G | VG | G | G | G | G | G | G |
| Time Management | FG | G | G | FG | FG | FG | FG | FG | G | G | FG | F |
| Management of Material Resources | G | G | G | G | G | G | G | G | G | G | G | G |
| Management of Personnel Resources | F | F | VG | FG | F | F | F | FG | G | G | F | F |
| Milk Production and Processing | G | G | G | G | G | G | VG | VG | VG | VG | VG | VG |
| Knowledge of Basic Electricity | G | G | G | G | G | G | FG | FG | G | FG | FG | G |
| Knowledge of Pneumatics | G | G | G | G | G | G | G | G | G | G | G | G |
| Knowledge of Hydraulics | G | G | G | G | G | G | G | G | G | G | G | G |
| Knowledge of Automation | G | G | G | G | G | G | G | G | G | G | G | G |
| Computer Skills (SAP R/3) | G | G | G | G | G | G | G | G | G | G | G | G |
| Computer Skills (MS-Office) | G | G | G | G | G | G | FG | FG | VG | G | G | FG |
| Computer Skills (AutoCAD) | F | F | G | FG | G | G | FG | F | G | G | FG | FG |
| General Leadership | FG | F | VG | G | F | F | F | FG | G | G | FG | F |
| Interest in Negotiation | G | G | G | VG | F | FG | G | FG | G | G | F | FG |
| Achievement Striving | G | FG | VG | FG | F | F | F | FG | VG | FG | G | F |
| Friendly Disposition | VG | VG | FG | G | FG | VG | FG | G | FG | G | VG | G |
| Sensitivity to interest of others | FG | G | F | FG | FG | FG | G | G | FG | FG | FG | FG |
| Cooperative or Collaborative Work Tendency | FG | G | VG | FG | FG | F | FG | FG | G | F | FG | F |
| General Trustworthiness | G | G | VG | FG | G | FG | G | G | VG | FG | G | G |
| Adherence to a Work Ethic | FG | G | VG | FG | FG | F | G | FG | G | FG | G | FG |
| Thoroughness and Attentiveness to Details | F | F | G | FG | FG | G | FG | F | VG | FG | F | F |
| Emotional Stability | FG | G | FG | F | FG | G | FG | G | G | F | FG | G |
| Desire to Generate Ideas | F | F | G | VG | FG | VG | F | F | FG | VG | FG | G |
| Tendency to Think Things Through | FG | FG | G | FG | VG | G | FG | FG | G | G | G | G |

These linguistic evaluations are converted to triangular fuzzy numbers and aggregated by computing their arithmetic means; and this aggregated performance matrix of candidates is used for applying FTOPSIS and FVIKOR methods.

### 5.3.2.1. Final selection by FTOPSIS

As in the application for SE position, FTOPSIS has been applied for selecting the most suitable person. When individual candidate assessment of PM and HRS are aggregated, candidate 3 is selected according to all FAHP and FTOPSIS combinations (See Table 5.26 and Table 5.27). Similarly, candidate 3 would be selected also in the cases where the decision is based on the individual assessments of either PM or HRS (See Tables 5.28 – 5.31).

**Table 5.26 :** CCs of the candidates.

| FTOPSIS Method | Chen (2000) | | | Kahraman et al. (2007) | | | Karsak (2002) | | |
|---|---|---|---|---|---|---|---|---|---|
| **FAHP Method** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** |
| **Cand. 1** | 0.4576 | 0.3324 | 0.3344 | 0.3246 | 0.3417 | 0.3420 | 0.6175 | 0.7889 | 0.7855 |
| **Cand. 2** | 0.4648 | 0.3366 | 0.3386 | 0.3881 | 0.4114 | 0.4116 | 0.6326 | 0.8090 | 0.8055 |
| **Cand. 3** | 0.5185 | 0.3583 | 0.3608 | 0.8775 | 0.8851 | 0.8849 | 0.7643 | 0.9163 | 0.9128 |
| **Cand. 4** | 0.4839 | 0.3453 | 0.3475 | 0.6037 | 0.6220 | 0.6215 | 0.6773 | 0.8518 | 0.8483 |
| **Cand. 5** | 0.4658 | 0.3367 | 0.3388 | 0.4089 | 0.4240 | 0.4237 | 0.6363 | 0.8095 | 0.8061 |
| **Cand. 6** | 0.4522 | 0.3288 | 0.3308 | 0.3417 | 0.3501 | 0.3497 | 0.6074 | 0.7705 | 0.7672 |

**Table 5.27 :** Ranking of candidates by FTOPSIS.

| FTOPSIS Method | Chen (2000) | | | Kahraman et al. (2007) | | | Karsak (2002) | | |
|---|---|---|---|---|---|---|---|---|---|
| **FAHP Method** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** |
| | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 |
| | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 |
| | Cand. 5 | Cand. 5 | Cand. 5 | Cand. 5 | Cand. 5 | Cand. 5 | Cand. 5 | Cand. 5 | Cand. 5 |
| | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 |
| | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 6 | Cand. 6 | Cand. 6 | Cand. 1 | Cand. 1 | Cand. 1 |
| | Cand. 6 | Cand. 6 | Cand. 6 | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 6 | Cand. 6 | Cand. 6 |

**Table 5.28 :** CCs of the candidates based on assessments of PM.

| FTOPSIS Method | Chen (2000) | | | Kahraman et al. (2007) | | | Karsak (2002) | | |
|---|---|---|---|---|---|---|---|---|---|
| **FAHP Method** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** |
| **Cand. 1** | 0.4599 | 0.3340 | 0.3360 | 0.3307 | 0.3558 | 0.3560 | 0.6248 | 0.7971 | 0.7934 |
| **Cand. 2** | 0.4681 | 0.3373 | 0.3394 | 0.4108 | 0.4359 | 0.4361 | 0.6460 | 0.8128 | 0.8091 |
| **Cand. 3** | 0.5197 | 0.3580 | 0.3605 | 0.8429 | 0.8498 | 0.8495 | 0.7636 | 0.9137 | 0.9102 |
| **Cand. 4** | 0.4835 | 0.3454 | 0.3476 | 0.5721 | 0.5982 | 0.5977 | 0.6770 | 0.8514 | 0.8477 |
| **Cand. 5** | 0.4589 | 0.3330 | 0.3351 | 0.3278 | 0.3433 | 0.3431 | 0.6228 | 0.7930 | 0.7895 |
| **Cand. 6** | 0.4555 | 0.3303 | 0.3323 | 0.3503 | 0.3664 | 0.3660 | 0.6163 | 0.7780 | 0.7746 |

**Table 5.29 :** Ranking of the candidates based on assessments of PM.

| FTOPSIS Method | Chen (2000) | | | Kahraman et al. (2007) | | | Karsak (2002) | | |
|---|---|---|---|---|---|---|---|---|---|
| **FAHP Method** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** |
| | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 |
| | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 |
| | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 |
| | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 6 | Cand. 6 | Cand. 6 | Cand. 1 | Cand. 1 | Cand. 1 |
| | Cand. 5 | Cand. 5 | Cand. 5 | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 5 | Cand. 5 | Cand. 5 |
| | Cand. 6 | Cand. 6 | Cand. 6 | Cand. 5 | Cand. 5 | Cand. 5 | Cand. 6 | Cand. 6 | Cand. 6 |

**Table 5.30 :** CCs of the candidates based on assessments of HRS.

| FTOPSIS Method | Chen (2000) | | | Kahraman et al. (2007) | | | Karsak (2002) | | |
|---|---|---|---|---|---|---|---|---|---|
| **FAHP Method** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** |
| **Cand. 1** | 0.4551 | 0.3306 | 0.3326 | 0.3046 | 0.3151 | 0.3155 | 0.6156 | 0.7819 | 0.7783 |
| **Cand. 2** | 0.4615 | 0.3358 | 0.3378 | 0.3448 | 0.3722 | 0.3723 | 0.6216 | 0.8020 | 0.7983 |
| **Cand. 3** | 0.5174 | 0.3587 | 0.3612 | 0.8865 | 0.8978 | 0.8977 | 0.7606 | 0.9168 | 0.9131 |
| **Cand. 4** | 0.4844 | 0.3452 | 0.3474 | 0.6185 | 0.6344 | 0.6340 | 0.6753 | 0.8463 | 0.8425 |
| **Cand. 5** | 0.4727 | 0.3402 | 0.3424 | 0.4693 | 0.4875 | 0.4872 | 0.6546 | 0.8278 | 0.8241 |
| **Cand. 6** | 0.4490 | 0.3273 | 0.3292 | 0.3021 | 0.3110 | 0.3107 | 0.6015 | 0.7643 | 0.7608 |

**Table 5.31 :** Ranking of the candidates based on assessments of HRS.

| FTOPSIS Method | Chen (2000) | | | Kahraman et al. (2007) | | | Karsak (2002) | | |
|---|---|---|---|---|---|---|---|---|---|
| **FAHP Method** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** | **Chang (1996)** | **Deng (1999)** | **Buckley (1985)** |
| | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 | Cand. 3 |
| | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 | Cand. 4 |
| | Cand. 5 | Cand. 5 | Cand. 5 | Cand. 5 | Cand. 5 | Cand. 5 | Cand. 5 | Cand. 5 | Cand. 5 |
| | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 | Cand. 2 |
| | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 1 | Cand. 1 |
| | Cand. 6 | Cand. 6 | Cand. 6 | Cand. 6 | Cand. 6 | Cand. 6 | Cand. 6 | Cand. 6 | Cand. 6 |

#### 5.3.2.2. Final selection by FVIKOR

FVIKOR method has been applied also in this application. In all cases candidate 3 was in the first position according to the $Q$ values was stable also in $S'_{[.]}$ and $R'_{[.]}$. The ranking of candidates by different ranking values and $Q_{[k]} - Q_{[1]}$ values can be seen in Table 5.32 and Table 5.33 respectively.

When tasks involved in the job are ranked by Chang's extent analysis (1996), candidate 3 has an acceptable advantage since $Q_{[2]} - Q_{[1]} \geq DQ$ for any strategy weight. Similarly, when Deng's FAHP method (1999) or Buckley's FAHP method (1985) is applied, same result is valid.

