INTELLIGENT TEAM FORMATION
FOR COMPANIES APPLYING
QUALITY CERTIFICATION

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T.C. YÜKSEKÖĞRETİM KURULU
DOKÜMANTASYON MERKEZİ

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ABSTRACT

INTELLIGENT TEAM FORMATION
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M.Sc. in Industrial Engineering

Supervisor: Assoc. Prof. Dr. Türkay DERELİ

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In this thesis, a *fuzzy team-formation model* has been developed for the formation of a **Quality Audit (QA)** team, which has the appropriate team size and team members.

The *team formation* problem is a decision-making problem, which contains subjectivity, imprecise information and vague human evaluations. Fuzzy Logic (FL) is used, in order to model the problem accurately and correctly. Fuzzy ratings method is used to calculate the fuzzy compatibility values of each candidate that shows the match between the skills of the team members and the skills required for an audit team. The obtained values are utilized to form the fuzzy objectives. Afterwards, the formulated fuzzy objectives are maximized to form the best team under several constraints like budget and schedule.

Simulated Annealing algorithm is employed for the solution of the proposed fuzzy mathematical model and a computer program in C++ programming language is prepared.

Keywords: Team Formation, Fuzzy Logic, Quality Auditing

ÖZ

KALİTE SERTİFİKASYONU İÇİN BAŞVURAN KURULUŞLARI DENETLEYECEK ZEKİ TAKIMLAR OLUŞTURMA

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Bu tezde, uygun takım büyüklüğü ve takım üyelerine sahip **Kalite Denetim** takımları kuracak bulanık bir *takım kurma* modeli geliştirilmiştir.

Takım kurma problemi öznel, eksik bilgi ve belirsiz kişisel değerlendirmeler içeren bir karar verme problemidir. Problemi tam ve doğru olarak modelleyebilmek için Bulanık Mantık kullanılmıştır. Bunun yanında, her adayın için - denetim takımının gerektirdiği kabiliyetler ile aday kabiliyetlerinin karşılaştırılmasıyla elde edilen- bulanık uygunluk değerleri Bulanık Değerlendirme metodu kullanılarak hesaplanmıştır. Elde edilen değerler kullanılarak ilk bulanık amaç fonksiyonu oluşturulmuştur. Sonrasında, formüle edilen bulanık amaç fonksiyonları en iyi takımı oluşturmak için bütçe ve çizelge gibi çeşitli kısıtlar altında eniyilenmiştir.

Önerilen bulanık matematiksel modelin çözümü için Tavlama Benzetimi algoritması kullanılmış ve geliştirilmiş model için C++ programlama dilinde bir bilgisayar programı hazırlanmıştır.

Anahtar kelimeler: Takım Kurma, Bulanık Mantık, Kalite Denetimi

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LIST OF ABREVIATIONS

QA	Quality Audit
FL	Fuzzy Logic
TQM	Total Quality Management
IPP	Integrated Planning Process
QFD	Quality Function Deployment
AHP	Analytical Hierarchy Process
DM	Decision Making
TB	Team Building
TD	Team Development
ISO	International Organization of Standardization
TSE	Turkish Standards Institution
TURKAK	Turkish Accreditation Agency
IAF	International Accreditation Forum
ASQ	American Society for Quality
SA	Simulated Annealing

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CHAPTER 1

SCOPE OF THE WORK AND OBJECTIVES

1.1 Introduction

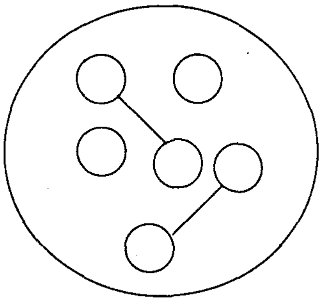
This chapter briefly introduces the context of the research and explains the importance of *team formation* for establishing effective. After the introduction of the *team formation* problem, objective of the thesis and the methodology used for the solution are explained. Finally, the organization of the thesis is presented.

1.2 Importance of Team Formation

Today, teamwork has become an important tool for many organizations, striving to increase their productivity and competence to overcome challenges of the global business environment. The wide use of teams for a variety of different purposes supports this fact and shows that organizations are aware of the power of effective teamwork.

The teams are the primary unit performance in many organizations. (Katzenbach and Smith, 1993) define a **team** as: ***"a small number of people with complementary skills who are committed to a common purpose, performance goals, and approach for which they hold themselves mutually accountable".***

The main distinguishing property (illustrated in Figure 1.1.) of a team from any group of people working together is the **"unity of purpose".** The teams can achieve more when they are working together because "**the whole is greater than the sum of the individual parts**". The teams can also be defined as **synergetic work structures** formed from individuals cooperating and communicating to reach a specific purpose.



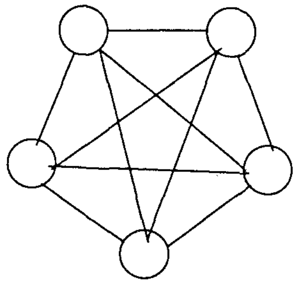


Figure 1.1.1 A group of people working together Figure 1.1.2 A team

The teams are formed when high performance is needed which requires multiple skills, judgments and experience beyond the reach of an individual. The teams are generally formed when (Castka et. al., 2001):

- The task is complex
- Productivity is needed
- The path forward is unclear
- More efficient use of resources is required
- Fast learning is necessary
- High commitment is desirable
- The implementation of a plan requires the co-operation of others
- The task of process is cross-functional

Stough et al. (2000) stated that the productivity, quality, and morale are improved with the use of teams. Organizational performance is improved by teamwork. The teamwork also encourages the formation of teams for many different purposes like management, strategic planning, decision-making, problem solving, new product development, auditing, quality improvement etc. A key precursor to teamwork is the ***team formation*** (Nair et al, 2002).

The *team formation* can be defined as forming the right team, which will perform a particular project / task within a given deadline. The following issues should be considered when a team (especially for high performance teams) is to be formed (Castka et al., 2001):

- Team member competency/compatibility/suitability,
- Skills (especially technical and functional ones), processes, tools and techniques,
- Interpersonal skills, communication, personality preferences,
- Value system,
- Shared vision, purpose, goals, direction,
- Organizational values including openness etc.

The research on the *team formation* for various problems and issues has been quite limited. Further, there has been no work in the literature on the *team formation* for audit cycles of quality certification issues. This thesis will attempt to solve the *team formation* problem for the formation of **Quality Audit** (**QA**) teams. For this purpose, issues affecting the *team formation* process are determined. Then, these issues are addressed in a model by using the FL and fuzzy ratings method due to imprecise information and a fuzzy decision-making model is developed. Finally, a case study about the problem is presented at Chapter 6.

The developed model handles the issues such as; skills, team member suitability, team size and interpersonal skills between team members and aims to form the appropriate **QA team** for quality certification, which has the appropriate team size and team members. The developed system is implemented by a computer program in C++ programming language, which is based on a Simulated Annealing algorithm.

1.3 Frame of the Work

The teamwork is the heart of **Total Quality Management (TQM)**. Many of the quality or quality-related efforts in an organization depend on the teams and teamwork. Many organizations have been forming quality or quality-improvement teams under different names to improve the quality. These internal teams usually try to adopt the requirements of a specific standard (like ISO 9000, ISO 14000 etc.) to their current system. However, accreditation organizations and certification bodies need independent and objective external teams to assess and audit these organizations.

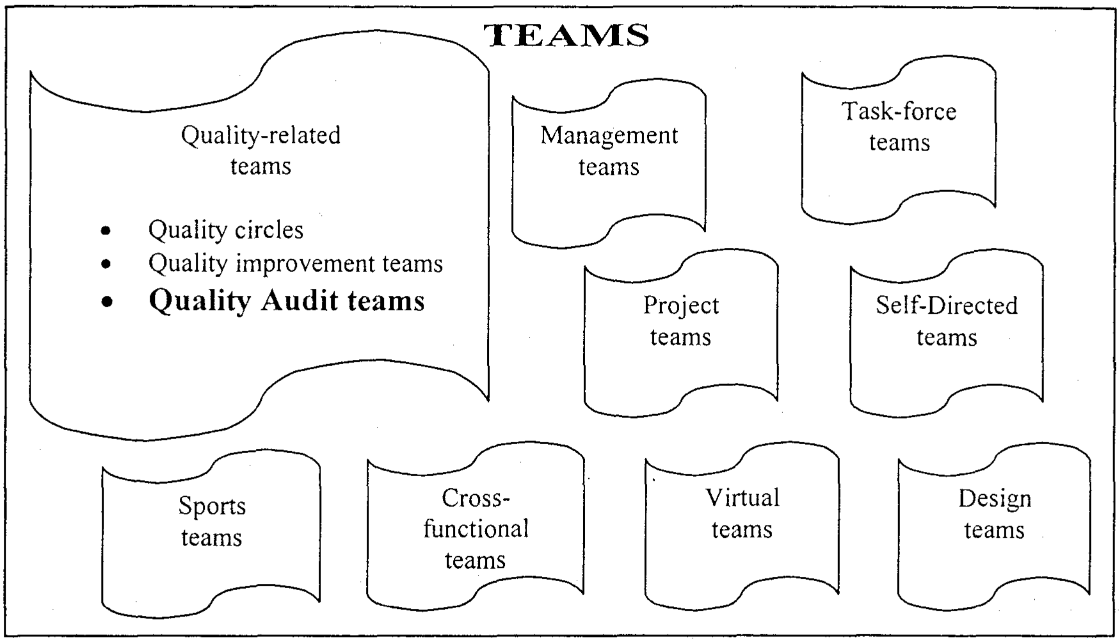


Figure 1.2 Types of teams

In this research about *team formation,* emphasis will be given to the formation of a **QA team**, which is unfamiliar to many people. In the literature, there are many studies and wide information about various teams (illustrated in Figure 1.2) like new product development teams, task force teams, management teams, self-directed teams, multi-functional teams, project teams, virtual teams and quality improvement teams etc. However, there is no work about the **QA teams**.

A **QA team** audit organizations from different sectors to evaluate an organization's quality system against a quality system standard and generally decide whether they should be given the quality certificate or not. **QA team** must be composed of a **lead auditor** and **auditors** who have the required skills for the execution of an audit. For a successful audit, the formation of the **QA team** is very vital since each auditor in the team must have some basic skills like basic auditing skills, communication skills etc.

This study has focused on the development of a mathematical model for the *team formation problem,* which yields effective teams especially for certification bodies.

1.4 Objectives of the Work

The main goal of this thesis is to develop an intelligent system for use in **QA teams**. It mainly concentrates on the following:

- Investigation of the *team formation problem* and the relevant studies in the literature,
- Examination of the process of quality certification and quality audit,
- Examination of the formation procedure of a **QA team**,
- Development of an intelligent model for the *team formation problem*,
- Coding a program for the model with C++ language,
- Formation of effective **QA teams** for the process of quality certification and quality audit,
- Testing the model with examples.

1.5 Methodology and Materials

In this study, an intelligent model for the selection of team members to a **QA team** is developed. A fuzzy multiple-objective optimization model is used together with fuzzy objectives and crisp constraints. The proposed model evaluates the skills of the each candidate team member based on the skill requirements that are needed for the completion of each audit process. Because of the imprecise nature of the problem, fuzzy ratings method are used to calculate the suitability in between the tasks and the team members. The suitabilities and size of each formed team are modeled as fuzzy objectives. The time constraints and budget limitations are also considered in the *team formation* process. These constraints are modeled as hard-crisp constraints. The model uses fuzzy objectives and crisp constraints to select the most suitable team members for an audit of quality certification.

The model is implemented on a computer program by using C++ programming language.

1.6 Organization of the Thesis

Following this introduction chapter, which explains the frame and the objectives of the conducted work, the literature about the *team formation problem* is involved in Chapter 2. In Chapter 3, the reasons for using FL will be explained and background knowledge about FL, Fuzzy Decision-Making and Fuzzy Ratings Method will be given shortly. In Chapter 4, the issues like teams, teamwork, team building, team development and *team formation* will be discussed in detail. In Chapter 5, the information on quality, quality assurance, quality certification and quality audit, which are subject to this thesis, will be presented in detail. In Chapter 6, the developed *fuzzy team-formation* model will be introduced and applications of the model will be presented. Finally, in Chapter 7, the merit and demerits of the research work, the capability and validity of the developed model and the results obtained from this thesis will be discussed.

CHAPTER 2

LITERATURE SURVEY

2.1 Introduction

There has been a considerable amount of work in the field of producing teams, observing how they function and monitoring their performance. In this chapter, a survey compiled from the previous studies related to the *team formation* problem will be presented. Conclusions drawn from the literature is then discussed at the end of the chapter.

2.2 Literature on "*Team Formation*" Problem

When previous work about the *team formation* is examined, it can be seen that different authors handle the problem in different perspectives and suggest different solutions to the problem. A careful examination of the literature, however, has shown that the majority of these studies suggest an empirical solution to the problem. Further, it is found out that only few studies provide analytical solutions. Considering this situation, the literature is surveyed under the two main titles;

- Empirical work and
- Analytical work.

2.2.1 Empirical work

Kezsbom (1995) offered an **Integrated Planning Process (IPP)** for the cross-functional project teams, which is designated to produce committed and well-balanced teams. The IPP is directed for producing a complete and integrated plan, a schedule and identified areas of risk and concerns, as well as building a truly cohesive team. She claims that similar to the team building process, the IPP is a more efficient method than team building. The steps of IPP and comparison of IPP and team building is given in Table 2.1.

Table 2.1 Integrated planning process vs. team building process

Steps in Integrated Planning Process	*Steps in the Team Building Process*
Establish a positive environment	Establish a positive environment
Define Mission Statement	Develop a sense of interdependence
Define the work via a participative Work Breakdown Structure Process	Define and clarify team goals
Establish precedence	Determine the role definition relationship
Identify trade-offs	Develop procedures
Present for approval	Develop a decision mailing process
Review & update	Review regularly

She also stated that IPP not only brings individuals together toward a common goal but also allows them a clearer understanding of the work.

Sommerville and Dalziel (1998) tried to identify how individuals should be combined to ensure group success. They used the **Belbin's team-role self-perception inventory** to examine the behaviors of team members and to monitor how they interact. According to Belbin, each team member in a team adopts some roles. He claims that the individuals are capable of adopting all roles, but they contribute to team under a single role, which reflects their natural ability or experience in the best manner. The team roles defined by Belbin are illustrated in Table 2.2. The study conducted by Sommersville and Dalziel supports the Belbin's assumption of roles. Thus, they concluded that a successful project team must consider the mix of these roles very carefully and ensure a balance, which is appropriate, for both the project and the client.

Table 2.2 The description of the Belbin's team-roles

Team Role	*Typical Features*	*Positive Qualities*	*Allowable Weaknesses*
Team worker	Socially oriented, rather mild, sensitive	An ability to respond to people and to situations, and to promote team spirit.	Indecisiveness at the moment of crisis
Implementer	Disciplined, reliable, conservative and efficient	Turns ideas into practical actions	Somewhat inflexible. Slow to respond to new possibilities
Shaper	Highly strung, outgoing dynamic	Drive and a readiness to challenge inertia, ineffectiveness, complacency or self- deception	Prone to provocation, irritation and impatience
Co-ordinator	Mature, confident, a good chairperson	Clarifies goals, promotes decision-making, delegates well	Can be seen as manipulative. Delegates personal work.

In another study, Butterfield and Pendegraft (1996) aim to explore the possible effects of using a ***game-based team selection process*** and discuss the use of games for the improvement of the *team formation* process. They reported that the lack of knowledge about the other team members foster some problems during the *team formation* process. The results of their study suggested that the use of gaming techniques could overcome these problems by encouraging self-disclosure and information sharing within a team. This results in a more satisfied selection process of the teams, which work more effective than the randomly selected teams.

Castka et al. (2001) believed that seven factors-including *team formation*-affect the implementation of ***high performance teams***. They discussed the factors affecting the successful implementation of the high performance teams and suggested a conceptual model to assist the implementation process.

Different from the above-mentioned studies, Stough et al. (2000) suggested ***virtual teaming*** as a different strategy. They discussed the use of computer-mediated communication technologies and other groupware technologies, which provide a workable, reliable and flexible platform for virtual teams and virtual organizations. They implied that the use of information technologies might have a greater impact on the team dynamics than the traditional approaches, trying to improve face-to-face interpersonal communication.

Joy-Matthews and Gladstone (2000) discussed ***virtual team formation*** as a new strategy. They pointed out that the teams brought together through an intranet could not be called as ***virtual teams***. Like traditional teams, the team members in virtual teams should establish open communication lines and interpersonal relations.

Other then the listed studies, there is a great amount of work about teams, team building and team development. Here, it is worth mentioning some of the pioneer works in this subject. Dyer (1994) investigated teams and their use. He examined team-building steps. Further, he suggested alternative team building designs.

Katzenbach and Smith (1993) investigated teams, team performance and ways to become a team. They believe that high performance teams can be formed if obstacles to teamwork are eliminated.

Kinlaw (1991) discussed groups, teams and superior teams. He also investigated team building, team development and the difference between team building and team development. Moreover, he suggested a model for superior team development and performance.

Clark (1994) investigated team and presented popular approaches to team building and design of team building.

Soliman and Gide (1998) discussed the importance of team building, important factors and limitations of team building, the role of team leader in team building techniques in detail.

2.2.2 Analytic work

With the increasing use and importance of teams in business life, many researchers are focusing on the problem of *team formation*. The methods that are used for the solution of the problem include mathematical programming, FL and agent theory (Tambe, 1997; Nair et al., 2002).

One of the outstanding works on the subject is the Zakarian and Kusiak's (1999) *team formation* model. Their model, which is based on the **Analytical Hierarchy Process (AHP)** approach and the **Quality Function Deployment (QFD)** method, prioritize team membership based on customer requirements or product specifications. In the study, QFD is utilized to organize the factors considered in the team selection and AHP is used to measure the importance of each team member. Using the stated methods, they suggested a mathematical programming model to determine the composition of a team.

Similar to Zakarian and Kusiak's model, Boon and Sierksma (2003) formulated linear optimization models to headhunt or scout a new team in soccer and volleyball to enhance the quality of a team. They aimed to form the optimal teams by combining the qualities of applicants and players with the functional requirements in order to assign the right person to the right team.

Different from the above approach, some of the authors prefer to use FL for the solution of the *team formation* problem. Yaakob and Kawata (1999) tried to solve the ***workers' placement*** problem in an industrial environment. They evaluated skills of workers and calculated suitability of the workers by using *triangular fuzzy numbers* to select the appropriate candidates for the work teams in industrial environments. In order to reach an accurate solution, they also considered the relationship among the workers while forming the teams. They concluded that the relationship among the workers is one of the important factors in *team formation.*

In another study on *fuzzy team formation*, de Korvin, et al. (2002) presented a model for the selection of the teams to a multi-phase project. During the selection procedure, like Yaakob and Kawata, they considered the skills of the candidate team member and utilized *fuzzy set theory* to calculate the compatibilities of skill sets. Different from Yaakob and Kawata, they offered a more realistic solution procedure, since budget considerations for each phase are included.

2.3 Conclusion

As seen from the previous studies, the *team formation* problem has many aspects. Therefore, there are many studies dealing with the different aspects of the problem. Although several models exist, none of these studies completely reflects the specific constraints like **time**, **budget, size of teams** and **interpersonal relationships** between team members. Further, there is gap in the literature about the formation of quality related teams.

In this thesis, a fuzzy model considering all of the above-mentioned constraints is formulated. The developed model that will be presented in Chapter 6, is an intelligent and more flexible one compared to the other studies. Because, the program can form desired or required kinds of teams like a lead auditor.

The *fuzzy team-formation* model has also a flexible structure. Although the model is formulated for a QA team, it could be used for the other *team formation* applications like sports teams, project teams etc.

As it can be inferred from the previous studies, evaluating the skills of the team members is a heuristic process. Among the previously mentioned techniques that are employed for the solution of the *team formation* problem, FL is preferred.

Mainly because, FL is a technique for dealing with sources of impression and uncertainty that are non-statistical in nature. It is an innovative technology that enhances conventional system design with engineering expertise. FL is based on a complex mathematical body. However, its practical use is easy to learn. FL is a true extension of conventional logic. Therefore, anything that was built using conventional techniques can be built with the FL. However, in a number of cases, conventional solutions are simpler, faster, and more efficient. The key to successful use of FL is clever combination with conventional techniques (Von Altrock, 1995).

CHAPTER 3

"The closer one looks at a real-world problem,
the fuzzier becomes its solution."(Zadeh)

FUZZY LOGIC, FUZZY SET THEORY AND FUZZY DECISION MAKING

3.1 Introduction

In this section, a brief introduction about FL is given. The fundamentals of the fuzzy set theory, the fuzzy decision-making and the fuzzy ratings method that are employed for the solution of the *team formation* problem are explained.

3.2 Fuzzy Logic

Most of the real life problems contain subjectivity, incomplete and imprecise information and vague human evaluations. In such problems, the decision-maker cannot model the problem using precise mathematical terms due to the imprecise nature of the problem. Zadeh firstly introduce FL in 1965, it can be used to represent and manipulate such data, which is not precise but rather fuzzy. Bellman and Zadeh (1970) stated, "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". **Imprecision** or **fuzziness** is the core of fuzzy sets or FL application.

3.3 Fuzzy Set Theory

3.3.1 Fuzzy set and membership

A *fuzzy set* is a set containing elements that have varying degrees of membership in the set. This idea is in contrast with classical, or crisp, sets because members of a crisp set would not be members unless their membership was full or, complete, in that set (Ross, 1995).

Fuzzy set A can be defined as follows;

Definition 1: Let X be a nonempty set. A ***fuzzy set*** A in X is a set of ordered pairs;

$$A = \{[x, \mu_A(x)] \mid x \in X\} \tag{3.1}$$

and $\mu_A(x)$ ***is the membership function*** .

Membership functions characterize the fuzziness in a fuzzy set-whether the elements in the set are discrete or continuous-in a graphical form for eventual use in the mathematical formalisms of fuzzy set theory (Ross, 1995). The membership function can take values between [0,1]. If the membership value of an element is equal to zero, this shows that this element has complete ***non-membership,*** where as in ***complete membership*** this value is equal to one. As the membership value $\mu_A(x)$ gets bigger, belonging of x to the fuzzy set A increases. In Figure 3.1., the difference between the crisp set and the fuzzy set can be seen.

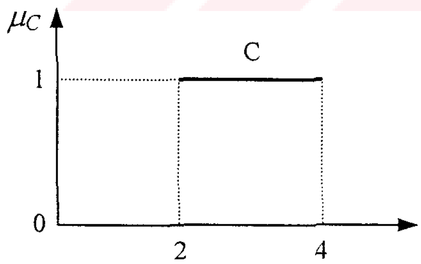


Figure 3.1.1 A crisp set

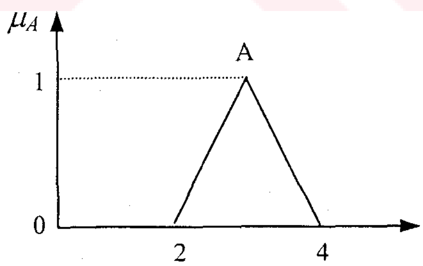


Figure 3.1.2 A fuzzy set

The membership function of a fuzzy set can be described by three different parts;

- the core,
- the support,
- the boundaries.

The **core** of a membership function for a fuzzy set *A* is defined by the region that contains elements having complete membership in the set ***A***. The **support** of a membership function for a fuzzy set *A* is defined by the region that contains elements having nonzero membership in the set *A*. The **boundaries** of a membership function for a fuzzy set *A* are defined by the region that contain elements having a nonzero membership but non-complete membership. The core, the support and the boundaries of a membership function can be seen in Figure 3.2.