**Table 5.32 :** Ranking of the candidates by FVIKOR.

| | ***v* = 0.50** | ***v* = 0.75** | ***v* = 1.00** |
|---|---|---|---|
| Chang (1996) | Cand. 3 | Cand. 3 | Cand. 3 |
| | Cand. 4 | Cand. 4 | Cand. 4 |
| | Cand. 1 | Cand. 5 | Cand. 5 |
| | Cand. 5 | Cand. 1 | Cand. 2 |
| | Cand. 2 | Cand. 2 | Cand. 1 |
| | Cand. 6 | Cand. 6 | Cand. 6 |

**Table 5.32 :** Ranking of the candidates by FVIKOR (contd.)

| | ***v* = 0.50** | ***v* = 0.75** | ***v* = 1.00** |
|---|---|---|---|
| Deng (1999) | Cand. 3 | Cand. 3 | Cand. 3 |
| | Cand. 1 | Cand. 1 | Cand. 4 |
| | Cand. 4 | Cand. 4 | Cand. 5 |
| | Cand. 5 | Cand. 5 | Cand. 2 |
| | Cand. 2 | Cand. 2 | Cand. 1 |
| | Cand. 6 | Cand. 6 | Cand. 6 |
| Buckley (1985) | Cand. 3 | Cand. 3 | Cand. 3 |
| | Cand. 1 | Cand. 1 | Cand. 4 |
| | Cand. 4 | Cand. 4 | Cand. 5 |
| | Cand. 5 | Cand. 5 | Cand. 2 |
| | Cand. 2 | Cand. 2 | Cand. 1 |
| | Cand. 6 | Cand. 6 | Cand. 6 |

**Table 5.33 :** Levels of advantage provided by selecting first-ranked candidate.

| | ***v* = 0.50** | | ***v* = 0.75** | | ***v* = 1.00** | |
|---|---|---|---|---|---|---|
| Chang (1996) | Q4-Q3 | 0.380 | Q4-Q3 | 0.332 | Q4-Q3 | 0.284 |
| | Q1-Q3 | 0.423 | Q5-Q3 | 0.446 | Q5-Q3 | 0.420 |
| | Q5-Q3 | 0.473 | Q1-Q3 | 0.452 | Q2-Q3 | 0.427 |
| | Q2-Q3 | 0.500 | Q2-Q3 | 0.464 | Q1-Q3 | 0.480 |
| | Q6-Q3 | 0.622 | Q6-Q3 | 0.570 | Q6-Q3 | 0.518 |
| Deng (1999) | Q1-Q3 | 0.510 | Q1-Q3 | 1.229 | Q4-Q3 | 1.154 |
| | Q4-Q3 | 1.540 | Q4-Q3 | 1.405 | Q5-Q3 | 1.685 |
| | Q5-Q3 | 1.827 | Q5-Q3 | 1.830 | Q2-Q3 | 1.704 |
| | Q2-Q3 | 1.981 | Q2-Q3 | 1.916 | Q1-Q3 | 1.928 |
| | Q6-Q3 | 2.561 | Q6-Q3 | 2.420 | Q6-Q3 | 2.078 |
| Buckley (1985) | Q1-Q3 | 0.510 | Q1-Q3 | 1.150 | Q4-Q3 | 1.071 |
| | Q4-Q3 | 1.540 | Q4-Q3 | 1.306 | Q5-Q3 | 1.563 |
| | Q5-Q3 | 1.827 | Q5-Q3 | 1.695 | Q2-Q3 | 1.583 |
| | Q2-Q3 | 1.981 | Q2-Q3 | 1.782 | Q1-Q3 | 1.790 |
| | Q6-Q3 | 2.561 | Q6-Q3 | 2.244 | Q6-Q3 | 1.928 |
| **DQ = 0.200** | | | | | | |

As it was applied for SE position, the cases where PM and HRS make the final selection individually are analyzed also in the FVIKOR application. The results for the case where PM individually evaluates the candidates are given in Table 5.34 and Table 5.35. In all cases, candidate 3 was in the first position according to the $Q$ values and was stable also in $S'_{[.]}$ and $R'_{[.]}$. When tasks involved in the job are ranked by any FAHP method, candidate 3 has an acceptable advantage since $Q_{[2]} - Q_{[1]} \geq DQ$ for all strategy weights $v \geq 0.5$.

**Table 5.34 :** Ranking of the candidates by FVIKOR based on assessments of PM.

| | ***v* = 0.50** | ***v* = 0.75** | ***v* = 1.00** |
|---|---|---|---|
| Chang (1996) | Cand. 3 | Cand. 3 | Cand. 3 |
| | Cand. 4 | Cand. 4 | Cand. 4 |
| | Cand. 1 | Cand. 2 | Cand. 2 |
| | Cand. 2 | Cand. 1 | Cand. 1 |
| | Cand. 5 | Cand. 5 | Cand. 5 |
| | Cand. 6 | Cand. 6 | Cand. 6 |
| Deng (1999) | Cand. 3 | Cand. 3 | Cand. 3 |
| | Cand. 1 | Cand. 4 | Cand. 4 |
| | Cand. 4 | Cand. 1 | Cand. 2 |
| | Cand. 2 | Cand. 2 | Cand. 1 |
| | Cand. 5 | Cand. 5 | Cand. 5 |
| | Cand. 6 | Cand. 6 | Cand. 6 |
| Buckley (1985) | Cand. 3 | Cand. 3 | Cand. 3 |
| | Cand. 1 | Cand. 4 | Cand. 4 |
| | Cand. 4 | Cand. 1 | Cand. 2 |
| | Cand. 2 | Cand. 2 | Cand. 1 |
| | Cand. 5 | Cand. 5 | Cand. 5 |
| | Cand. 6 | Cand. 6 | Cand. 6 |

**Table 5.35 :** Levels of advantage provided by selecting first-ranked candidate based on assessments of PM.

| | ***v* = 0.50** | | ***v* = 0.75** | | ***v* = 1.00** | |
|---|---|---|---|---|---|---|
| Chang (1996) | Q4-Q3 | 0.311 | Q4-Q3 | 0.307 | Q4-Q3 | 0.303 |
| | Q1-Q3 | 0.419 | Q2-Q3 | 0.438 | Q2-Q3 | 0.422 |
| | Q2-Q3 | 0.454 | Q1-Q3 | 0.452 | Q1-Q3 | 0.485 |
| | Q5-Q3 | 0.524 | Q5-Q3 | 0.512 | Q5-Q3 | 0.501 |
| | Q6-Q3 | 0.599 | Q6-Q3 | 0.558 | Q6-Q3 | 0.517 |
| Deng (1999) | Q1-Q3 | 0.533 | Q4-Q3 | 1.126 | Q4-Q3 | 1.213 |
| | Q4-Q3 | 1.038 | Q1-Q3 | 1.229 | Q2-Q3 | 1.678 |
| | Q2-Q3 | 1.665 | Q2-Q3 | 1.672 | Q1-Q3 | 1.925 |
| | Q5-Q3 | 2.005 | Q5-Q3 | 2.009 | Q5-Q3 | 2.014 |
| | Q6-Q3 | 2.077 | Q6-Q3 | 2.074 | Q6-Q3 | 2.070 |
| Buckley (1985) | Q1-Q3 | 0.516 | Q4-Q3 | 1.046 | Q4-Q3 | 1.126 |
| | Q4-Q3 | 0.966 | Q1-Q3 | 1.152 | Q2-Q3 | 1.558 |
| | Q2-Q3 | 1.544 | Q2-Q3 | 1.551 | Q1-Q3 | 1.788 |
| | Q5-Q3 | 1.858 | Q5-Q3 | 1.862 | Q5-Q3 | 1.867 |
| | Q6-Q3 | 1.929 | Q6-Q3 | 1.925 | Q6-Q3 | 1.920 |
| **DQ = 0.200** | | | | | | |

The same results have been obtained for the case where HRS individually evaluates the candidates as given in Table 5.36 and Table 5.37. In all cases, candidate 3 was in the first position according to the $Q$ values and was stable also in $S^{'}_{[.]}$ and $R^{'}_{[.]}$. When tasks involved in the job are ranked by any FAHP method, candidate 3 has an acceptable advantage since $Q_{[2]} - Q_{[1]} \geq DQ$ for all strategy weights $v \geq 0.5$.

**Table 5.36 :** Ranking of the candidates by FVIKOR based on assessments of HRS.

| | *v* = 0.50 | *v* = 0.75 | *v* = 1.00 |
|---|---|---|---|
| Chang (1996) | Cand. 3 | Cand. 3 | Cand. 3 |
| | Cand. 1 | Cand. 4 | Cand. 4 |
| | Cand. 5 | Cand. 5 | Cand. 5 |
| | Cand. 4 | Cand. 1 | Cand. 2 |
| | Cand. 2 | Cand. 2 | Cand. 1 |
| | Cand. 6 | Cand. 6 | Cand. 6 |
| Deng (1999) | Cand. 3 | Cand. 3 | Cand. 3 |
| | Cand. 1 | Cand. 1 | Cand. 4 |
| | Cand. 5 | Cand. 4 | Cand. 5 |
| | Cand. 4 | Cand. 5 | Cand. 2 |
| | Cand. 2 | Cand. 2 | Cand. 1 |
| | Cand. 6 | Cand. 6 | Cand. 6 |
| Buckley (1985) | Cand. 3 | Cand. 3 | Cand. 3 |
| | Cand. 1 | Cand. 1 | Cand. 4 |
| | Cand. 5 | Cand. 4 | Cand. 5 |
| | Cand. 4 | Cand. 5 | Cand. 2 |
| | Cand. 2 | Cand. 2 | Cand. 1 |
| | Cand. 6 | Cand. 6 | Cand. 6 |

**Table 5.37 :** Levels of advantage provided by selecting first-ranked candidate based on assessments of HRS.

| | *v* = 0.50 | | *v* = 0.75 | | *v* = 1.00 | |
|---|---|---|---|---|---|---|
| Chang (1996) | Q1-Q3 | 0.406 | Q4-Q3 | 0.356 | Q4-Q3 | 0.265 |
| | Q5-Q3 | 0.438 | Q5-Q3 | 0.392 | Q5-Q3 | 0.345 |
| | Q4-Q3 | 0.446 | Q1-Q3 | 0.441 | Q2-Q3 | 0.432 |
| | Q2-Q3 | 0.482 | Q2-Q3 | 0.457 | Q1-Q3 | 0.475 |
| | Q6-Q3 | 0.601 | Q6-Q3 | 0.559 | Q6-Q3 | 0.517 |
| Deng (1999) | Q1-Q3 | 0.405 | Q1-Q3 | 1.170 | Q4-Q3 | 1.092 |
| | Q5-Q3 | 1.832 | Q4-Q3 | 1.490 | Q5-Q3 | 1.377 |
| | Q4-Q3 | 1.888 | Q5-Q3 | 1.604 | Q2-Q3 | 1.725 |
| | Q2-Q3 | 2.006 | Q2-Q3 | 1.866 | Q1-Q3 | 1.934 |
| | Q6-Q3 | 2.629 | Q6-Q3 | 2.355 | Q6-Q3 | 2.081 |
| Buckley (1985) | Q1-Q3 | 0.396 | Q1-Q3 | 1.096 | Q4-Q3 | 1.014 |
| | Q5-Q3 | 1.707 | Q4-Q3 | 1.386 | Q5-Q3 | 1.278 |
| | Q4-Q3 | 1.759 | Q5-Q3 | 1.493 | Q2-Q3 | 1.603 |
| | Q2-Q3 | 1.869 | Q2-Q3 | 1.736 | Q1-Q3 | 1.795 |
| | Q6-Q3 | 2.440 | Q6-Q3 | 2.186 | Q6-Q3 | 1.931 |
| **DQ = 0.200** | | | | | | |

## 5.4. Summary and Discussion

In this chapter, the framework provided by the proposed model and methods used within this framework have been explained in detail. As it has been mentioned before, FQFD has been used to translate task statements into KSAOs, which are then used in the final selection process. The task statements and KSAOs are determined by work-oriented and worker-oriented job analysis. The weights of task statements including work and organizational context and tools and technology used, are obtained by using FAHP methods based on three criteria: task criticality, task frequency and time spent. After determination of tasks' weights, tasks-KSAOs linkages are performed by a fuzzy relationship matrix and fuzzy weights of KSAOs are determined. Using the fuzzy weights of KSAOs and evaluation of assessments of candidates by the decision makers, final selection phase is realized by using FTOPSIS and FVIKOR methods. Why FAHP is not used in the final selection process is a possible question to be asked in this phase. If FAHP had been applied through the whole selection process as seen in Figure 5.6, first the KSAOs would be ranked in the hierarchy level 2 and then, candidates would be compared pairwise with each other with respect to each KSAO in the hierarchy level 3 and finally, the overall candidate scores would be calculated by using the candidates' scores for each KSAO and the weights of the KSAOs.

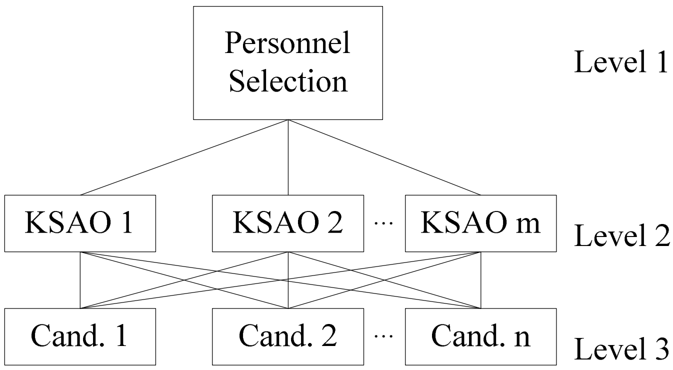


**Figure 5.6 :** Hierarchy for personnel selection problem.

Since personnel selection problems may involve many candidates to be evaluated based on many KSAOs, huge consistency problems would arise in many pairwise comparison matrices depending on the number of KSAOs and the number of candidates if FAHP had been applied. Also, in such an application we would not be able to use the notion of translating the job description into KSAOs and their levels, which is provided by FQFD. Thus, FTOPSIS has been used in the final selection due to its advantages over FAHP as mentioned in Table 4.4.

The model has been applied for two positions in of the leading companies in milk and milk products sector in Turkey. The first position which the model has been applied is Shift Engineer position. There were four candidates for this position after the pre-screening phase and selection ratio was 0.25, which is a fairly high value. In order to determine the KSAOs required for the job and their weight, job analysis has been performed prior to the final selection phase. Two decision makers' assessed the four candidates based on the predetermined KSAOs and best candidate has been determined by applying FTOPSIS and FVIKOR methods. As a result of this process, candidate 2 has been found to be the most suitable person for the position in 8 of the 9 combinations of FAHP and FTOPSIS methods, when the decision making is performed by aggregating the individual candidate assessments of the HoPD and HRS. If the selection was performed based solely on the assessments of HoPD, candidate 2 would be selected according to all FAHP and FTOPSIS combinations. If the selection was performed based solely on the assessments of HRS, candidate 2 has been found to be the most suitable person for the position in 8 of the 9 combinations of FAHP and FTOPSIS methods.

FVIKOR method also has been applied for the same problem. When the decision making is performed by aggregating the individual candidate assessments of the HoPD and HRS, candidate 2 is always in the first rank independent of the FAHP method used for determination of tasks' weights. However, when the tasks involved in the job are ranked by Chang's extent analysis (1996), candidate 2 does not have an acceptable advantage for any strategy weight. When Deng's FAHP method (1999) is applied, candidate 2 has an acceptable advantage only when $v > 0.641$. Similarly, critical strategy weight for candidate 2 to have an acceptable advantage is 0.673 when Buckley's FAHP method (1985) is applied for determining the task importance ratings. For strategy weights greater than this value, candidate 2 will have an acceptable advantage.

If the selection was performed based solely on the assessments of HoPD, tasks involved in the job are ranked by Chang's extent analysis (1996), candidate 2 does not have an acceptable advantage for any strategy weight. When Deng's FAHP method (1999) or Buckley's FAHP method (1985) is applied for determining the task importance ratings, candidate 2 has an acceptable advantage for all strategy weights $v \geq 0.5$. Thus, final decision is independent of the determination of strategy weight.

If the selection was performed based solely on the assessments of HRS, when tasks involved in the job are ranked by Chang's extent analysis, candidate 2 and candidate

3 do not have an acceptable advantage for any strategy weight and the critical strategy weight that candidate 2 first passes candidate 3 is 0.597. If strategy weight is greater than 0.597, then candidate 2 is the winner. When Deng's FAHP method (1999) is applied, candidate 2 or candidate 3 does not have an acceptable advantage for any strategy weight $v \geq 0.5$. The critical strategy weight that candidate 2 first passes candidate 3 is 0.504. Similarly, candidate 2 or candidate 3 does not have an acceptable advantage for any strategy weight $v \geq 0.5$ when Buckley's FAHP method (1985) is applied for determining the task importance ratings. The critical strategy weight that candidate 2 first passes candidate 3 is 0.505.

The second position which the model has been applied is Chief Maintenance Engineer position. There were six candidates for this position within the company. Two decision makers' assessed the six candidates based on the predetermined KSAOs and best candidate has been determined by applying FTOPSIS and FVIKOR methods. As a result of FTOPSIS, candidate 3 has been found to be the most suitable person for the position in all combinations of FAHP and FTOPSIS methods and when the decision is based on either aggregated or individual assessments.

FVIKOR has been performed also for this application for CME position. When the decision making is performed by aggregating the individual candidate assessments of the PM and HRS and tasks involved in the job are ranked by any FAHP method, candidate 3 is selected also in the cases where selection is based on the assessment of a single decision maker (i.e. PM or HRS), and final decision is independent of FAHP method used and valid for all strategy weights $v \geq 0.5$.

Considering the outcomes of the selection process for SE position, we can conclude that results of both FTOPSIS and FVIKOR generate same results in which candidate 2 comes out to be the most suitable person among the candidates. When task weights obtained by Chang's extent analysis (1996) are used, the outcomes of FVIKOR related to the level of acceptable advantage are different than the cases in which task weights are obtained by the other FAHP methods. However, the ranking of the candidates do not change. Also, the ranking of candidates would not change if the selection was performed based on the assessments of a single decision maker (i.e. HoPD or HRS).

In the second application, one of the six MEs who are currently employed in the company was to be selected for promoting to CME position. Thus, the selection ratio was approximately 0.17, which is a fairly high value. As a result of the application, candidate 3 is selected as the most suitable person by dominating the other candidates according to both FTOPSIS and FVIKOR methods. In the FVIKOR application, independent of strategy weights and the FAHP method used for determination of task weights, selecting candidate 3 has acceptable advantage over the selecting any other candidate. This outcome was consistent with the outcomes of the traditional selection process in the company, which is based on personal judgments of the decision makers and consensus. Thus, it can be concluded that the model results in rational outcomes when realistic information about job and candidates are provided. Also, the outcomes with respect to assessment by single decision maker are consistent with the outcomes based on the aggregated evaluations of candidates.

## 6. CONCLUSION AND RECOMMENDATIONS

In this study, a personnel selection model has been developed based on FQFD framework, which targets to minimize selection errors with minimum cost and effort by covering the whole work domain and including the vagueness and subjectivity associated with personnel selection processes. The model assumes that there are a number of candidates applying for a particular job and a certain number of candidate(s) are to be selected for the job in question. The model is applicable for both white-collar and blue-collar positions and the expected outcome from the model is improved content-related validity, which consists of demonstration of a strong linkage between the content of the selection procedure and important work behaviors, activities, worker requirements, or outcomes on the job. Since criterion-related validity requires longitudinal collection of actual job performance data of individuals who are selected for employment, it is beyond the scope of this study. However, improving the content-related validity of the selection process also results in an improved criterion-related validity.

Personnel selection process involves vagueness and subjectivity in two phases of the selection process. First one is associated with the determination of personnel characteristics and their levels required for performing the job. Second one is associated with the assessments of the candidates with respect to personnel characteristics which the new personnel is expected to have in order to perform the job in question successfully. Thus, linguistic variables, which can be expressed as fuzzy numbers, are used in the model to evaluate both the levels of personnel characteristics required for the job in question, and candidates with respect to these personnel characteristics.

The proposed model uses FQFD for providing a strong linkage between the content of the job and characteristics of selected candidate(s) by translating the task statements into personnel characteristics. Thus, content-related validity of the model is ensured; and the vagueness and subjectivity, inherent in personnel selection processes, are involved in the model. The model also allows multiple decision makers in the determination of personnel characteristics and final selection processes so that various people within the organization who are responsible for; or who are affected by the selection decision can be involved in both phases of the FQFD process. In order to make the selection process more practical, computer software has been developed to apply the proposed selection model so that computational burden associated with the model is reduced. The fuzzy personnel selection software is capable of running both phases of FQFD and it involves an interface which uses linguistic variables for assessments throughout the model. It also allows group decision-making so that multiple decision makers can be involved in the personnel selection process. As a result, the users are avoided getting lost in huge number of matrix operations with triangular fuzzy numbers.

In the first phase of FQFD, the model identifies statements of tasks including work and organizational context descriptors, and tools and technology used for performing the job. Then, by using FAHP, the fuzzy importance weights of the task statements are obtained by using three criteria: task criticality, task frequency and time spent for the task. Since there are different FAHP methods proposed by different authors, three FAHP methods have been used. Also, required personnel characteristics are identified in this phase and they are linked to task statements by using a fuzzy relationship matrix. In this step, the checklist which is a compilation of O*NET® Content Model has been used. The use of O*NET® Content Model includes a list of well defined personnel characteristics which provide a common language for defining personnel characteristics for many jobs and across many organizations. Thus, consistency problem in the understanding and communication of personnel characteristics with respect to inclusion of multiple decision makers is resolved. The proposed model also uses the twelve broad categories of Position-related Personality Requirements Form so that personality traits required for performing a job and their levels can be determined. This provides a "whole person" approach to personnel selection problem. In the end of Phase I, importance weights of the KSAOs are obtained by using fuzzy weighted summation. In the second phase of FQFD process, candidates are evaluated by the multiple decision makers using linguistic variables and these evaluations are aggregated by fuzzy arithmetic mean. By using the weights of the KSAOs obtained in Phase I, FTOPSIS and FVIKOR are used for performing the final selection phase. Since there are different FTOPSIS methods in the literature, three FTOPSIS methods in the literature have been applied for ensuring the consistency of the results with respect to different normalization and distance calculation approaches in these FTOPSIS methods.

Two real-life applications of the proposed selection model have been performed in one of the leading companies in milk and milk products sector in Turkey. Two white-collar positions, namely Shift Engineer and Chief Maintenance Engineer, have been determined for application and testing of the proposed model. In these applications, the selection ratios were fairly high (1/4 for Shift Engineer and 1/6 for Chief Maintenance Engineer). The findings from two applications lead to following conclusions. When candidates are very similar to each other in terms of their characteristics, as it occurred in the Shift Engineer selection, it becomes a difficult process to select the most suitable candidate by a judgmental assessment and finally, the outcomes of selection process becomes a random choice. Therefore, the model helps to organize decision makers' ideas by breaking down the selection process into well-connected steps so that a rational decision can be made when none of the candidates seem to be more eligible. Different from the Shift Engineer selection, the Chief Maintenance Engineer selection was an internal allocation problem. The decision reached by using the proposed model was consistent with the decision makers' judgmental decision about the most appropriate candidate. Assuming the proposed selection model as a black-box, this consistency proves that the selection model can transform the inputs into outputs accurately when realistic inputs are provided. The model has been also tested with respect to the combinations of different FAHP methods used for ranking the tasks; and different FTOPSIS methods and FVIKOR method which are used in the second phase of the model. As a result, it has been also seen that ranking of the candidates were also consistent with respect to the FMCDM methods used.