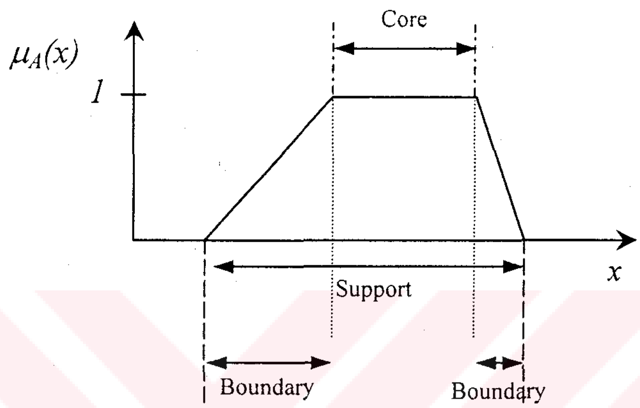


Figure 3.2 The core, support and boundaries of a fuzzy set

Definition 2: A ***normal fuzzy set (A) unity*** (illustrated in Figure 3.3) is one whose membership function has at least one element x in the universe whose membership is *unity*. The most common forms of membership functions are those that are normal and convex.

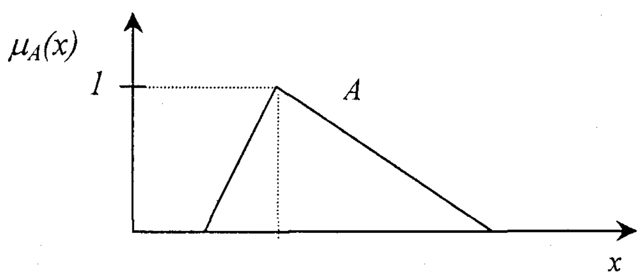


Figure 3.3 Membership function of a normal fuzzy set

There are many ways to assign membership values of functions to fuzzy variables. This assignment can be intuitive or it can be based on some algebraic or logical operations (Ross, 1995). Below, there are assignment methods, which are used in the literature (Ross, 1995);

- Intuition
- Inference
- Rank Ordering
- Angular Fuzzy Sets
- Neural Networks
- Genetic Algorithms
- Inductive Reasoning
- Soft Partitioning
- Meta Rules
- Fuzzy Statistics.

The easiest method among the listed ones is Intuition. It is simply derived from the capacity of humans to develop membership functions through their own innate intelligence and understanding (Ross, 1995).

3.3.2 Fuzzy set operations

Classical set operations like union, intersection and complement can be applied to fuzzy sets.

Definition 3: Let ***A*** and ***B*** fuzzy sets;

Union: The union of A and B is defined as

$$\mu_{A\cup B}(x)= \mu_A(x) \vee \mu_B(x) = max\{ \mu_A(x), \mu_B(x) \} \quad (3.2)$$

Intersection: The intersection of A and B is defined as

$$\mu_{A\cap B}(x)= \mu_A(x) \wedge \mu_B(x) = min\{ \mu_A(x), \mu_B(x) \} \quad (3.3)$$

Complement: The complement of a fuzzy set *A is defined as*

$$\mu_A(x) = 1-\mu_A(x) \quad (3.4)$$

3.3.3 Fuzzy number

When the fuzzy set is of a certain restricted type, it is called a **fuzzy number** (Chen,1996). Below there is the definition of a fuzzy number.

Definition 4: If A is a convex single-point normal fuzzy set defined on a real line, than A is called a ***fuzzy number***. While a crisp number is defined at a single point with a membership value 0 or 1, a fuzzy number is defined in at least one interval and has a membership value $\mu_A(x)$ between [0,1].

Especially for the solution of fuzzy mathematical programming problems, triangular and trapezoidal fuzzy numbers are used (Atin, 1999). For this purpose, in this section, triangular and trapezoidal fuzzy numbers and arithmetic operations on these fuzzy numbers will be investigated.

Definition 5: A fuzzy set A is called ***triangular fuzzy number*** with peak (or center) a, left width $\alpha>0$ and right width $\beta>0$ if its membership function has the following form

$$\mu_A(x)=\begin{cases} 0 & x < a-\alpha \\ 1-(a-x)/\alpha & a-\alpha \leq x \leq a \\ 1-(x-a)/\beta & a \leq x \leq a+\beta \\ 0 & x > a+\beta \end{cases} \tag{3.5}$$

and denoted as A=(a, α, β). A triangular fuzzy number (shown in Figure 3.4) with center a may be seen as a fuzzy quantity **"x is approximately equal to a"** (Zadeh, 1965).

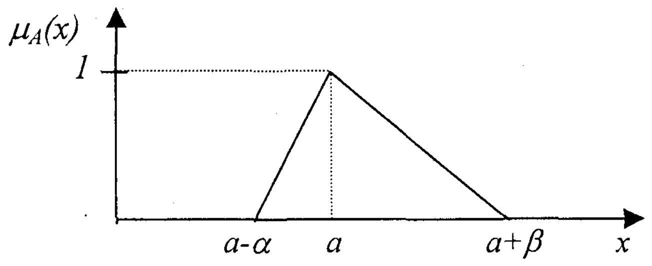


Figure 3.4 A triangular fuzzy number

Triangular fuzzy numbers are used a lot especially in systems modeling (Kaufman and Gupta, 1988).

Definition 6: A fuzzy set A is called *trapezoidal fuzzy number* (shown in Figure 3.5) with tolerance interval [a,b], *left width* α and *right width* β if its membership function has the following form;

$$\mu_A(t)=\begin{cases} 1-(a-t)/\alpha & a-\alpha< t < a \\ 1 & a \le t \le b \\ 1-(t-b)/\beta & b \le t \le b+\beta \\ 0 & \text{otherwise} \end{cases} \tag{3.6}$$

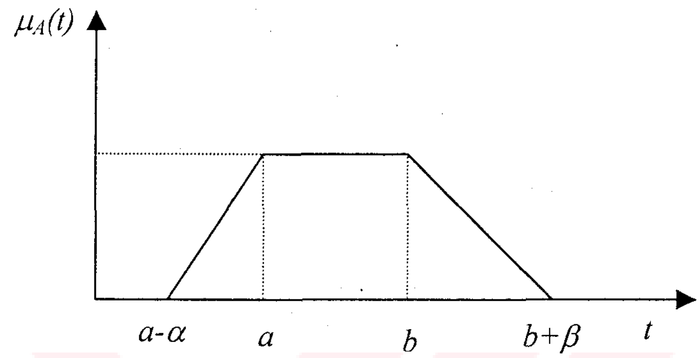


Figure 3.5 A trapezoidal fuzzy number

A trapezoidal fuzzy number may be seen as a fuzzy quantity " x is approximately in the interval [a,b]" (Zadeh, 1965) .

Algebraic operations on fuzzy numbers can be defined by using the extension principle. In our study, some algebraic operations developed by Dubois and Prade (1978) are used.

Some algebraic properties of triangular fuzzy numbers can be listed as follows (Atin, 1999);

- When addition or subtraction is applied to two triangular fuzzy numbers, the result will be a triangular fuzzy number.
- When multiplication or division is applied to two triangular fuzzy numbers, the result is not always a triangular fuzzy number.

However, in operations where the result is not a triangular fuzzy number, the result can be converged to a triangular fuzzy number.

For two triangular fuzzy numbers $A=(x_1, \alpha_1, \beta_1)$ and $B=(x_2, \alpha_2, \beta_2)$;

Extended addition;

$$A+B=(x_1+x_2, \alpha_1+\alpha_2, \beta_1+\beta_2) \quad (3.7)$$

Extended subtraction;

$$A-B=(x_1-x_2, \alpha_1+\alpha_2, \beta_1+\beta_2) \quad (3.8)$$

Extended multiplication;

$$A\times B \cong (x_1 \times x_2, x_2\alpha_1+x_1\alpha_2, x_2\beta_1+x_1\beta_2) \quad \text{where } A\geq 0, B\geq 0 \quad (3.9)$$

$$A\times B \cong (x_1 \times x_2, x_2\alpha_1-x_1\beta_2, x_2\beta_1-x_1\beta_2) \quad \text{where } A<0, B\geq 0$$

$$A\times B \cong (x_1 \times x_2, -x_2\beta_1-x_1\beta_2, -x_2\alpha_1-x_1\alpha_2) \quad \text{where } A<0, B<0$$

Some algebraic properties of trapezoidal fuzzy numbers can be listed as follows (Atin, 1999);

- When addition or subtraction is applied to two trapezoidal fuzzy numbers, the result will be a trapezoidal fuzzy number.
- When multiplication or division is applied to two trapezoidal fuzzy numbers, the result is not always a trapezoidal fuzzy number.

As in the case of triangular fuzzy numbers, in operations where the result is not a trapezoidal fuzzy number, the result can be converged to a trapezoidal fuzzy number.

For two trapezoidal fuzzy numbers $A=(x_1, x_2, \alpha, \beta)$ and $B=(y_1, y_2, \gamma, \delta)$;

Extended addition;

$$A+B=(x_1+y_1, x_2+y_2, \alpha+\gamma, \beta+\delta) \quad (3.10)$$

Extended subtraction;

$$A-B=(x_1-y_2, x_2-y_1, \alpha+\delta, \beta+\gamma) \quad (3.11)$$

Extended multiplication;

$$A\times B \cong (x_1 \times y_1, x_2 \times y_2, x_1\gamma+y_1\alpha-\alpha\gamma, x_2\delta+y_2\beta-\beta\delta) \quad \text{where } A\geq 0, B\geq 0 \quad (3.12)$$

$$A\times B \cong (x_1 \times y_2, x_2 \times y_1, y_2\alpha-x_1\delta+\alpha\delta, y_1\beta-x_2\gamma-\beta\gamma) \quad \text{where } A<0, B\geq 0$$

$$A\times B \cong (x_2 \times y_2, x_1 \times y_1, -x_2\delta-y_2\beta-\beta\delta, -x_1\gamma-y_1\alpha+\alpha\gamma) \quad \text{where } A<0, B<0$$

3.3.4 Linguistic variables

In daily life, to convey information we use natural language. By its very nature, natural language is vague and imprecise; yet it is the most powerful form of communication and information exchange among humans. Despite the vagueness in natural language, humans have little trouble in understanding one another's concepts and ideas. For instance, what is the meaning of a 'tall person?'. To individual A a tall person might be anybody over 5'11''. To individual B a tall person is someone who is 6'2'' or taller. Despite the potential for misunderstanding, the term 'tall' conveys sufficiently similar information to the two individuals, even if they are different heights themselves, understanding and communication is possible between them. The underlying power of fuzzy set theory is that it uses ***linguistic variables***, rather than ***quantitative variables***, to represent imprecise concepts (Ross, 1995).

A ***linguistic variable*** differs from a numerical variable in that its values are not numbers, but words or sentences in natural or artificial language (Zadeh, 1965). The reason for using the linguistic variables is the difficulty of expressing human judgments in crisp values. These variables reflect the decision makers' assessments/judgments about the alternatives. Figure 3.6 illustrates the body temperature of a human by linguistic variables.

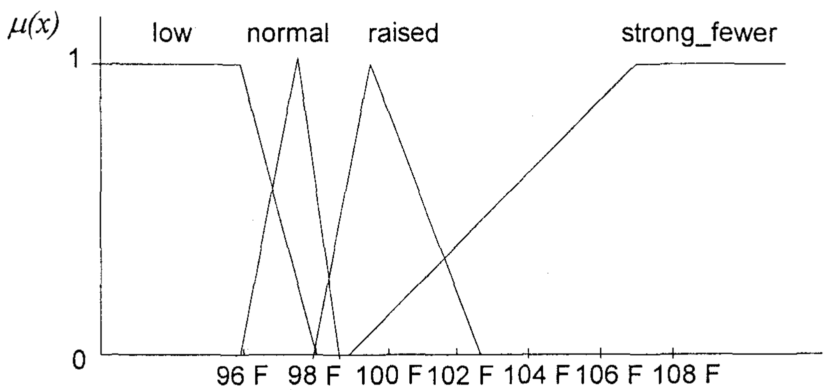


Figure 3.6 Linguistic variables for body temperature

Here, multiple subjective categories describing the same context are combined. In case of fewer, not only high but also raised temperature, normal temperature, and low temperature exist. These are called "linguistic terms" and represents the possible values of linguistic variables (Von Altrock, 1995).

Classical sets contain objects satisfy precise properties of membership; fuzzy sets contain objects that satisfy imprecise properties of membership. For example, the set of heights *form 5 to 7 feet* is crisp; the set of heights in the region *around 6 feet* is fuzzy (Ross, 1995).