The most significant contribution provided by the proposed model is about determining what to expect from the new personnel based on the true and up-to-date information about the job. Thus, an organization may select the most suitable person based on the subjective evaluations of multiple decision makers involved in a formal way in every step of the personnel selection processes, from job analysis to final selection process. The use of FQFD as a framework for personnel selection problem also provides the effective and analytical use of job analysis information which is neglected in many organizations most of the time although job analysis is the key to many human resources management decisions. As a result, a content-valid selection procedure is obtained; and improved criterion validity is expected. Another expectation is improved test-retest and inter-rater reliability since a systematic way of determining the required personnel characteristics with their levels is revealed in the first phase of the proposed model. Thus, the only variation in final decision may be due to the assessment of candidates with respect to KSAOs. The proposed model is expected to be much more useful when the selection ratio is low, since decision makers are not mentally capable of analyzing and synthesizing vast amount of job and candidate information judgmentally.

Also, literature analysis shows that there are a few studies which apply fuzzy models for personnel selection and none of these studies use FQFD for personnel selection problems. These fuzzy personnel selection models use arbitrarily determined set of personnel characteristics in their models. Hence, no linkage between the job content and personnel characteristic used for personnel selection is claimed or proven. Thus, the use of FQFD in the personnel selection process is a new and a useful concept since; a solid way of developing hypotheses about performance-predictor relationships in the personnel selection is maintained.

For future research, extension of the proposed model to a fuzzy competency management system is suggested. If the proposed model is applied to include all positions in an organization for determining the required and existing levels of each competency in a certain organization, fuzzy competency-based allocation within the organization may be possible. Thus, matching the individual competencies to positions may lead to improved job performance and job satisfaction of employees. Also, employees may understand what competencies are needed to be successful, not only in their current jobs, but also in their future career paths. In the macro level, the organization can increase its capacity by achieving a holistic view of the accumulated competence of the entire organization. By establishing a clear and consistent framework, the organization can create a process for the movement of employees across functions of the organization. They may also be able to analyze where there may be a shortfall of competences in critical business areas. Thus, employee training and recruitment plans are enriched with information which is generated from identifying competence gaps.

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# APPENDICES

**APPENDIX A :** List of Personnel Characteristics and Their Definitions Compiled from O*NET® Content Model and PPRF

## I. ABILITIES

### 1. Cognitive Abilities — Abilities that influence the acquisition and application of knowledge in problem solving

1.1. Verbal Abilities — Abilities that influence the acquisition and application of verbal information in problem solving

1.1.1. Oral Comprehension — The ability to listen to and understand information and ideas presented through spoken words and sentences.

1.1.2. Written Comprehension — The ability to read and understand information and ideas presented in writing.

1.1.3. Oral Expression — The ability to communicate information and ideas in speaking so others will understand.

1.1.4. Written Expression — The ability to communicate information and ideas in writing so others will understand.

1.2. Idea Generation and Reasoning Abilities — Abilities that influence the application and manipulation of information in problem solving

1.2.1. Fluency of Ideas — The ability to come up with a number of ideas about a topic (the number of ideas is important, not their quality, correctness, or creativity).

1.2.2. Originality — The ability to come up with unusual or clever ideas about a given topic or situation, or to develop creative ways to solve a problem.

1.2.3. Problem Sensitivity — The ability to tell when something is wrong or is likely to go wrong. It does not involve solving the problem, only recognizing there is a problem.

1.2.4. Deductive Reasoning — The ability to apply general rules to specific problems to produce answers that make sense.

1.2.5. Inductive Reasoning — The ability to combine pieces of information to form general rules or conclusions (includes finding a relationship among seemingly unrelated events).

1.2.6. Information Ordering — The ability to arrange things or actions in a certain order or pattern according to a specific rule or set of rules (e.g., patterns of numbers, letters, words, pictures, mathematical operations).

1.2.7. Category Flexibility — The ability to generate or use different sets of rules for combining or grouping things in different ways.

1.3. Quantitative Abilities — Abilities that influence the solution of problems involving mathematical relationships

1.3.1 Mathematical Reasoning — The ability to choose the right mathematical methods or formulas to solve a problem.

1.3.2. Number Facility — The ability to add, subtract, multiply, or divide quickly and correctly.

1.4. Memory — Abilities related to the recall of available information

1.4.1. Memorization — The ability to remember information such as words, numbers, pictures, and procedures.

1.5. Perceptual Abilities — Abilities related to the acquisition and organization of visual information

1.5.1. Speed of Closure — The ability to quickly make sense of, combine, and organize information into meaningful patterns.

1.5.2. Flexibility of Closure — The ability to identify or detect a known pattern (a figure, object, word, or sound) that is hidden in other distracting material.

1.5.3. Perceptual Speed — The ability to quickly and accurately compare similarities and differences among sets of letters, numbers, objects,pictures, or patterns. The things to be compared may be presented at thesame time or one after the other. This ability also includes comparing a presented object with a remembered object.

1.6. Spatial Abilities — Abilities related to the manipulation and organization of spatial information

1.6.1. Spatial Orientation — The ability to know your location in relation to the environment or to know where other objects are in relation to you.

1.6.2. Visualization — The ability to imagine how something will look after it is moved around or when its parts are moved or rearranged.

1.7. Attentiveness — Abilities related to application of attention

1.7.1. Selective Attention — The ability to concentrate on a task over a period of time without being distracted.

1.7.2. Time Sharing — The ability to shift back and forth between two or more activities or sources of information (such as speech, sounds, touch, or other sources).

**2. Psychomotor Abilities — Abilities that influence the capacity to manipulate and control objects**

2.1. Fine Manipulative Abilities — Abilities related to the manipulation of objects

2.1.1. Arm-Hand Steadiness — The ability to keep your hand and arm steady while moving your arm or while holding your arm and hand in one position.

2.1.2. Manual Dexterity — The ability to quickly move your hand, your hand together with your arm, or your two hands to grasp, manipulate, or assemble objects.

2.1.3. Finger Dexterity — The ability to make precisely coordinated movements of the fingers of one or both hands to grasp, manipulate, or assemble very small objects.

2.2. Control Movement Abilities — Abilities related to the control and manipulation of objects in time and space

2.2.1. Control Precision — The ability to quickly and repeatedly adjust the controls of a machine or a vehicle to exact positions.

2.2.2. Multi-limb Coordination — The ability to coordinate two or more limbs (for example, two arms, two legs, or one leg and one arm) while sitting, standing, or lying down. It does not involve performing the activities while the whole body is in motion.

2.2.3. Response Orientation — The ability to choose quickly between two or more movements in response to two or more different signals (lights, sounds, pictures). It includes the speed with which the correct response is started with the hand, foot, or other body part.

2.2.4. Rate Control — The ability to time your movements or the movement of a piece of equipment in anticipation of changes in the speed and/or direction of a moving object or scene.

2.3. Reaction Time and Speed Abilities — Abilities related to speed of manipulation of objects

2.3.1. Reaction Time — The ability to quickly respond (with the hand, finger, or foot) to a signal (sound, light, picture) when it appears.

2.3.2. Wrist-Finger Speed — The ability to make fast, simple, repeated movements of the fingers, hands, and wrists.

2.3.3. Speed of Limb Movement — The ability to quickly move the arms and legs.

**3. Physical Abilities — Abilities that influence strength, endurance, flexibility, balance and coordination**

3.1. Physical Strength Abilities — Abilities related to the capacity to exert force

3.1.1. Static Strength — The ability to exert maximum muscle force to lift, push, pull, or carry objects.

3.1.2. Explosive Strength — The ability to use short bursts of muscle force to propel oneself (as in jumping or sprinting), or to throw an object.

3.1.3. Dynamic Strength — The ability to exert muscle force repeatedly or continuously over time. This involves muscular endurance and resistance to muscle fatigue.

3.1.4. Trunk Strength — The ability to use your abdominal and lower back muscles to support part of the body repeatedly or continuously over time without 'giving out' or fatiguing.

3.2. Endurance — The ability to exert oneself physically over long periods without getting out of breath

3.2.1. Stamina — The ability to exert yourself physically over long periods of time without getting winded or out of breath.

3.3. Flexibility, Balance, and Coordination — Abilities related to the control of gross body movements

3.3.1. Extent Flexibility — The ability to bend, stretch, twist, or reach with your body, arms, and/or legs.

3.3.2. Dynamic Flexibility — The ability to quickly and repeatedly bend, stretch, twist, or reach out with your body, arms, and/or legs.

3.3.3. Gross Body Coordination — The ability to coordinate the movement of your arms, legs, and torso together when the whole body is in motion.

3.3.4. Gross Body Equilibrium — The ability to keep or regain your body balance or stay upright when in an unstable position.

**4. Sensory Abilities — Abilities that influence visual, auditory and speech perception**

4.1. Visual Abilities — Abilities related to visual sensory input

4.1.1. Near Vision — The ability to see details at close range (within a few feet of the observer).

4.1.2. Far Vision — The ability to see details at a distance.

4.1.3. Visual Color Discrimination — The ability to match or detect differences between colors, including shades of color and brightness.

4.1.4. Night Vision — The ability to see under low light conditions.

4.1.5. Peripheral Vision — The ability to see objects or movement of objects to one's side when the eyes are looking ahead.

4.1.6. Depth Perception — The ability to judge which of several objects is closer or farther away from you, or to judge the distance between you and an object.

4.1.7. Glare Sensitivity — The ability to see objects in the presence of glare or bright lighting

4.2. Auditory and Speech Abilities — Abilities related to auditory and oral input

4.2.1. Hearing Sensitivity — The ability to detect or tell the differences between sounds that vary in pitch and loudness.

4.2.2. Auditory Attention — The ability to focus on a single source of sound in the presence of other distracting sounds.

4.2.3. Sound Localization — The ability to tell the direction from which a sound originated.

4.2.4. Speech Recognition — The ability to identify and understand the speech of another person.

4.2.5. Speech Clarity — The ability to speak clearly so others can understand you.

## II. SKILLS

### 1. Basic Skills — Developed capacities that facilitate learning or the more rapid acquisition of knowledge

1.1. Content — Background structures needed to work with and acquire more specific skills in a variety of different domains

1.1.1. Reading Comprehension — Understanding written sentences and paragraphs in work related documents.

1.1.2. Active Listening — Giving full attention to what other people are saying, taking time to understand the points being made, asking questions as appropriate, and not interrupting at inappropriate times.

1.1.3. Writing — Communicating effectively in writing as appropriate for the needs of the audience.

1.1.4. Speaking — Talking to others to convey information effectively.

1.1.5. Mathematics — Using mathematics to solve problems.

1.1.6. Science — Using scientific rules and methods to solve problems.

1.2. Process — Procedures that contribute to the more rapid acquisition of knowledge and skill across a variety of domains

1.2.1 Critical Thinking — Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems.

1.2.2. Active Learning — Understanding the implications of new information for both current and future problem-solving and decision-making.

1.2.3. Learning Strategies — Selecting and using training/instructional methods and procedures appropriate for the situation when learning or teaching new things.

1.2.4. Monitoring — Monitoring/Assessing performance of yourself, other individuals, or organizations to make improvements or take corrective action.

**2. Cross-Functional Skills — Developed capacities that facilitate performance of activities that ocur across jobs**

2.1. Social Skills — Developed capacities used to work with people to achieve goals

2.1.1. Social Perceptiveness — Being aware of others' reactions and understanding why they react as they do.

2.1.2. Coordination — Adjusting actions in relation to others' actions.

2.1.3. Persuasion — Persuading others to change their minds or behavior.

2.1.4. Negotiation — Bringing others together and trying to reconcile differences.

2.1.5. Instructing — Teaching others how to do something.

2.1.6. Service Orientation — Actively looking for ways to help people.

2.2. Complex Problem Solving Skills — Developed capacities used to solve novel, ill-defined problems in complex, real-world settings

2.2.1. Complex Problem Solving — Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions.

2.2.2. Problem Identification — Identifying the nature of problems

2.2.3. Information Gathering — Knowing how to find information and identifying essential information

2.2.4. Information Organization — Finding ways to structure or classify multiple pieces of information

2.2.5. Synthesis/Reorganization — Reorganizing information to get a better approach to problems or tasks

2.2.6. Idea Generation —Generating a number of different approaches to problems

2.2.7. Idea Evaluation — Evaluating the likely success of an idea in relation to the demands of the situation

2.2.8. Implementation Planning — Developing approaches for implementing an idea

2.2.9. Solution Appraisal — Observing and evaluating the outcomes of a problem solution to identify lessons learned or redirect efforts

2.3. Technical Skills — Developed capacities used to design, set-up, operate, and correct malfunctions involving application of machines or technological systems

2.3.1. Operations Analysis — Analyzing needs and product requirements to create a design.

2.3.2. Technology Design — Generating or adapting equipment and technology to serve user needs.

2.3.3. Equipment Selection — Determining the kind of tools and equipment needed to do a job.

2.3.4. Installation — Installing equipment, machines, wiring, or programs to meet specifications.

2.3.5. Programming — Writing computer programs for various purposes.

2.3.6. Testing — Conducting tests to determine whether equipment, software, or procedures are operating as expected

2.3.7. Operation Monitoring — Watching gauges, dials, or other indicators to make sure a machine is working properly.

2.3.8. Operation and Control — Controlling operations of equipment or systems.

2.3.9. Equipment Maintenance — Performing routine maintenance on equipment and determining when and what kind of maintenance is needed.

2.3.10. Troubleshooting — Determining causes of operating errors and deciding what to do about it.

2.3.11 Repairing — Repairing machines or systems using the needed tools.

2.3.12. Quality Control Analysis — Conducting tests and inspections of products, services, or processes to evaluate quality or performance.

2.4. Systems Skills — Developed capacities used to understand, monitor, and improve socio-technical systems

2.4.1. Visioning — Developing an image of how a system should work under ideal conditions

2.4.2. Systems Perception — Determining when important changes have occurred in a system or are likely to ocur

2.4.3. Identifying Downstream Consequences — Determining the long-term outcomes of a change in operations

2.4.4. Judgment and Decision Making — Considering the relative costs and benefits of potential actions to choose the most appropriate one.

2.4.5. Systems Analysis — Determining how a system should work and how changes in conditions, operations, and the environment will affect outcomes.

2.4.6. Systems Evaluation — Identifying measures or indicators of system performance and taking into account their accuracy and the actions needed to improve or correct performance, relative to the goals of the system.

2.4.7. Identification of Key Causes — Identifying the things that must be changed to achieve a goal

2.5. Resource Management Skills — Developed capacities used to allocate resources efficiently

2.5.1. Time Management — Managing one's own time and the time of others

2.5.2. Management of Financial Resources — Determining how money will be spent to get the work done, and accounting for these expenditures

2.5.3. Management of Material Resources — Obtaining and seeing to the appropriate use of equipment, facilities, and materials needed to do certain work

2.5.4. Management of Personnel Resources — Motivating, developing, and directing people as they work, identifying the best people for the job

**III. KNOWLEDGE:** Organized sets of principles and facts applying in general domains

**1. Business and Management — Knowledge of principles and facts related to business administration and accounting, human and material resource management in organizations, sales and marketing, economics, and office information and organizing systems**

1.1. Administration and Management — Knowledge of business and management principles involved in strategic planning, resource allocation, human resources modeling, leadership technique, production methods, and coordination of people and resources.

1.2. Clerical — Knowledge of administrative and clerical procedures and systems such as word processing, managing files and records, stenography and transcription, designing forms, and other office procedures and terminology.

1.3. Economics and Accounting — Knowledge of economic and accounting principles and practices, the financial markets, banking and the analysis and reporting of financial data.

1.4. Sales and Marketing — Knowledge of principles and methods for showing, promoting, and selling products or services. This includes marketing strategy and tactics, product demonstration, sales techniques, and sales control systems.

1.5. Customer and Personal Service — Knowledge of principles and processes for providing customer and personal services. This includes customer needs assessment, meeting quality standards for services, and evaluation of customer satisfaction.

1.6. Personnel and Human Resources — Knowledge of principles and procedures for personnel recruitment, selection, training, compensation and benefits, labor relations and negotiation, and personnel information systems.

**2. Manufacturing and Production — Knowledge of principles and facts related to the production, processing, storage, and distribution of manufactured and agricultural goods**

2.1. Production and Processing — Knowledge of raw materials, production processes, quality control, costs, and other techniques for maximizing the effective manufacture and distribution of goods.

2.2. Food Production — Knowledge of techniques and equipment for planting, growing, and harvesting food products (both plant and animal) for consumption, including storage/handling techniques.

**3. Engineering and Technology — Knowledge of the design, development, and application of technology for specific purposes.**

3.1. Computers and Electronics — Knowledge of circuit boards, processors, chips, electronic equipment, and computer hardware and software, including applications and programming.

3.2. Engineering and Technology — Knowledge of the practical application of engineering science and technology. This includes applying principles,techniques, procedures, and equipment to the design and production of various goods and services.

3.3. Design — Knowledge of design techniques, tools, and principles involved in production of precision technical plans, blueprints, drawings, and models.

3.4. Building and Construction — Knowledge of materials, methods, and the tools involved in the construction or repair of houses, buildings, or other structures such as highways and roads.

3.5. Mechanical — Knowledge of machines and tools, including their designs, uses, repair, and maintenance.

**4. Mathematics and Science — Knowledge of the history, theories, methods, and applications of the physical, biological, social, mathematical, and geography**

4.1. Mathematics — Knowledge of arithmetic, algebra, geometry, calculus, statistics, and their applications.

4.2. Physics — Knowledge and prediction of physical principles, laws, their interrelationships, and applications to understanding fluid, material, and atmospheric dynamics, and mechanical, electrical, atomic and sub- atomic structures and processes.

4.3. Chemistry — Knowledge of the chemical composition, structure, and properties of substances and of the chemical processes and transformations that they undergo. This includes uses of chemicals and their interactions, danger signs, production techniques, and disposal methods.

4.4. Biology — Knowledge of plant and animal organisms, their tissues, cells, functions, interdependencies, and interactions with each other and the environment.

4.5. Psychology — Knowledge of human behavior and performance; individual differences in ability, personality, and interests; learning and motivation; psychological research methods; and the assessment and treatment of behavioral and affective disorders.

4.6. Sociology and Anthropology — Knowledge of group behavior and dynamics, societal trends and influences, human migrations, ethnicity, cultures and their history and origins.

4.7. Geography — Knowledge of principles and methods for describing the features of land, sea, and air masses, including their physical characteristics, locations, interrelationships, and distribution of plant, animal, and human life.

**5. Health Services — Knowledge of principles and facts regarding diagnosing, curing, and preventing disease, and improving and preserving physical and mental health and wellbeing**

5.1. Medicine and Dentistry — Knowledge of the information and techniques needed to diagnose and treat human injuries, diseases, and deformities. This includes symptoms, treatment alternatives, drug properties and interactions, and preventive health-care measures.

5.2. Therapy and Counseling — Knowledge of principles, methods, and procedures for diagnosis, treatment, and rehabilitation of physical and mental dysfunctions, and for career counseling and guidance.

**6. Education and Training — Knowledge of principles and methods for curriculum and training design, teaching and instruction for individuals and groups, and the measurement of training effects.**

**7. Arts and Humanities — Knowledge of facts and principles related to the branches of learning concerned with human thought, language, and the arts.**

7.1. English Language — Knowledge of the structure and content of the English language including the meaning and spelling of words, rules of composition, and grammar.

7.2. Foreign Language — Knowledge of the structure and content of a foreign (non-English) language including the meaning and spelling of words, rules of composition and grammar, and pronunciation.

7.3. Fine Arts — Knowledge of the theory and techniques required to compose, produce, and perform works of music, dance, visual arts, drama, and sculpture.

7.4. History and Archeology — Knowledge of historical events and their causes, indicators, and effects on civilizations and cultures.

7.5. Philosophy and Theology — Knowledge of different philosophical systems and religions. This includes their basic principles, values, ethics, ways of thinking, customs, practices, and their impact on human culture.

**8. Law and Public Safety — Knowledge of regulations and methods for maintaining people and property free from danger, injury, or damage; the rules of public conduct established and enforced by legislation, and the political process establishing such rules.**

8.1. Public Safety and Security — Knowledge of relevant equipment, policies, procedures, and strategies to promote effective local, state, or national security operations for the protection of people, data, property, and institutions.

8.2. Law and Government — Knowledge of laws, legal codes, court procedures, precedents, government regulations, executive orders, agency rules, and the democratic political process.

**9. Communications — Knowledge of the science and art of delivering information**

9.1. Telecommunications — Knowledge of transmission, broadcasting, switching, control, and operation of telecommunications systems.

9.2. Communications and Media — Knowledge of media production, communication, and dissemination techniques and methods. This includes alternative ways to inform and entertain via written, oral, and visual media.