Ross (1995) explains this property of the fuzzy sets as follows;

Suppose that an exhaustive collection of individual elements (singletons) x, make up a universe of information (discourse), X. Further, various combinations of these individual elements make up sets, say A, on the universe. For crisp sets an element x in the universe X is either a member of some crisp set A or not. For the example of universe of heights of people, suppose set A is the crisp set of all people with

$$5 \leq x \leq 7 \text{ feet.}$$

An individual that has a height of 6.0 feet is the member of this set and the membership of this individual is 1. Another individual that has a height 4.9 feet is not a member of this set and the membership of this individual is 0.

Zadeh (1965) extended the notion of binary membership and defined "degrees of membership " on continuous interval [0,1]. The sets on the universe X that can accommodate "degrees of membership" were termed by Zadeh as *fuzzy sets*. Continuing the example on heights, consider a set H consisting of heights *near 6 feet*. Since the property *near 6 feet* is fuzzy, there is not a unique membership function for H. Rather the analyst must decide the membership function, denoted by μ_H, look like (Ross, 1995). This is the Intuition method, which is explained in section 3.3.1.

Similar to the expression of the body temperature of a human and the judgments about the height, linguistic variables and their membership functions to evaluate a person can be chosen using Intuition method by the decision maker.

In the model, the candidate team members are scored for certain factors, which are expressed using linguistic variables such as "poor (P)", "fair (F)", "good (G)" and "very good (VG)".

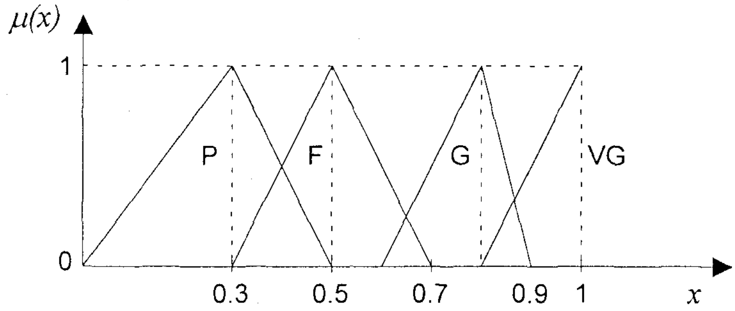


Figure 3.7 Levels represented as linguistic variables and their membership values (Karsak, 2000)

In this study, the candidate team members are evaluated by the levels determined by Karsak (2002), which are seen appropriate for the problem (illustrated in Figure 3.7).

3.4 Fuzzy Decision-Making

Decision-making (DM) is a process of problem solving involving the pursuing of goals under constraints (Bojadziev, 1998). In other words, it can be defined as ***"selection from a set of alternatives".*** When a decision has to be made, traditionally the decision-maker deals with;

- a set of decision variables (alternatives),
- a set of constraints which limit the solution space,
- an objective function which will be optimized.

Then, the optimal decision can be defined as the selection of the alternative that optimizes both the objective function and the constraints at the same time.

In real life, the decision-making is not as simple as stated above, since the decision-maker cannot always state the goal and the constraints in precise mathematical terms due to the imprecise nature of the real world problem. Here, the decision problem might only be defined in a fuzzy way.

In such a fuzzy environment, the objective function(s) and the constraints can be fuzzy by defining membership functions for both the objective and the constraints. Analogy to the traditional decision-making, the **"decision"** in a fuzzy environment can therefore be viewed as the intersection of fuzzy constraints and fuzzy objective function(s). The relationship between constraints and objective functions, in a fuzzy environment are therefore fully symmetric, i.e. there is no longer a difference between the former and the latter (Zimmerman, 1976).

Definition 7: ***(Fuzzy Decision-Making)*** Assuming ***D*** is a fuzzy decision represented by its membership function $\mu_D(x)$, ***G*** is a fuzzy goal with membership function $\mu_G(x)$, and ***C*** is a fuzzy constraint with membership function $\mu_C(x)$, decision in fuzzy environment is the intersection of ***G*** and ***C***. In Figure 3.8 the graphical representation of fuzzy decision can be seen (Bojadziev, 1998).

$$D = G \cap C \tag{3.13}$$

or

$$\mu_D(x) = min(\mu_G(x),\ \mu_C(x)),\ x \in X \tag{3.14}$$

The optimal decision *x* is equal to;

$$X_{opt} = \{x|\ max\ \mu_D(x) = max\ min(\mu_G(x), \mu_C(x))\} \tag{3.15}$$

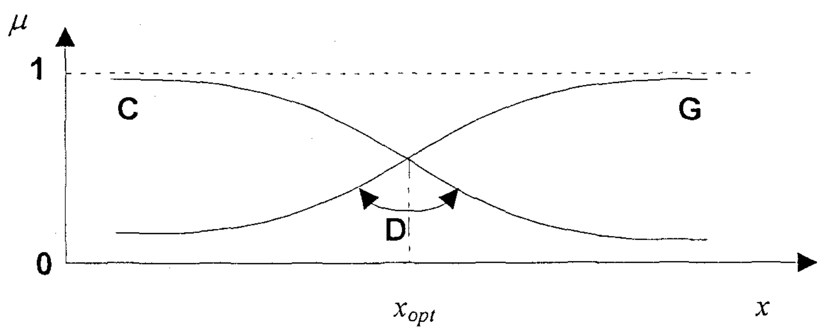


Figure 3.8 Fuzzy objective function, constraint and decision (Bojadziev, 1998)

Definition 8: (***Fuzzy Multi Objective Decision-Making***) Above formulas can be extended for decision-making problems with more goals and constraints. Assuming

G_1, G_2 and G_3 goals and C_1 and C_2 constraints, decision D can be defined as (Bojadziev, 1998);

$$D = G_1 \cap G_2 \cap G_3 \cap C_1 \cap C_2 \qquad (3.16)$$

With membership function

$$\mu_D(x) = min(\mu_{G1}(x), \mu_{G2}(x), \mu_{G3}(x), \mu_{C1}(x)\ \mu_{C2}(x)) \qquad (3.17)$$

Then, the optimal decision x is

$$X_{opt} = \{x|\ \mu_D(x) \text{ is max}\} \qquad (3.18)$$

Zimmerman (1976) used the max-min operator of Bellman and Zadeh (1970) for solving fuzzy mathematical programming problems.

A fuzzy multi objective mathematical problem with fuzzy objectives and fuzzy constraints can be denoted as follows;

$$\widetilde{\max}\ Z_k(x) \qquad k=1,\ldots,n \qquad (3.19)$$

$$\text{s.t.;} \sum_{j=1}^{n} a_{ij} x_j \lesssim b_i \qquad i=1,\ldots,m$$

$$x_j \geq 0 \qquad j=1,\ldots,r$$

The membership functions of the objectives and constraints are $\mu_k(x)$ and $\mu_i(x)$, respectively. Then the membership function of the fuzzy decision set, $\mu_D(x)$, is defined as;

$$\mu_D(x) = \mu_k(x) \wedge \mu_i(x) = min\{\mu_k(x), \mu_i(x)\}. \qquad (3.20)$$

To reach the optimal fuzzy decision, the decision, which is more favorable than others, should be found. Zimmerman (1976) defined the decision as;

$$\mu_D(x_{opt}) = max\,\mu_D(x) \quad , x \in D \qquad (3.21)$$

In summary, the fuzzy multi objective mathematical programming problem that has fuzzy objectives and fuzzy constraints can be represented in the following form;

$$\max \min \{\mu_k(x), \mu_i(x)\} \qquad k=1,\ldots,n\ ;\ i=1,\ldots,m \qquad (3.22)$$
$$\text{s.t. } x_j \geq 0 \qquad j=1,\ldots,r.$$

3.5 Fuzzy Ratings Method

Fuzzy rating and ranking method is used in a situation that does not allow a more structured decision approach. Such problems are usually characterized by the lack of objective and reliable information (Chen, 1996).

In the literature, this method has been successfully applied to the decision-making problems by Chen (1996) and Yaakob & Kawata (1997). The method is explained by Chen as the following:

Suppose a number of alternatives, which are denoted as $\mathbf{A_1, A_2,\ldots, A_m}$. The aspects that influence all the alternatives are identified as $\mathbf{a_1, a_2, \ldots, a_n}$. Then for a given **alternative** $\mathbf{A_i}$, a rating, denoted as $\mathbf{r_{ij}}$, assesses the relative merit of aspect $\mathbf{a_j}$. Furthermore, the relative importance of each aspect is assessed by a weighting coefficient say $\mathbf{w_j}$ for aspect $\mathbf{a_j}$. Then, the alternative $\mathbf{A_i}$ receives the weighted average rating;

$$\bar{r} = \frac{\sum_{j=1}^{n} w_j r_j}{w_j} \qquad (3.23)$$

In order to simplify the implementation, the weighted average will not consider the extended division. The revised form is given by;

$$\bar{r}_i = \sum_{j=1}^{n} w_j r_{ij} \qquad (3.24)$$

In this method, the ratings and weights are considered as fuzzy quantities and are characterized by appropriate linguistic variables and corresponding membership functions.

In the proposed fuzzy team formation model (given in Chapter 6) coefficients of the candidate team member Suitability Objective (Objective Function 1) is calculated by using the fuzzy ratings method.

In the Chapter 1 and Chapter 4, the importance of the skills of the candidate team members for the *team formation* is discussed. To reflect the skills of candidate team members to the *team formation* process fuzzy ratings method is used.

Firstly, the skills of the candidates are represented by linguistically. This kind of linguistic description can be best coded in fuzzy terms as mentioned in Section 3.3. Four levels are used: VG (very good), G (good), F (fair) and P (poor). Triangular membership functions that Karsak(2000) chosen are used for the calculations (shown in Figure 3.9)

As an example, 10 candidate team members are evaluated and each candidate team member is evaluated according to skills, which are listed below:

- Business Knowledge (BK)
- Communication Skills (CS)
- Auditing Skills (AS)
- Auditors Expertise (AE)

In Chapter 5, the selection of these skills will be discussed in detail.

Suppose that a QA team will be formed and a lead auditor, which is chosen by the quality agency, is responsible for the formation the team. The lead auditors describe the candidates by using the **Auditor Information and Evaluation Form** in **Appendix 2** and the fuzzy descriptions for the candidate team members are given in Table 3.1.

When forming a team, the lead auditor/ the project manager (the person responsible for the formation of the team) should specify the requirements of these skills. If the requirement for BK is (G), CS is (F), AS is (VG) and AE is (G), then the fuzzy rating calculated from the extended fuzzy number multiplication and summation is given in Table 3.2.

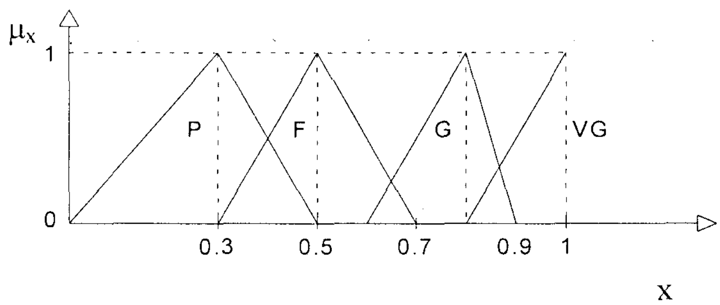


Figure 3.9. Membership functions of fuzzy numbers

Table 3.1. Fuzzy descriptions of the candidate team members

Candidate Auditors (cn=10)	*Business Know.*	*Comm. Skills*	*Auditing Skills*	*Auditing Expertise*
1	VG	F	G	F
2	G	VG	VG	VG
3	VG	G	P	F
4	P	VG	G	VG
5	F	F	VG	G
6	VG	F	G	VG
7	VG	VG	F	G
8	G	F	G	VG
9	VG	VG	F	F
10	G	P	G	G

The membership function of the fuzzy rating r_i can be calculated for each candidate team member using the weighted average Equation (3.24). The membership functions for the ratings are not triangular, but rather parabolic. However, a triangular approximation would be extremely close (Chen,1996).