**10. Transportation — Knowledge of principles and methods for moving people or goods by air, rail, sea, or road, including the relative costs and benefits.**

**11. Job-specific knowledge – Specific knowledge about the job under consideration.**

**IV. EDUCATION:** Prior educational experience required to perform in a job

**1. Instructional Program Required — The instructional program required for this job**

**2. Education Level in Specific Subjects — The amount of education required in 15 subject areas to perform in a job. Subject areas cover most of the courses that occur in high school, junior college, college undergraduate degree programs, and other education and training programs**

2.1. Technical Vocational — Courses focus on non-business technical skills, such as Agriculture, Industrial Arts, Automobile and Shop, and Electronics

2.2. Business Vocational — Courses focus on basic business skills, such as Word Processing, Filing, Bookkeeping/Basic Accounting

2.3. English/language Arts — Courses focus on reading, interpretation, and writing, such as Literature, Composition, Journalism, and Creative Writing

2.4. Oral Communication — Courses focus on oral communication and speech, such as Oral Communication, Speech, and Interpersonal Communication

2.5. Languages — Courses focus on reading, writing, and/or speaking languages other than English, such as French, Chinese, German, Japanese, Latin, Russian, and Spanish

2.6. Basic Math — Courses focus on basic and applied math, such as General Math and Business Math

2.7. Advanced Math — Courses focus on advanced topics in math, such as Algebra, Geometry, Calculus, and Statistics

2.8. Physical Science — Courses focus on the study of matter and/or energy, such as Physics, Chemistry, and Astronomy

2.9. Computer Science — Courses focus on computers and their uses, such as Programming, Information Systems Management, and Software Applications

2.10. Biological Science — Courses focus on the study of life and living beings, such as life science, biology, anatomy and physiology

2.11. Applied Science — Courses focus on the application of science, such as Engineering, Health, and Medicine

2.12. Social Science — Courses focus on the behavioral sciences, such as Social Studies, Economics, History, Psychology, and Sociology

2.13. Arts — Courses focus on visual and performing arts, such as Arts and Crafts, Music, Painting, Sculpture, Theater, and Voice

2.14. Humanities — Courses focus on cultural and philosophical aspects of humans, such as Minority Studies, Philosophy, and Religion

2.15. Physical Education — Courses focus on physical fitness and sports, such as Aerobics, Jogging, Weight Lifting, and Specific Sports

**V. EXPERIENCE:** If someone were being hired to perform this job, how much of the following would be required?

**1. Experience and Training — If someone were being hired to perform this job, how much of the following would be required?**

1.1. Related Work Experience — Amount of related work experience required to get hired for the job?

1.2. On-Site or In-Plant Training — Amount of on-site or in-plant training (e.g., organizedclass room instruction) required to perform the job?

1.3. On-the-Job Training — Amount of on the job training required to perform the job?

**2. Licensing — Licenses, certificates, or registrations that are awarded to show that a job holder has gained certain skills. This includes requirements for obtaining these credentials, and the organization or agency requiring their possession.**

2.1. License, Certificate, or Registration Required — At least one license, certificate, or registration is required to perform in this job, including a driver's or vehicle operator's license. The specific license(s), certificate(s), or registration(s) are listed.

2.1.1. Specific License or Certificate Required — Specific education, training, examination, or other requirements for obtaining the licenses, certificates, or registration needed to perform in this job

2.1.2. Post-Secondary Degree — Obtaining the licenses, certificates, or registration needed to perform in this job requires a post-secondary degree, for example an Associate's or Bachelor's degree.

2.1.3. Graduate Degree — Obtaining the licenses, certificates, or registration needed to perform in this job requires a graduate degree, for example, a Master's or Doctoral degree.

2.1.4. On-the-Job Training — Obtaining the licenses, certificates, or registration needed to perform in this job requires on-the-job training, including apprenticeships, internships, and other supervised experiences.

2.1.5. Examination — Obtaining the licenses, certificates, or registration needed to perform in this job requires an examination, for example, written, oral, or performance assessments.

2.1.6. Character References — Obtaining the licenses, certificates, or registration needed to perform in this job requires one or more character references from other individuals.

2.1.7 Additional Education and Training — Retaining the licenses, certificates, or registration needed to perform in this job requires additional course work.

2.2. Organization and Agency Requirements — Organizations or agencies requiring the specific licenses, certificates, or registration needed to perform in a job.

2.2.1. Legal Requirement — Federal, state, or local law requires possessing specific licenses, certificates, or registration for performance in this job.

2.2.2. Employer Requirement — Employers require possessing specific licenses, certificates, or registration for performance in this job.

2.2.3. Union, Guild, or Professional Association — A union or professional association requires possessing specific licenses, certificates, or registration for performance in this job.

## VI. PERSONALITY

### 1. Surgency

1.1. General Leadership: a tendency to take charge of situations or groups. To influence or motivate behavior or thinking of other persons.

*Sample items:* Lead group activities through exercise of power or authority; Take control in group situations.

1.2. Interest in Negotiation: an interest in bringing together contesting parties through mediation or arbitration or as a contesting party, an ability and willingness to see and understand differing points of view.

*Sample items:* Negotiate on behalf of the work unit for a fair share of organizational resources; Mediate and resolve disputes at individual, group, or organizational levels.

1.3. Achievement Striving: an ambition and desire to achieve, to win, or to do better than others, a desire to exert effort to advance, to do better than one's own prior achievement.

*Sample items:* Work beyond established or ordinary work period to perfect services or products; Work to excel rather than work to perform assigned tasks.

**2. Agreeableness**

2.1. Friendly Disposition: a tendency to be outgoing in association with other people, to seek and enjoy the company of others, to be gregarious, to interact easily and well with others.

*Sample items:* Represent and promote the organization in social contacts away from work; Attract new clients or customers through friendly interactions.

2.2. Sensitivity to interest of others: a tendency to be a caring person in relation to other people, to be considerate, understanding, and to have genuine concern for others.

*Sample items:* Listen attentively to the work-related problems of others; Give constructive criticism tactfully.

2.3. Cooperative or Collaborative Work Tendency: a desire or willingness to work with others to achieve a common purpose and to be part of a group, a willingness and interest in assisting clients, customers, or coworkers.

*Sample items:* Work as part of an interacting work group; Work with one or more co-workers to complete assigned tasks.

**3. Conscientiousness**

3.1. General Trustworthiness: a pattern of behavior that leads one to be trusted by other people with property, money, or confidential information, a demonstration of honesty, truthfulness, and fairness.

*Sample items:* Refuse to share or release confidential information; Make commitments and follow through on them.

3.2. Adherence to a Work Ethic: a tendency to work hard and to be loyal, to give a full day's work each day and to do one's best to perform well, a tendency to follow instructions and accept company goals, policies, and rules.

*Sample items:* See things that need to be done and do them without waiting for instructions; Work until task is done rather than stopping at quitting time.

3.3. Thoroughness and Attentiveness to Details: a tendency to carry out tasks with attention to every aspect, a meticulous approach to one's own task performance.

*Sample items:* Examine all aspects of written reports to be sure that nothing has been omitted; remain attentive to details over extended periods of time.

**4. Emotional Stability**

4.1. Emotional Stability: a calm, relaxed approach to situations, events, or people, emotionally controlled responses to changes in the work environment situations.

*Sample items:* Adapt easily to changes in work procedures; Keep cool when confronted with conflicts.

**5. lntellectance**

5.1. Desire to Generate Ideas: a preference for situations in which one can develop new things, ideas, or solutions to problems through creativity or insight, or try new or innovative approaches to tasks or situations.

*Sample items:* Help find solutions for the work problems of other employees or clients; Develop innovative approaches to old or everyday problems.

5.2. Tendency to Think Things Through: a habit of mentally going through procedures or a sequence of probable events before taking action, a tendency to seek and evaluate information, and to consider consequences.

*Sample items:* Solve complex problems one step at a time; Analyze past mistakes when faced with similar problems.

**APPENDIX B :** Information Input for Shift Engineer Selection Problem

**Table B.1 :** Pairwise comparison of task importance criteria by SE 1.

| | CRITICALITY | FREQUENCY | TIME SPENT |
|---|---|---|---|
| **CRITICALITY** | JE | VSMI | VSMI |
| **FREQUENCY** | | JE | EI |
| **TIME SPENT** | | | JE |
| **CR = 0.037** | | | |

**Table B.2 :** Pairwise comparison of task importance criteria by SE 2.

| | CRITICALITY | FREQUENCY | TIME SPENT |
|---|---|---|---|
| **CRITICALITY** | JE | VSMI | VSMI |
| **FREQUENCY** | | JE | EI |
| **TIME SPENT** | | | JE |
| **CR = 0.037** | | | |

**Table B.3 :** Pairwise comparison of tasks by SE 1 with respect to task criticality.

| | TASK 1 | TASK 2 | TASK 3 | TASK 4 | TASK 5 | TASK 6 | TASK 7 | TASK 8 | TASK 9 | TASK 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **TASK 1** | JE | EI | VSMI | WMI | RWMI | EI | SMI | SMI | EI | SMI |
| **TASK 2** | | JE | SMI | WMI | RWMI | RWMI | SMI | SMI | EI | SMI |
| **TASK 3** | | | JE | WMI | RSMI | RSMI | EI | WMI | EI | SMI |
| **TASK 4** | | | | JE | RVSMI | RVSMI | WMI | RWMI | RSMI | RWMI |
| **TASK 5** | | | | | JE | EI | VSMI | SMI | WMI | VSMI |
| **TASK 6** | | | | | | JE | SMI | SMI | WMI | VSMI |
| **TASK 7** | | | | | | | JE | EI | RSMI | WMI |
| **TASK 8** | | | | | | | | JE | RWMI | EI |
| **TASK 9** | | | | | | | | | JE | WMI |
| **TASK 10** | | | | | | | | | | JE |
| **CR = 0.019** | | | | | | | | | | |

**Table B.4 :** Pairwise comparison of tasks by SE 2 with respect to task criticality.

| | TASK 1 | TASK 2 | TASK 3 | TASK 4 | TASK 5 | TASK 6 | TASK 7 | TASK 8 | TASK 9 | TASK 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **TASK 1** | JE | EI | WMI | RVSMI | EI | EI | SMI | RWMI | EI | SMI |
| **TASK 2** | | JE | WMI | RVSMI | EI | EI | SMI | RWMI | EI | SMI |
| **TASK 3** | | | JE | WMI | RSMI | RSMI | EI | EI | EI | EI |
| **TASK 4** | | | | JE | RSMI | RSMI | EI | EI | RSMI | EI |
| **TASK 5** | | | | | JE | EI | SMI | SMI | EI | SMI |
| **TASK 6** | | | | | | JE | SMI | SMI | EI | SMI |
| **TASK 7** | | | | | | | JE | EI | RSMI | EI |
| **TASK 8** | | | | | | | | JE | RSMI | EI |
| **TASK 9** | | | | | | | | | JE | SMI |
| **TASK 10** | | | | | | | | | | JE |
| **CR = 0.044** | | | | | | | | | | |

**Table B.5 :** Pairwise comparison of tasks by SE 1 with respect to task frequency.

| | TASK 1 | TASK 2 | TASK 3 | TASK 4 | TASK 5 | TASK 6 | TASK 7 | TASK 8 | TASK 9 | TASK 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **TASK 1** | JE | EI | EI | EI | RWMI | RWMI | SMI | VSMI | EI | EI |
| **TASK 2** | | JE | WMI | WMI | RSMI | EI | WMI | AMI | EI | EI |
| **TASK 3** | | | JE | EI | EI | EI | EI | AMI | RWMI | EI |
| **TASK 4** | | | | JE | EI | RWMI | WMI | VSMI | RWMI | RWMI |
| **TASK 5** | | | | | JE | EI | SMI | AMI | WMI | WMI |
| **TASK 6** | | | | | | JE | SMI | AMI | EI | WMI |
| **TASK 7** | | | | | | | JE | SMI | RVSMI | RWMI |
| **TASK 8** | | | | | | | | JE | RAMI | RVSMI |
| **TASK 9** | | | | | | | | | JE | WMI |
| **TASK 10** | | | | | | | | | | JE |
| **CR = 0.019** | | | | | | | | | | |