Table 3.2. Fuzzy rating evaluation of the candidate team members for *Audit 1*

Candidate Auditor	r_i
1	G × VG + F × F + VG × G + G × F
2	G × G + F × VG + VG × VG + G × VG
3	G × VG + F × G + VG × P + G × F
4	G × P + F × VG + VG × G+ G × VG
5	G × F + F × F + VG × VG + G × G
6	G × VG + F × F + VG × G + G × VG
7	G × VG + F × VG + VG × F + G × G
8	G × G + F × F + VG × G + G × VG
9	G × VG + F × VG + VG × F + G × F
10	G × G + F × P + VG × G + G × G

After the evaluation, the membership functions for each candidate team member ratings are presented in triplets at Table 3.3. The approximate plot of the membership functions is given in Figure 3.10.

Table 3.3 Membership functions of the ratings

Rating	Membership function
r_1	(2.04, 2.25, 2.92)
r_2	(1.72, 2.94, 3.41)
r_3	(0.84, 1.9, 2.66)
r_4	(1.8, 2.34, 2.95)
r_5	(2.08, 2.29, 2.93)
r_6	(2.34, 2.65, 3.19)
r_7	(1.32, 2.44, 3.11)
r_8	(2.22, 2.49, 3.1)
r_9	(1.14, 2.2, 2.93)
r_{10}	(1.2, 2.23, 2.87)

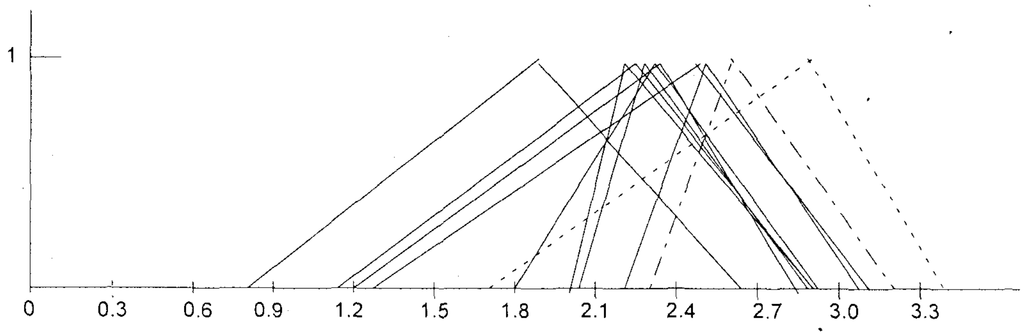


Figure 3.10 Approximate plot of the membership functions

The dashed line shows the membership function of the second candidate team member, which is ranked first in the evaluation. The dashed-dotted line is the membership function of the sixth candidate team member and ranked second. Second candidate team member is preferable to sixth candidate team member. This can be seen from the center values of their corresponding membership functions. According to Zadeh (1965) a triangular fuzzy number with center a may be seen as a fuzzy quantity **"*x* is approximately equal to *a*".**

Considering this, the center value of membership functions of each rating is used as suitability values for each candidate team members in the *fuzzy team formation* model. In Table 3.4 the suitability value for each candidate team members according to each team can be seen.

Table 3.4 Suitability value of each candidate team member according to each team

Candidate Auditor	C_{i1}	C_{i2}
1	2.25	1.89
2	2.94	2.7
3	1.9	1.64
4	2.34	2.29
5	2.29	2.1
6	2.65	2.39
7	2.44	2.2
8	2.49	2.29
9	2.2	1.9
10	2.23	1.99

3.6 Conclusions

FL is a technique for dealing with sources of impression and uncertainty that are non-statistical in nature (Zadeh 1965). FL seems to be most successful in two kinds of situations:

- Very complex models where understanding is strictly limited or, in fact, quite judgmental, and
- Processes where human reasoning, human perception or human decision-making are inextricably involved (Ross, 1995).

Team formation problem is one of these real-world problems, which involves processes where human reasoning and human decision-making are involved. This makes use of FL necessary.

The problem has many aspects. The **size of the team** and **the suitability of each team member** are considered as fuzzy objectives in the modeling procedure of the problem. The use **of linguistic variables** and the **fuzzy ratings method** are required in the solution of the *team formation* problem since expressing the skill levels of the team members and evaluating the candidates for the teams are difficult in precise mathematical terms. Other issues such as schedule and budget are formulated as crisp constraints. Finally, fuzzy ratings method is used to calculate the coefficients of the fuzzy objective and fuzzy decision-making is used to solve the developed model.

CHAPTER 4

TEAM FORMATION

4.1 Introduction

In this chapter, the basics of teams, teamwork and the types of teams will be introduced. Following this part, the terms "team building" and "team development", which are generally confused with "*the team formation*", will be introduced. Finally, *the team formation* problem and its importance to the team success will be discussed.

4.2 Teams and Teamwork

4.2.1 Teams

Current scholarly research defines **a team** as: "a small number of people with complementary skills who are committed to a common purpose, set of performance goals, and approach for which they hold themselves mutually accountable" (Katzenbach and Smith, 1993). In addition, similar definitions of the concept can be found in a number of research papers and books about the teams and the team building. In his book "Team Building" Dyer (1994) states that, "All teams represent a collection of people who must collaborate, to some degree to achieve common goals".

Salas et. al. (1992) suggest a definition of the team, which describes the basic characteristics of a team, too. "A distinguishable set of two or more people, who interact, dynamically, independently, and adaptively toward a common and valued goal/objective/mission, who have each been assigned specific roles or functions to perform, and who have limited lifespan and membership" (Salas et. al., 1992). Figure 4.1 schematizes the team basics that are discussed by Katzenbach and Smith (1993).

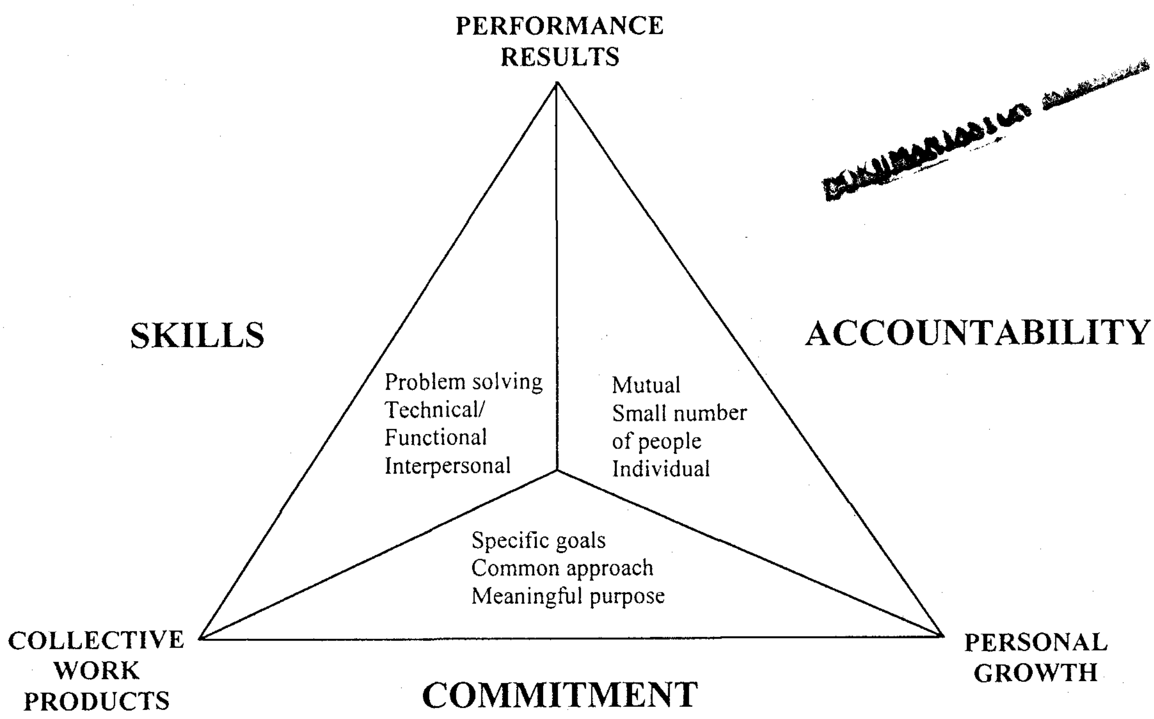


Figure 4.1 Team basics (Katzenbach and Smith, 1993)

Not every group of people working together forms a team and not every team has an effective teamwork. The main distinguishing property of a team from any group of people working together is the **"unity of purpose".** Different from a group of people, a team consists of team members who affect and depend on each other's performance to complete a task or to reach a common purpose.

The members of a group, who have the same purpose, can be more successful when they are working together. This shows that, the teams are **"synergetic work structures"**. The main idea here is that **"the whole is greater than the sum of the individual parts".**

4.2.2 Differences between the team and the group

Many writers (Smith, 2000; Blair, 1991) use the terms **"group"** and **"team"** interchangeably. However, there are major distinctions between a group and a team. Katzenbach and Smith (1993) summarize the difference between them in Table 4.1.

Table 4.1 Differences between the group and the team (Katzenbach and Smith, 1993)

Working group	*Team*
Strong, clearly focused leader	Shared leadership
Individual accountability	Individual and mutual accountability
The group's purpose is the same as the broader organization mission	Specific team purpose that the team itself delivers
Individual work products	Collective work-products
Runs efficient meetings	Encourages open-ended discussion and active problem–solving meetings
Measures its effectiveness indirectly by its influence on others	Measures performance directly by assessing collective work-products
Discusses, decides and delegates	Discusses, decides, and does real work together

Many attempts have been made by researchers to specify the characteristics of **"a team",** which make it different from **"a group".** These characteristics are;

- a definable membership,
- group consciousness,
- sense of shared purpose, vision, goals, direction,
- interdependence, structured relationship,
- interaction, communication,
- ability to act in a unitary manner.

However, the above discussion should not be interpreted that the groups are useless structures in business. Since, the performance that a group shows is enough for the completion of many tasks, many organizations still use the traditional groups.

Unlike the teams, the groups are not synergistic structures. That is, their performance is equal to the sum of the individual performances. On the other hand, teams are synergistic structures, which means that the team performance is greater than the sum of the individual performances. In summary, the teams show better performance compared to the groups. There are several reasons that explain the synergy and performance of the teams in organizations (Katzenbach and Smith, 1993).

- Teams bring together complementary skills and experiences that exceed those of any individual on the team.
- Teams develop clear goals and approaches and establish communications that support real-time problem solving.
- Teams are flexible and responsive to changing events and demands.
- Teams provide a unique social dimension that enhances the economic and administrative aspects of work.
- Teams have more fun.

The teams share authority, responsibility, decision-making, results and rewards (Stough et. al., 2000). This increases trust, collaboration and the quality of personal relationships between team members. Further, it makes every team member feel valuable and equal. This in turn results in effective teamwork.

4.2.3 Teamwork and its importance

Teamwork is the vehicle for integrating information, technology, competence, and resources – starting with human (Kinlaw, 1991). Many organizations utilize the teamwork to increase the organizational performance by using the human knowledge and skills in a better and effective way. The teamwork encourages the team members to achieve the common goals. However, it never makes a team alone. Castka et. al. (2001) suggest seven principles for effective teamwork:

- Members respect and trust each other.
- Members protect and support each other.
- Members interact and communicate.
- Members share a common goal, vision.
- Members have strongly shared values and beliefs.
- Members subordinate their own objectives to those of the team.
- Members subscribe to "distributed" leadership.

Some specific skills and strategies required for effective teamwork can be summarized as follows:

- Effective communication
- Shared/Distributed Leadership
- Decision making and problem solving skills
- Conflict management

In summary, obtaining effective teamwork is not an easy task. In order to be effective, the teams should direct their efforts to accomplish the task and to get better at working with one another.

4.3 Types of Teams

Although all the teams have some common properties and functions, they have a variety of aspects. When the teams are examined more carefully, a classification according to their specific properties can be made. A basic classification of the teams, which is done in this manner by Ölçer (1999), is developed and illustrated at Table 4.2.

Table 4.2 A basic classification of the teams according to some properties

Teams According to	*Teams*	
Purpose and given task	Work Teams	Decision Teams
Time	Temporary Teams	Permanent Teams
Given authority	Work Teams	Self Directed Work Teams ▪ also called Autonomous Teams ▪ Semi-Autonomous Teams
Members role in the organization	Functional Teams	Cross-Functional Teams
Geographical location of the members	Work Teams	Virtual Work Teams

In the following section, the above classification will be introduced and each type of team will be examined in detail.

4.3.1 Teams according to the purpose and the given task

Teams can be classified as **"decision teams", "work teams"** and **"improvement teams"** according to their purpose and mission (Ölçer, 1999, Dereli and Baykasoğlu, 2003).

Decision teams

Decision teams primarily focus on giving large-scale decisions. These teams meet to make decisions to set goals, to develop strategies, to make the needed resource and human assignments, to prepare budget, to set schedules etc. Since these decisions affect many people within an organization, the quality and the accuracy of these decisions get very important. Management teams, committees and audit teams are type of decision teams.

Work teams

Organizations employ work teams to carry out certain activities in order to produce a certain product or service within the organization. Similar to the decision teams these teams also make decisions, but usually work related ones (Ölçer, 1999).

The members of work teams work together and physically cooperate their efforts to accomplish a given task. Production units in a factory or operating teams in a hospital are examples of this kind of teams (Dyer, 1994).

Improvement teams

Improvement teams facilitate to improve the current status of an organization.

4.3.2 Teams according to time

Teams can be classified into two groups as **"permanent teams"** and **"temporary teams"** when time constraint is taken into account.

Permanent teams

Permanent teams are traditional work teams that contain team members working together for a long time. These teams are usually **"self-directed"** which means that they have the authority to make decisions and to take and implement the task-related actions.

Temporary teams

Temporary teams focus on a single project within a given time and have many names like committees, task forces, work groups and project teams because of their common use (Dyer, 1994). The members of these teams come together for a short time to complete the given task/project. Due to the completion of the task, the team breaks up. These teams are generally consists employees from various departments in an organization which makes these teams cross-functional.

Temporary teams are usually constrained by time (Dyer, 1994). This constraint force the members to come together quickly, to make decisions and to take the needed actions within a short time to accomplish the specific goals.

Similar to other teams, temporary teams have a major task/mission, too. In order to complete the given task successfully, the team members must build a strong relationship depending on trust and mutuality. Team members must determine the needed methods to (Dyer, 1994);

- set goals,
- solve problems,

- make decisions,
- steadily control the task,
- complete the task,
- develop collaboration in the team,
- develop interpersonal communication and establish openness,
- manage team conflict effectively and support valuable discussion.

To achieve the given task within the given time, the team must understand the goals, plan the work and make the needed assignments. Besides, as Dyer (1994) pointed, the team members must spend enough time together and must be given adequate authority to get the work done (like permanent teams).

These teams need highly competent team members having the required technical, interpersonal and problem solving skills to complete the given task on time. For these teams, time is too limited for sharing competencies and taking relevant training. This makes *the team formation* a very important issue for temporary teams like project or new product development teams.

4.3.3 Teams according to the given authority

Self-directed teams

The concept of self-directed teams is growing among organizations. Self-directed work teams, also known as **self-managing teams**, represent a revolutionary approach to the way work is organized and performed (William, 2003). They act like work teams in many ways. However, as opposed to work teams, they also make the managerial work of the team.

Because of the changed role of the leadership, some call these teams as "**autonomous**" or "**semi-autonomous work teams**". Autonomous work teams do not have a formal leader. In these teams, the team members select their own leader, rotate leadership or without a leader, they work as a committee. However, in semi-autonomous work teams there is a formal leader. The team makes its own decisions and takes actions without the help of their leader. In self-directed teams, there is a different kind of leadership. Dyer (1994) mentions that organizations adopting self-directed teams are redefining the role of the formal leader in some combination of the following:

- The leader functions as a training resource to examine the work and give the needed training
- The leader arranges and coordinates the relations with other units and top management.
- The leader helps the team to deal with team problems, conflicts etc. like a consultant.
- The leader attends team meeting (sometimes attend only when invited) but only formally open the meeting.

Training is a critical factor for the self-directed teams. Managing a self-directed team without required knowledge and experience is a difficult work. Without training, a self-directed team can easily fail. Therefore, members -forming such team- must be trained about basic management skills in addition to problem solving and decision-making skills.

4.3.4 Teams according to the member's role in the organization

Cross-functional teams

Nowadays many organizations see **the cross-functional teams** as a recipe to integrate their concurrent engineering efforts. Further, in the literature there is an increasing attention on cross-functional teams, which indicates that these teams are seen as the most suitable structures to the development and innovation. These teams are usually formed when the problem is very important and must be solved within a very short time through collaboration (Dyer, 1994).

Cross-functional teams include experts from various disciplines that come together for a limited time to work as a team to develop or improve a product or service or to advise on a specific problem. Members of these teams can be involved in more than one cross-functional team. These teams encourage problem solving and brainstorming for complicated tasks since they allow experts from different disciplines to exchange information and interaction.

In spite of their advantages, they face some problems as the following, which make cross-functional teams difficult to manage.

- Team members must spend enough time to learn working with each other.
- Team members' communication and coordination is difficult since every member has a different background, expertise and experience.
- Because of the limited working time, they have a stressful working condition.

Many organizations around the world that want to utilize this powerful structure like Toyota, Ford, Motorola etc. successfully adopt these teams by eliminating their disadvantages (Ölçer, 1999).

4.3.5 Teams according to the geographical location of the members

Virtual teams

The globalization of business generates a new challenge and opportunity for assembling teams who must collaborate closely even though they are separated by national boundaries, time and organizational barriers (Stough, 2000). The computer-mediated technologies help the formation of so called **"virtual teams"**. A **virtual team**– also known as **a Geographically Dispersed Team (GDT)** – is a group of individuals who work across time, space, and organizational boundaries with links strengthened by webs of communication technology. For example, a virtual team having members contributing from different places, at different times and from different organizations can be formed. In Figure 4.2., the differences between traditional teams and virtual teams can be seen.

Virtual teams consist of people who collaborate and communicate although they are geographically scattered. The idea behind the formation of these teams is to overcome the limitations of the traditional teams by using the global network, which are **space**, **time** and **organizational barriers**.

These teams use information technologies to overcome the before mentioned barriers. Virtual teams have some common characteristics, which are not found in traditional teams. Stough et al.(2000) summarize these characteristics as follows:

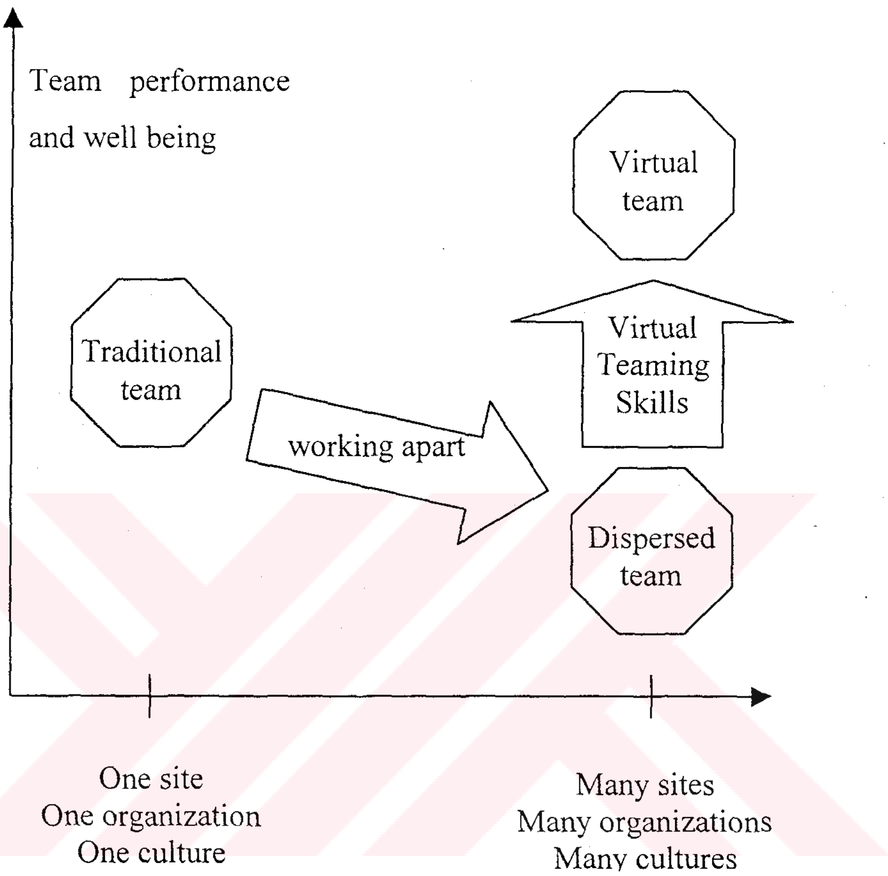


Figure 4.2 Differences between traditional, dispersed and virtual team (www.knowab.cu.uk/ wbw2c.html, 2003)

- **Transcendency:** Virtual teams transcend time, distance and organization size by communicating via computer conferencing systems, the Internet-based virtual meeting system and electronic meeting systems.
- **Infinity:** Virtual teams can have an infinite number of participants, because network technology and groupware enables share of information between participants from all over the world.
- **Anonymity:** Virtual teams enable the members to keep their participation anonymous. These teams can be designed to conceal the members or the whole team in order to overcome the security problems.

Having an empowered structure according to the traditional teams, the virtual teams are an innovative way of utilizing teamwork.

4.4 Size of Teams

What is the optimal size of a team? This is a challenging question since there are many different ideas on the size of a team. In order to form a team, at least two members should be brought together. In the literature, there is a range for the size of teams, which is between two and twenty-five people.

Katzenbach and Smith (1993) indicates that the team size differs according to meaningful purpose, specific performance goals, common approach, complementary skills and mutual accountability. Supporting this idea, Dyer (1994) points out that there is not an exact size for the number of members to be included in a team. Besides, he advocates that the team size is not a critical factor in determining a team. What Dyer (1994) advocates is true when all types of teams like sports teams are included. According to Dyer, "a team may be two people playing doubles in tennis, or a team may be players functioning alone, as on a golf team". However, when forming a work team; the team size gets an important factor that should be taken into account.

The team size directly affects the team effectiveness. A research conducted by DuPont indicates that when there are more than twelve to fourteen members in a team, quality and productivity of the team interactions start to fall seriously. Actually, as the team gets larger, problems about scheduling, attendance and participation begin to arise. Following, the interaction in between the team members and teamwork start to decrease. However, small teams also face some problems related to the team size. In the smaller teams, the problem solving ability is decreased due to the lack of adequate information and interaction.

A survey conducted among thirty-five companies about the effects of the team rewards on the team performance indicated that, the average size of the work teams is seven (McClurg, 2001). Besides, many authors (Katzenbach and Smith, 1993;

Scholtes et. al.., 1996; Ölçer, 1999) states that the ideal team size is in between five and seven.

4.5 Team Building & Team Development

Some authors (for example; Dyer, 1994) use the terms "**Team Building"** (TB) and "**Team Development"** (TD) interchangeably. This points out a general confusion about the usage of these terms in the literature. Kinlaw (1991) makes some useful distinctions between TB and TD, which can be seen in Table 4.3.

Table 4.3 Distinctions between team building and team development (Kinlaw, 1991)

Team building (TB)	*Team development (TD)*
Deficit focus on overall team performance	Focuses on positive opportunities for continuous improvement in performance
Short-term activity; emphasis on fixing immediate problems	Long-term activity; emphasis on setting up the system
Intense; usually varies from a few hours to a few days	Diffused and on going; a part of day-to-day processes of work
Typically targets problems in the relationships among team members	Targets creating and improving all the team's systems to insure they support sustained superior performance and continuous development

4.5.1 Team building

During their development, every team faces some common, immediate problems, which affects the team performance. These problems can be listed as follows;

- *Communication*: Effective communication is at the heart of effective teamwork (Smith, 2000). In order to be successful, the team leader and the team members must overcome communication problems that arise within a team.
- *Decision-making*: To overcome decision-making problems, every team must use a group of decision-making methods depending on the importance of the decision and the time given to make the decision. Smith (2000) offers seven methods for making decisions:

    - Decision by authority without discussion
    - Decision of an expert member
    - Average of members' opinion
    - Decision by authority after team discussion
    - Decision of an executive committee or a problem solving sub group
    - Decision by a Majority vote when at least 51 percent of the members decide on a specific idea
    - Consensus

- *Lack of discussion:* Every member of the team must contribute to discussion.
- *Open conflict:* Conflicts that arise within a team must be solved. There is no doubt that an unresolved conflict would give a great harm to a team. In case of conflict, teams can use five conflict strategies. These are;

    - Withdrawal
    - Forcing
    - Smoothing
    - Compromise
    - Confrontation

TB is an important set of interventions in the ongoing process of TD (Kinlaw, 1991). What TB activities focus on is solving these immediate problems within a short time. This activity generally takes place in team meetings and the approach of this meeting is "Nobody leaves until we fix the problem".