**Table B.6 :** Pairwise comparison of tasks by SE 2 with respect to task frequency.

| | TASK 1 | TASK 2 | TASK 3 | TASK 4 | TASK 5 | TASK 6 | TASK 7 | TASK 8 | TASK 9 | TASK 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **TASK 1** | JE | EI | SMI | VSMI | EI | EI | VSMI | AMI | EI | EI |
| **TASK 2** | | JE | SMI | SMI | WMI | EI | VSMI | AMI | EI | EI |
| **TASK 3** | | | JE | SMI | RSMI | RWMI | EI | SMI | RSMI | EI |
| **TASK 4** | | | | JE | RSMI | RWMI | EI | SMI | RWMI | EI |
| **TASK 5** | | | | | JE | RWMI | EI | WMI | RWMI | EI |
| **TASK 6** | | | | | | JE | VSMI | AMI | EI | EI |
| **TASK 7** | | | | | | | JE | EI | RVSMI | EI |
| **TASK 8** | | | | | | | | JE | RVSMI | EI |
| **TASK 9** | | | | | | | | | JE | VSMI |
| **TASK 10** | | | | | | | | | | JE |
| **CR = 0.034** | | | | | | | | | | |

**Table B.7 :** Pairwise comparison of tasks by SE 1 with respect to time spent.

| | TASK 1 | TASK 2 | TASK 3 | TASK 4 | TASK 5 | TASK 6 | TASK 7 | TASK 8 | TASK 9 | TASK 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **TASK 1** | JE | EI | SMI | EI | RSMI | RSMI | SMI | VSMI | EI | SMI |
| **TASK 2** | | JE | VSMI | EI | RVSMI | RSMI | SMI | VSMI | EI | SMI |
| **TASK 3** | | | JE | RWMI | RAMI | RVSMI | EI | WMI | RSMI | EI |
| **TASK 4** | | | | JE | RWMI | RWMI | SMI | VSMI | RWMI | VSMI |
| **TASK 5** | | | | | JE | EI | VSMI | AMI | SMI | VSMI |
| **TASK 6** | | | | | | JE | VSMI | VSMI | WMI | VSMI |
| **TASK 7** | | | | | | | JE | WMI | RSMI | EI |
| **TASK 8** | | | | | | | | JE | RVSMI | RWMI |
| **TASK 9** | | | | | | | | | JE | VSMI |
| **TASK 10** | | | | | | | | | | JE |
| **CR = 0.016** | | | | | | | | | | |

**Table B.8 :** Pairwise comparison of tasks by SE 2 with respect to time spent.

| | TASK 1 | TASK 2 | TASK 3 | TASK 4 | TASK 5 | TASK 6 | TASK 7 | TASK 8 | TASK 9 | TASK 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **TASK 1** | JE | EI | VSMI | WMI | EI | EI | VSMI | VSMI | EI | VSMI |
| **TASK 2** | | JE | VSMI | WMI | EI | EI | VSMI | VSMI | EI | VSMI |
| **TASK 3** | | | JE | RSMI | RSMI | RSMI | EI | RWMI | RWMI | EI |
| **TASK 4** | | | | JE | RWMI | RWMI | WMI | EI | EI | EI |
| **TASK 5** | | | | | JE | EI | VSMI | SMI | EI | VSMI |
| **TASK 6** | | | | | | JE | SMI | SMI | EI | VSMI |
| **TASK 7** | | | | | | | JE | RSMI | RSMI | EI |
| **TASK 8** | | | | | | | | JE | EI | VSMI |
| **TASK 9** | | | | | | | | | JE | VSMI |
| **TASK 10** | | | | | | | | | | JE |
| **CR = 0.023** | | | | | | | | | | |

**Table B.9 :** Tasks – KSAOs linkages by two SEs.

| | KSAO 1 | KSAO 2 | KSAO 3 | KSAO 4 | KSAO 5 | KSAO 6 | KSAO 7 | KSAO 8 | KSAO 9 | KSAO 10 | KSAO 11 | KSAO 12 | KSAO 13 | KSAO 14 | KSAO 15 | KSAO 16 | KSAO 17 | KSAO 18 | KSAO 19 | KSAO 20 | KSAO 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TASK 1** | M | M | M | M | M | M | M | VH | MH | | | VH | M | | M | VH | VH | VH | H | M | M |
| **TASK 2** | M | M | M | M | M | | | | MH | M | | VH | M | | M | VH | VH | VH | H | M | M |
| **TASK 3** | | | | | | | | | MH | M | | VH | M | | | VH | VH | VH | H | | VH |
| **TASK 4** | | | | | | H | H | H | MH | | | VH | M | M | M | VH | VH | | H | | |
| **TASK 5** | M | M | M | M | M | VH | VH | VH | MH | M | M | VH | M | | VH | VH | VH | VH | H | | H |
| **TASK 6** | M | M | M | M | M | VH | VH | VH | MH | M | M | VH | M | | VH | VH | VH | VH | H | | H |
| **TASK 7** | M | M | M | M | M | | | | MH | M | M | VH | M | | M | VH | VH | M | H | | M |
| **TASK 8** | M | M | M | M | M | | | | MH | | M | VH | M | | VH | VH | VH | H | H | H | H |
| **TASK 9** | M | M | | | M | VH | | VH | MH | | | VH | M | | M | VH | VH | VH | H | | M |
| **TASK 10** | L | L | | | | | | | MH | | | VH | M | | | VH | VH | | H | | |

**Table B.10 :** Tasks – KSAOs linkages by HRS.

| | KSAO 1 | KSAO 2 | KSAO 3 | KSAO 4 | KSAO 5 | KSAO 6 | KSAO 7 | KSAO 8 | KSAO 9 | KSAO 10 | KSAO 11 | KSAO 12 | KSAO 13 | KSAO 14 | KSAO 15 | KSAO 16 | KSAO 17 | KSAO 18 | KSAO 19 | KSAO 20 | KSAO 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TASK 1** | M | M | M | M | M | M | M | VH | H | L | | H | M | | M | VH | VH | VH | H | M | M |
| **TASK 2** | M | M | M | M | M | | | | H | M | | H | MH | | M | VH | VH | VH | H | M | M |
| **TASK 3** | | | | | | | | | H | M | | H | M | | | VH | VH | VH | H | | VH |
| **TASK 4** | | | | | | H | H | H | H | L | | H | M | M | M | H | VH | | H | | |
| **TASK 5** | M | M | M | M | M | VH | VH | VH | H | M | M | H | MH | | VH | H | VH | VH | H | | H |
| **TASK 6** | M | M | M | M | M | VH | VH | VH | H | M | M | H | MH | | VH | H | VH | VH | H | | H |
| **TASK 7** | M | M | M | M | M | | | | H | M | M | H | M | | M | H | VH | M | H | | M |
| **TASK 8** | M | M | M | M | M | | | | H | L | M | H | M | | VH | H | VH | H | H | H | H |
| **TASK 9** | M | M | | | M | VH | | VH | H | L | | H | M | | M | H | VH | VH | H | | M |
| **TASK 10** | L | L | | | | | | | H | L | | H | MH | | | H | VH | | H | | |

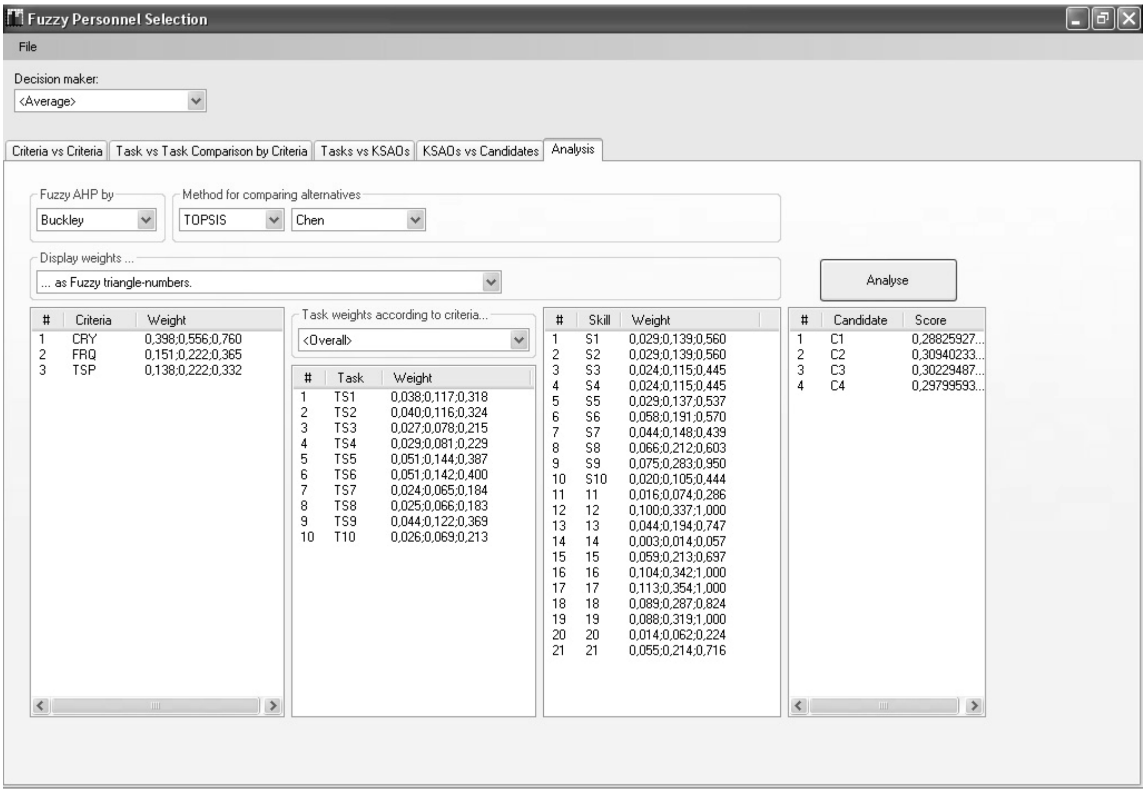


**Figure B.1 :** Results window of FPSS for SE selection problem.

**APPENDIX C :** Information Input for Chief Maintenance Engineer Selection Problem

**Table C.1 :** Pairwise comparison of task importance criteria.

| | CRITICALITY | FREQUENCY | TIME SPENT |
|---|---|---|---|
| **CRITICALITY** | JE | VSMI | VSMI |
| **FREQUENCY** | | JE | EI |
| **TIME SPENT** | | | JE |
| **CR = 0.037** | | | |

**Table C.2 :** Pairwise comparison of tasks with respect to task criticality.

| | TASK 1 | TASK 2 | TASK 3 | TASK 4 | TASK 5 | TASK 6 | TASK 7 | TASK 8 | TASK 9 | TASK 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **TASK 1** | JE | AMI | WMI | WMI | SMI | SMI | SMI | SMI | VSMI | VSMI |
| **TASK 2** | | JE | RSMI | RSMI | RSMI | RSMI | RSMI | RSMI | RWMI | RWMI |
| **TASK 3** | | | JE | WMI | SMI | EI | EI | EI | WMI | WMI |
| **TASK 4** | | | | JE | WMI | EI | EI | RWMI | WMI | WMI |
| **TASK 5** | | | | | JE | RWMI | RWMI | RWMI | WMI | WMI |
| **TASK 6** | | | | | | JE | EI | EI | WMI | WMI |
| **TASK 7** | | | | | | | JE | EI | WMI | WMI |
| **TASK 8** | | | | | | | | JE | WMI | WMI |
| **TASK 9** | | | | | | | | | JE | EI |
| **TASK 10** | | | | | | | | | | JE |
| **CR = 0.012** | | | | | | | | | | |

**Table C.3 :** Pairwise comparison of tasks with respect to task frequency.

| | TASK 1 | TASK 2 | TASK 3 | TASK 4 | TASK 5 | TASK 6 | TASK 7 | TASK 8 | TASK 9 | TASK 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **TASK 1** | JE | WMI | SMI | WMI | VSMI | SMI | RWMI | RSMI | VSMI | VSMI |
| **TASK 2** | | JE | RWMI | EI | WMI | WMI | WMI | RVSMI | VSMI | VSMI |
| **TASK 3** | | | JE | SMI | RWMI | SMI | SMI | RVSMI | VSMI | VSMI |
| **TASK 4** | | | | JE | RSMI | EI | RSMI | RSMI | SMI | SMI |
| **TASK 5** | | | | | JE | VSMI | RSMI | RVSMI | SMI | SMI |
| **TASK 6** | | | | | | JE | RVSMI | RVSMI | SMI | SMI |
| **TASK 7** | | | | | | | JE | RWMI | SMI | SMI |
| **TASK 8** | | | | | | | | JE | AMI | AMI |
| **TASK 9** | | | | | | | | | JE | EI |
| **TASK 10** | | | | | | | | | | JE |
| **CR = 0.038** | | | | | | | | | | |

**Table C.4 :** Pairwise comparison of tasks with respect to time spent.

| | TASK 1 | TASK 2 | TASK 3 | TASK 4 | TASK 5 | TASK 6 | TASK 7 | TASK 8 | TASK 9 | TASK 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **TASK 1** | JE | SMI | RSMI | RVSMI | SMI | SMI | SMI | WMI | RSMI | RSMI |
| **TASK 2** | | JE | RSMI | RSMI | RWMI | EI | RSMI | RSMI | RVSMI | RVSMI |
| **TASK 3** | | | JE | RWMI | SMI | VSMI | SMI | WMI | RSMI | RSMI |
| **TASK 4** | | | | JE | AMI | VSMI | SMI | SMI | RWMI | RWMI |
| **TASK 5** | | | | | JE | WMI | EI | RSMI | RVSMI | RVSMI |
| **TASK 6** | | | | | | JE | RSMI | RSMI | RAMI | RAMI |
| **TASK 7** | | | | | | | JE | RSMI | RVSMI | RVSMI |
| **TASK 8** | | | | | | | | JE | RAMI | RAMI |
| **TASK 9** | | | | | | | | | JE | EI |
| **TASK 10** | | | | | | | | | | JE |
| **CR = 0.024** | | | | | | | | | | |

**Table C.5 :** Tasks – KSAOs linkages by the current CME.

| | KSAO 1 | KSAO 2 | KSAO 3 | KSAO 4 | KSAO 5 | KSAO 6 | KSAO 7 | KSAO 8 | KSAO 9 | KSAO 10 | KSAO 11 | KSAO 12 | KSAO 13 | KSAO 14 | KSAO 15 | KSAO 16 | KSAO 17 | KSAO 18 | KSAO 19 | KSAO 20 | KSAO 21 | KSAO 22 | KSAO 23 | KSAO 24 | KSAO 25 | KSAO 26 | KSAO 27 | KSAO 28 | KSAO 29 | KSAO 30 | KSAO 31 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TASK 1** | MH | M | MH | M | MH | ML | VL | | VH | | H | MH | MH | VH | VH | VH | M | M | | H | M | MH | M | MH | H | H | VH | M | M | | M |
| **TASK 2** | ML | M | L | L | ML | L | VL | | H | | M | | | | | | | M | | M | ML | L | M | M | ML | H | VH | ML | M | | ML |
| **TASK 3** | H | | MH | ML | H | H | M | VH | VH | | MH | MH | MH | VH | VH | VH | L | M | H | MH | | VH | M | | H | H | VH | | M | H | M |
| **TASK 4** | ML | | M | | M | VH | VH | VH | M | | | MH | VH | VH | VH | VH | L | M | VH | M | | VH | | | H | H | VH | H | M | VH | VH |
| **TASK 5** | ML | M | ML | M | | L | | | | VH | MH | | | | | | VH | MH | | H | | M | M | ML | ML | M | ML | L | M | | |
| **TASK 6** | M | | MH | M | M | ML | ML | | | VH | | | MH | M | M | M | M | M | | | M | ML | | | | M | ML | M | M | M | |
| **TASK 7** | MH | | MH | ML | H | M | ML | | M | MH | VH | | M | M | M | M | M | | H | H | M | ML | H | M | M | H | H | | M | | |
| **TASK 8** | ML | ML | | ML | | L | L | L | M | | ML | H | | M | M | M | ML | M | H | M | | | | | M | | ML | L | M | | M |
| **TASK 9** | H | M | H | MH | H | MH | MH | VH | H | M | VH | H | MH | MH | MH | MH | M | M | H | VH | M | MH | M | M | H | H | VH | H | M | VH | H |
| **TASK 10** | M | H | M | MH | M | M | MH | M | | VH | ML | | MH | VH | VH | VH | VH | MH | | H | | MH | | | H | | VH | H | M | | H |

**Table C.6 :** Tasks – KSAOs linkages by the ME.

| | KSAO 1 | KSAO 2 | KSAO 3 | KSAO 4 | KSAO 5 | KSAO 6 | KSAO 7 | KSAO 8 | KSAO 9 | KSAO 10 | KSAO 11 | KSAO 12 | KSAO 13 | KSAO 14 | KSAO 15 | KSAO 16 | KSAO 17 | KSAO 18 | KSAO 19 | KSAO 20 | KSAO 21 | KSAO 22 | KSAO 23 | KSAO 24 | KSAO 25 | KSAO 26 | KSAO 27 | KSAO 28 | KSAO 29 | KSAO 30 | KSAO 31 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TASK 1** | H | M | H | M | MH | ML | VL | | VH | MH | H | H | MH | VH | VH | VH | M | M | | MH | M | MH | M | MH | H | | VH | VH | M | | H |
| **TASK 2** | M | M | M | L | ML | L | VL | | H | | M | | | | | | | M | | M | ML | M | M | M | M | H | VH | M | M | | M |
| **TASK 3** | M | M | H | ML | H | H | M | VH | VH | MH | MH | MH | MH | VH | VH | VH | L | M | MH | MH | | VH | M | | H | H | VH | VH | M | H | H |
| **TASK 4** | M | H | M | | M | VH | VH | VH | M | MH | | MH | VH | VH | VH | VH | L | M | VH | M | | VH | | | H | H | VH | VH | | VH | VH |
| **TASK 5** | M | M | MH | M | | L | | | | VH | MH | | | | | | VH | MH | | MH | | M | | ML | M | | M | M | | | |
| **TASK 6** | M | M | H | M | M | ML | ML | | | VH | | | MH | M | M | M | M | M | | | M | M | | | | | M | M | | M | |
| **TASK 7** | H | | M | ML | H | M | ML | | M | MH | VH | H | M | M | M | M | M | | H | MH | M | M | M | ML | M | H | H | H | M | | |
| **TASK 8** | M | ML | M | ML | M | L | L | L | M | | ML | VH | | M | M | M | ML | M | H | M | | MH | | | M | | M | M | | | M |
| **TASK 9** | H | M | H | MH | H | MH | MH | VH | H | M | VH | M | MH | MH | MH | MH | M | M | H | VH | M | MH | | ML | H | H | VH | H | M | M | VH |
| **TASK 10** | M | H | M | MH | M | M | MH | M | | VH | ML | | MH | VH | VH | VH | VH | MH | | M | | MH | | | H | | VH | VH | M | | VH |

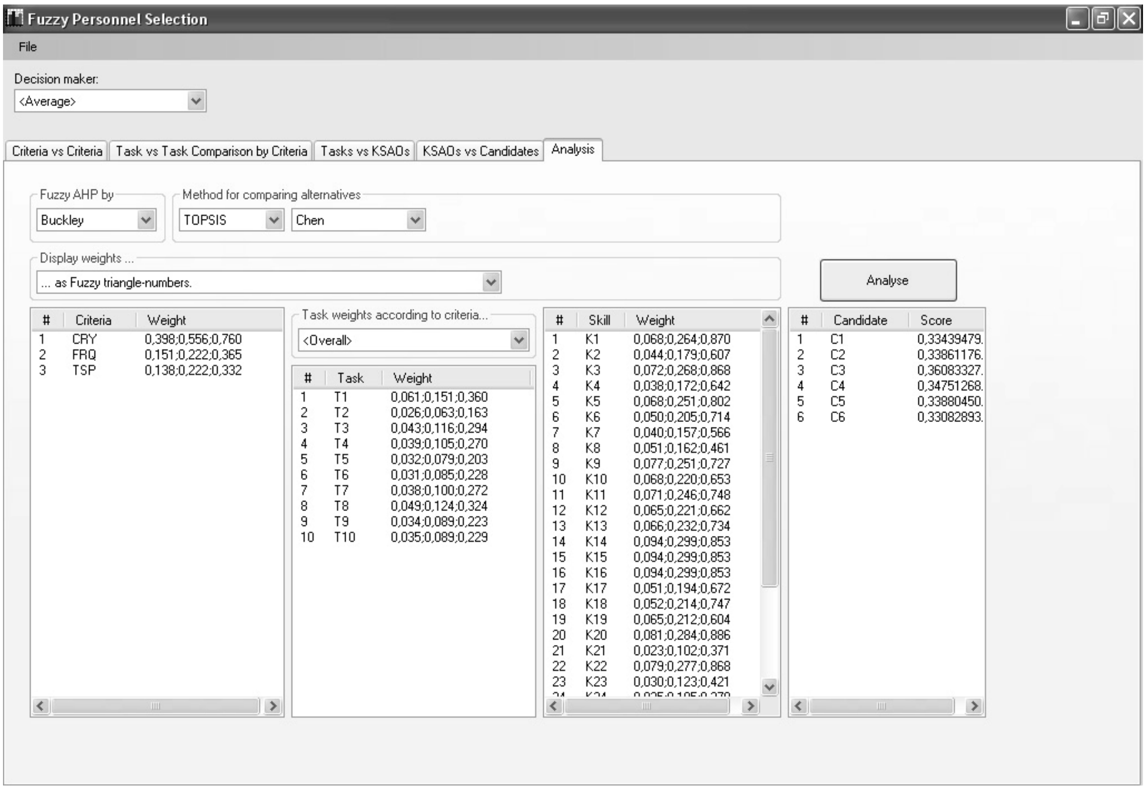


**Figure C.1 :** Results window of FPSS for CME selection problem.

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| | | |
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**Publications:**

- Kozanoğlu, O. and Özok, A. F., (2005). A Fuzzy Quality Function Deployment Model for Personel Selection under Ergonomics Considerations, *35$^{th}$ International Conference on Computers & Industrial Engineering*, July 19-22, 2005 İstanbul, Turkey