The activity starts with the determination of the problem and goes through some stages like data gathering, diagnosis, action planning, implementing and evaluating. Dyer (1994) defines these stages as **team-building cycle**. This cycle is illustrated in Figure 4.3.

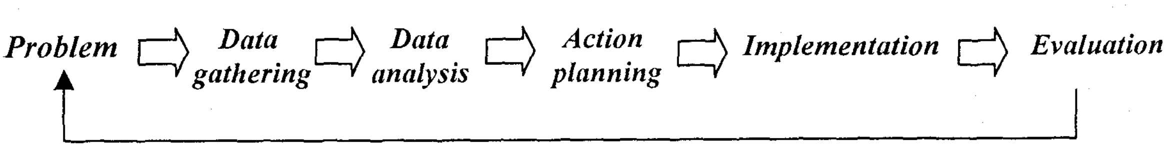


Figure 4.3 The team building cycle (Dyer, 1994)

The activity begins when a problem is recognized in the team. First, all the relevant data are gathered to determine the causes of the problem. From this collected data, a diagnosis is made to identify the causes of the problem. After the diagnosis, an action is planned to solve the problem. Finally, the plans are implemented and the results are evaluated.

4.5.2 Team development

TD activities do not work on fixing immediate problems. Rather these activities focus on positive opportunities, which can improve the team's performance in the long-term. Unlike TB, TD is an ongoing process of continuous improvement as the team moves from one step to another.

There are some TD models in the literature. But many researchers and authors see the Tuckman's **"FSNP model"** as a starting point for their work. As it can be seen from the Figure 4.4., the **Tuckman's model** has four stages, which he defined as **"form-storm-norm-perform".** Team is a living entity and it matures after these stages. Even if one of these stages is skipped, the team will not be successful.

- ***Forming:*** At this stage, the group comes together for the first time. Therefore, the team members try to know each other and the team. They are unsure of the task and the procedures. They try to learn how things work and they are eager to answer the leader's requests. Besides, they are usually shy to talk and to express their ideas.

- ***Storming:*** At this stage, the team members are more comfortable to express their ideas. However, little communication occurs since no one is listening to each other and some are unwilling to talk. As a result, conflict arises between the team members about the task and how to do it.

- ***Norming:*** At this stage, the team members start to listen each other. They realize that they must work together to accomplish the task and they utilize their skills to resolve the conflict and work as a team. They establish procedures for handling conflicts, decisions and methods to complete the given task.

- ***Performing:*** After passing these stages, the team achieves a harmony and starts to work efficiently. They define the task, establish the relationships and begin to produce results, which affects the task positively. During this stage, they work together to accomplish the given task.

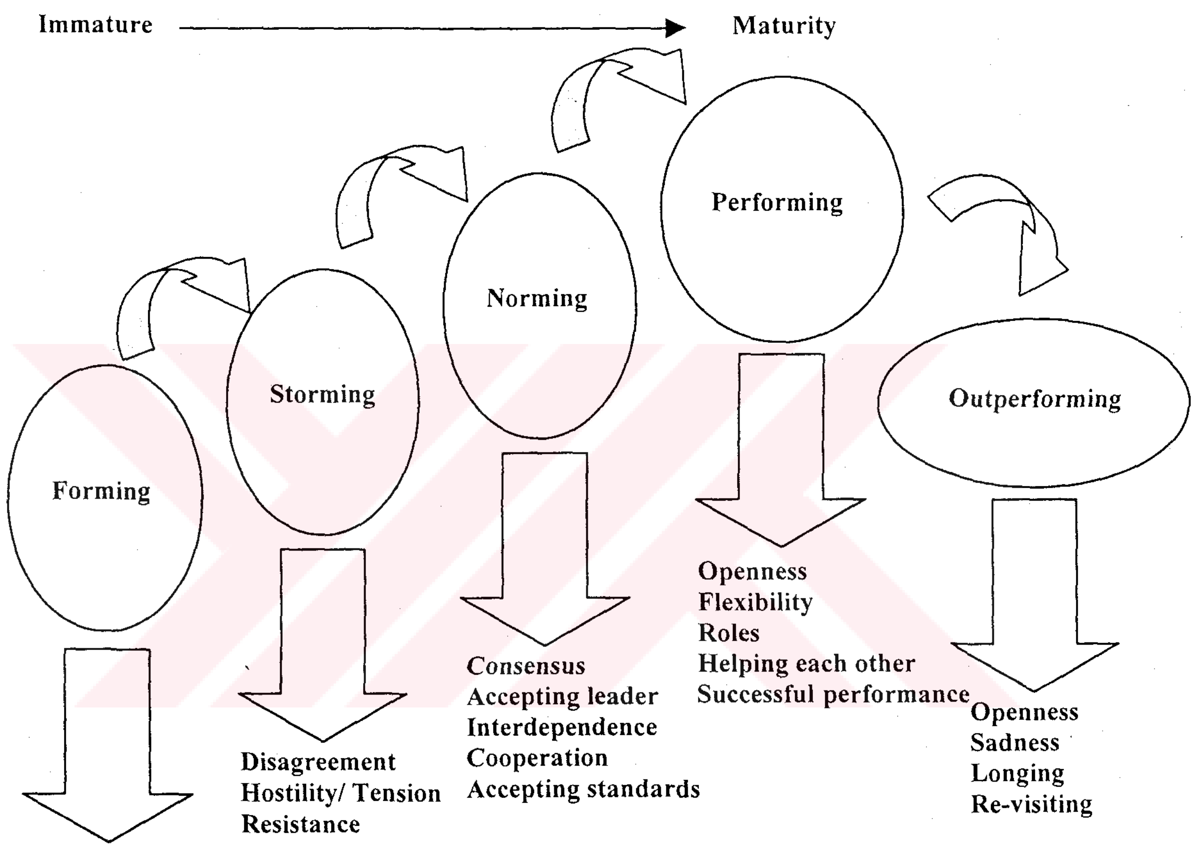


Figure 4.4 The team development model (Sommerville, 1998)

These stages are vital for the team's development since members learn to work together, manage conflict and contribute to the goals of the team.

Many authors advocate that a final step must be added to the Tuckman's model in order the model to reflect all the stages that a team goes through. This final step is ***Outperforming.*** At this stage, the work slows down and finally stops when the task is completed. The team dissolves. Although, the team members are happy that they have reached their goal, they are also anxious since the team is disbanding.

Another team development model in the literature is the Stott and Walker's **"multidimensional model".** What they propose in their model is that team development has more than one dimension. These dimensions are related to **"the individual, the task and the organization".** They propose that;

- Team development has a multidimensional construct in which the conditions in one dimension affect the conditions in other dimensions.
- For effective team development, the conditions of each dimension must be optimized.
- Each team must identify these dimensions and employ the appropriate development strategies. Performance is dependent upon accurate diagnosis.
- Responsibility for the team development should largely be in the team itself.
- Dimensional development is determined in part by the development level of the team.

Similar to Stott and Walker's model, Scholtes et. al. (1996) suggests a similar model named **"team development model".** In this model, he argues that for each dimension, there are three primary tasks: purpose, partnership and process. He states that the teams should consider this model as a framework for the team development. His model and the relationship in between primary tasks and dimensions can be seen from the Table 4.4.

Table 4.4 Scholtes's team development model (Castka et al., 2001)

		DIMENSIONS		
		Organization	**Team**	**Individual**
PRIMARY TASKS	Purpose (Why ?, What?)	Mission	Charter & Goals	Roles & Responsibilities
	Partnership (With Whom?)	Values & Beliefs	Norms & Communication channels	Interpersonal skills
	Process (How ?)	Management systems and reviews	Methods & Procedures	Problem solving & Planning skills

In general, teams start like the teams from hell and proceed to become dream teams. Katzenbach and Smith's (1993) work also supports this idea. They argue team development and team performance with **"the team performance curve"**. This curve (in Figure 4.5) shows, "how well any small group of people performs depend on the basic approach it takes and how efficiently it implements this approach" (Katzenbach and Smith, 1993).

When performance is taken into account, they define five types of teams on this curve.

- ***Working group:*** The curve starts from this point. Here, the group's performance is equal to the **"sum of individual performances".** The members of the team only share information, best practices and they help each other in decision making about the individual responsibilities. At this point, there are no collective work products. If high performance is wanted, this group should become a team.
- ***Pseudo-teams:*** These teams are the weakest teams in the curve. The performance of pseudo-teams is lower than a work group, since the performance is less than the **"sum of individual performances".** Although many people call them teams, pseudo-teams are not actual teams. Because, these teams do not focus on collective performance.

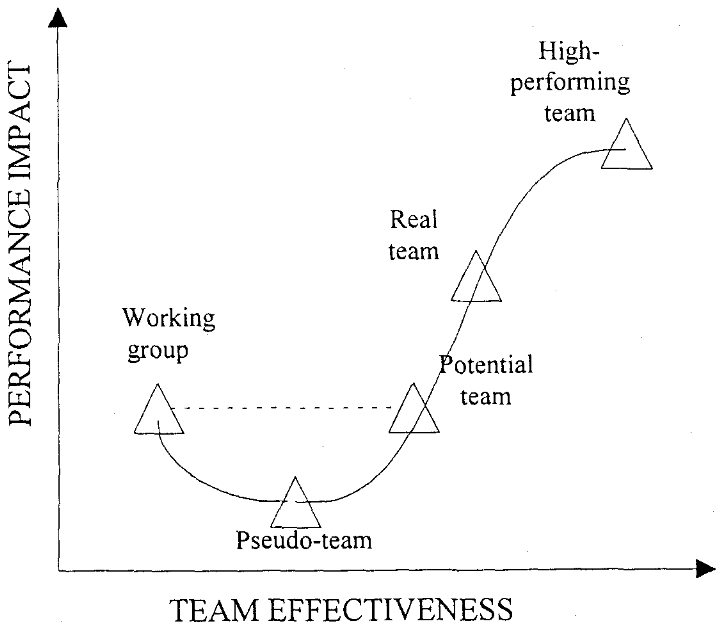


Figure 4.5 The team performance curve (Katzenbach and Smith, 1993)

- ***Potential teams:*** These teams start to climb the curve upward, despite of the above-mentioned obstacles. At this stage, the team tries to clearly define its goal, performance goals and its working approach. However, many teams get stuck during this process. **Performance, not team building, can save potential or pseudo-teams, no matter how they are stuck.**
- ***Real team:*** Potential teams must show a big performance jump to become real teams. Real teams are a basic unit of performance.
- ***High-performance team:*** If a real team *has members who are also deeply committed to one another's personal growth and success,* a high-performance team can be reached. High performance teams show a superior performance compared to all real and potential teams.

4.6 Team Formation

From the review of the literature and discussion in this chapter, one can easily figure out that *the team formation* – a different concept from TB and TD - is an important process that a team must go through and the organization should show great attention.

Team formation is forming the right team for a particular project/task. The problem is that how to organize/form teams that will successfully perform the arising task within the given deadline. As the task changes, mostly the members of the team can not handle the changes and fail.

Team formation can be also defined as combining the skills and properties of the team members with the functional requirements of each team in such a way that, the optimal teams for each task are formed. The illustration of this definition can be seen in Figure 4.6. In *team formation*, the aim is to enhance the quality of a newly formed team and to overcome the weaknesses in early stages, which cause disappointing team performance. This increases the importance of the formation process.

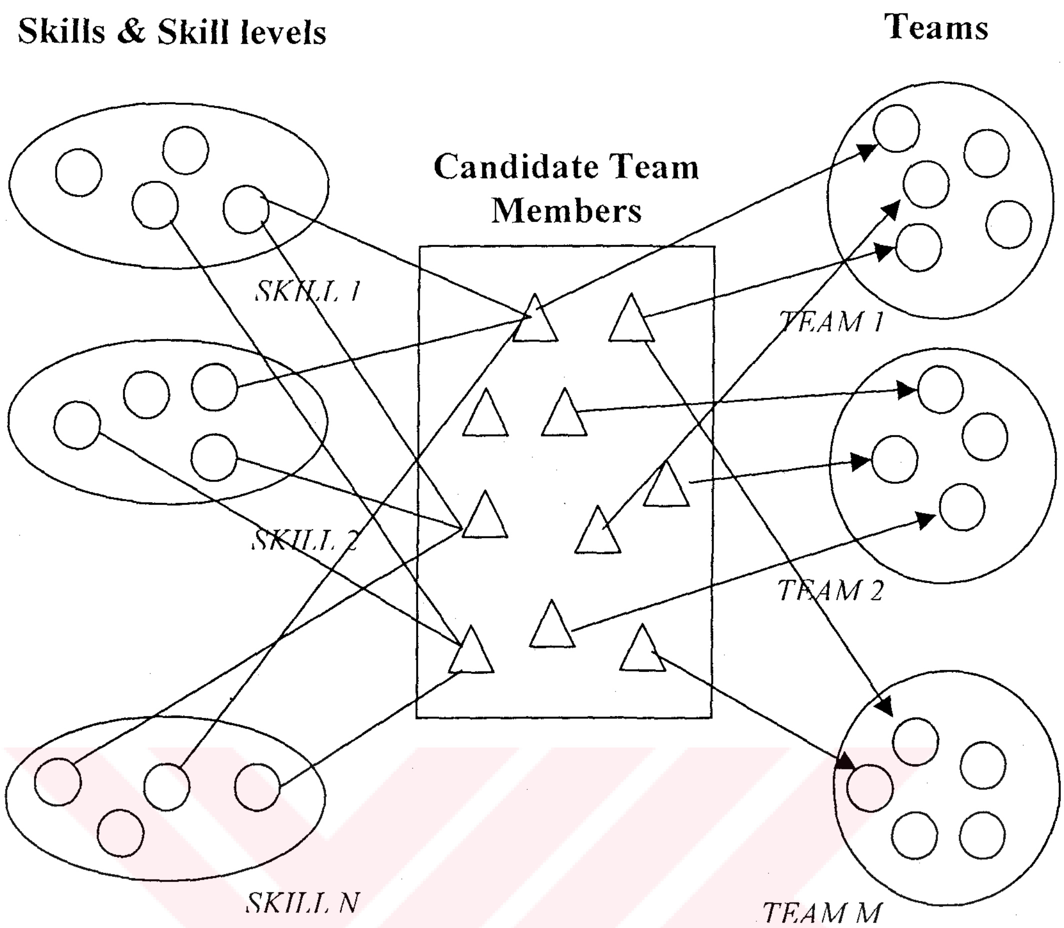


Figure 4.6 The illustration of the *team formation problem*

As stated before, *the team formation problem* has many different aspects. These aspects can be summarized as :

- Team's task
- Team size,
- Team members' knowledge and skills,
- Interpersonal relations in between the team members,
- Projects/Tasks deadline and
- Budget for an audit/project/task.

Most of the above factors concerning *the team formation problem* are discussed at the previous sections. However, some of these factors will be examined in this section due to their importance to the developed model.

4.6.1 Team members' knowledge and skills

Among the above-mentioned factors, probably the most important one is the team members' knowledge and skills. Common sense tells us that it is a mistake to ignore skills when forming a team. A team cannot get started without some minimum complement of skills, especially technical and functional ones (Katzenbach and Smith, 1993). This is why every team must have the right mix of skills for the completion of the task. These skills are:

- *Technical or functional expertise* that include professional knowledge related to a particular job,
- *Problem-solving and decision-making skills* that include problem solving ability, analytic thinking ability, knowledge of decision-making and seven basic quality control tools,
- *Interpersonal skills* that include active listening, conflict management, ability to conduct meetings, effective decision making, effective record keeping and effective communication.

Most project successes depend on the people involved in the project team (Katzenbach and Smith, 1993). Since effective teams show high performance, they positively affect the project/task and the organization. A research conducted by MIT (1999) about *the project team formation* supports this idea and points out that **team selection predicts team performance.** According to this research's findings, effective teams base member selection in technical and behavioral competence. Therefore, team selection should be made in the light of the project/task team's scope of work.

There is no doubt that without the required skills for an activity/project/task, no team can be successful. Thus, every team must have some minimum complement of skills, especially technical and functional ones.

4.6.2 Interpersonal relations in between team members

The interpersonal relationship among the team members is another important factor affecting *the team formation* process. Lack of effective communication and interpersonal relationships are barriers to effective and productive teamwork. To overcome these problems, the team members must establish open communication lines and interpersonal relationships. If this does not work, the team leader or the project manager can assign those people who cannot work together to different teams.

4.7 Conclusion

Teams and teamwork are vital for organizations that want to be successful in business life. If teams can be built by considering the requirements of the task and the organization, effectiveness of a team can be improved.

In this thesis, *team formation problem* is discussed and a model containing the aforementioned constraints like schedule, budget and interpersonal relationships in between team members etc. is developed.

CHAPTER 5

QUALITY CERTIFICATION AND AUDITING

5.1 Introduction

In this chapter, the information on quality and quality assurance, ISO 9000 standards and ISO certification is presented concisely. Following this introduction part, the types and the process of quality audit and the process of formation of a QA team are explained in detail.

5.2 Quality And Quality Assurance

The concept of quality standards and certifications can be traced back to history and has been around for a long time (Stamatis, 2003). Quality is a very subjective concept. It depends on many factors like customer satisfaction, product fitness, product price, etc. Due to this fact, there exist many definitions about the quality. Below, there are definitions and slogans from famous quality gurus and various researchers (Sentrong, 2000):

- Feigenbaum : "Quality is the degree to which a specific product conforms to a design or specification."
- Edwards : "Quality consists of the capacity to satisfy wants."
- Gilmore : "Quality is the degree to which a specific product or service satisfy the wants of a specific customer or client."
- Juran : "Quality is fitness for use."

- Oakland : "The core of quality approach is to identify and meet the requirements of both internal and external customers."

- Crosby : "Quality means conformance to requirements."

- Price : "Do it right the first time."

- Broh : "Quality is the degree of excellence at an acceptable price and the control of variability at a low cost."

Keeping the above definitions in mind, a complete definition of the quality would be **" The totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs."** (BS 4778, 1987)

ISO 8402-1994 defines **Quality Assurance** as: all the planned and systematic activities implemented within the quality system, and demonstrated as needed, to provide adequate confidence that an entity will fulfill requirements for quality (Gryna, 2002).

Quality Assurance is an overall system that aims to prevent quality deviations or poor quality products starting from the design of the product to the delivery of the product to final customers. Since having an ISO certification means reaching a desired level of quality in product life cycle, ISO 9000 standards are accepted as quality assurance standards.

There are many forms of Quality Assurance. Three forms of company-wide Quality Assurance are (Gryna, 2002):

- Quality audits
- Quality assessments and
- Product audit

The following sections will focus on quality audits.

5.3 ISO 9000 Series And Certification

5.3.1 ISO and ISO 9000 series

Meeting the needs of customers is the main objective of a Quality Management System such as ISO 9000. Success with such a program is usually attained with a systematic approach to Quality Assurance, including the elements of planning, organization, performance, and evaluation. Evaluation is often considered as the most beneficial element for ISO 9000 organizations because it reveals ways to further improvement of quality and incrementally increase customer satisfaction. Evaluation is facilitated by audits (http://www.foodagrosys.com/iso.htm, 2003).

Nowadays, many organizations implement an ISO 9000 standard to their system in order to;

- satisfy their customers requirements
- open up to new markets where ISO 9000 is required
- start quality efforts within the organization
- increase organizational competence

ISO is a synonym for **"International Organization of Standardization"** which is based in Geneva Switzerland. "*This organization is comprised of over 125 nations that have developed voluntary standards used worldwide in industry and manufacturing. Currently there are nearly 300,000 sites registered to ISO standards. ISO through loose Greek translation also means,* ***"equal"*** *In keeping with that skeletal translation ISO 9000 provides a "equal" platform for comparing how businesses establish, document and maintain a creditable quality systems.* " (Clause, 2003)

ISO 9000 is a quality management system subject to third party audit. It is defined as: **an operational guide outlining business goals and objects, then thoroughly documenting the procedures implemented to meet those goals and objectives.**

The ISO 9000 series consists of three quality assurance standards:

- ISO 9000: 2000 Quality Management Systems- Fundamentals and Vocabulary
- ISO 9001: 2000 Quality Management Systems- Requirements
- ISO 9004: 2000 Quality Management Systems- Guidance for Performance Improvement

ISO 9000 specifies requirements for a quality management system that can be used by an organization to address customer satisfaction, by meeting customer and applicable regulatory requirements. This standard discusses the underlying concepts, approaches and roles of key elements and provides definitions for the new vocabulary. ISO 9000 can be used by internal and external parties including certification bodies, **to assess the organization's ability to meet customer satisfaction and regulatory requirements.**

In all successful ISO quality management systems, eight guiding principles are highlighted;

- customer focus
- leadership
- involvement of people
- process approach
- system approach to management
- continual improvement
- factual approach to decision-making
- mutually beneficial supplier relationships

5.3.2 ISO Certification

Certification means the activities of establishing in writing that the product/service, laboratory, system or personnel comply with a certain standard or technical regulations. Further, **certificate** means the certificates showing compliance with standard and technical regulations, prepared by private or public laboratories and inspection and certification bodies authorized by competent public agencies and organizations on the basis of field of activity to issue certificates in compulsory areas within the framework of the relevant legislation (TURKAK, Accreditation law no: 4457, 19). Simply, **certification** is a procedure whereby a third party gives written assurance that a product/service, laboratory, system or personnel perform the specified requirements.

Accreditation has a different meaning when compared to the certification. The **accreditation** means the evaluation according to nationally and/or internationally recognized criteria, approval of competence and assessment at regular intervals of laboratories, inspection and certification bodies by the agency (TURKAK, Accreditation law no: 4457,19).

In Turkey, ISO certificates are issued by **Turkish Standards Institution (TSE)** and by private certification bodies. These organizations are accredited by national quality agencies as **TURKAK (Turkish Accreditation Agency)**. The relations between National Quality Agencies, Certification Bodies and the audited organization can be seen in Figure 5.1. Further, in Figure 5.2. National Quality Agencies are illustrated.

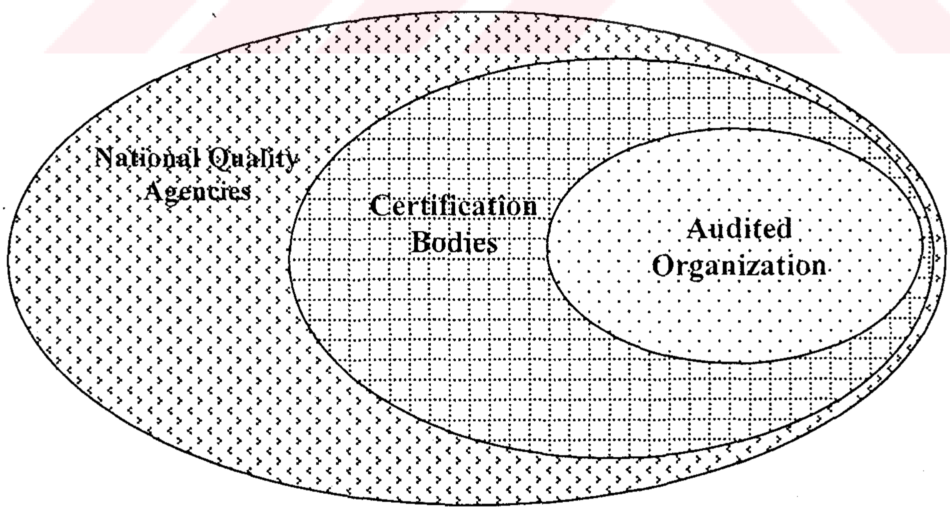


Figure 5.1. The hierarchy for the certification process

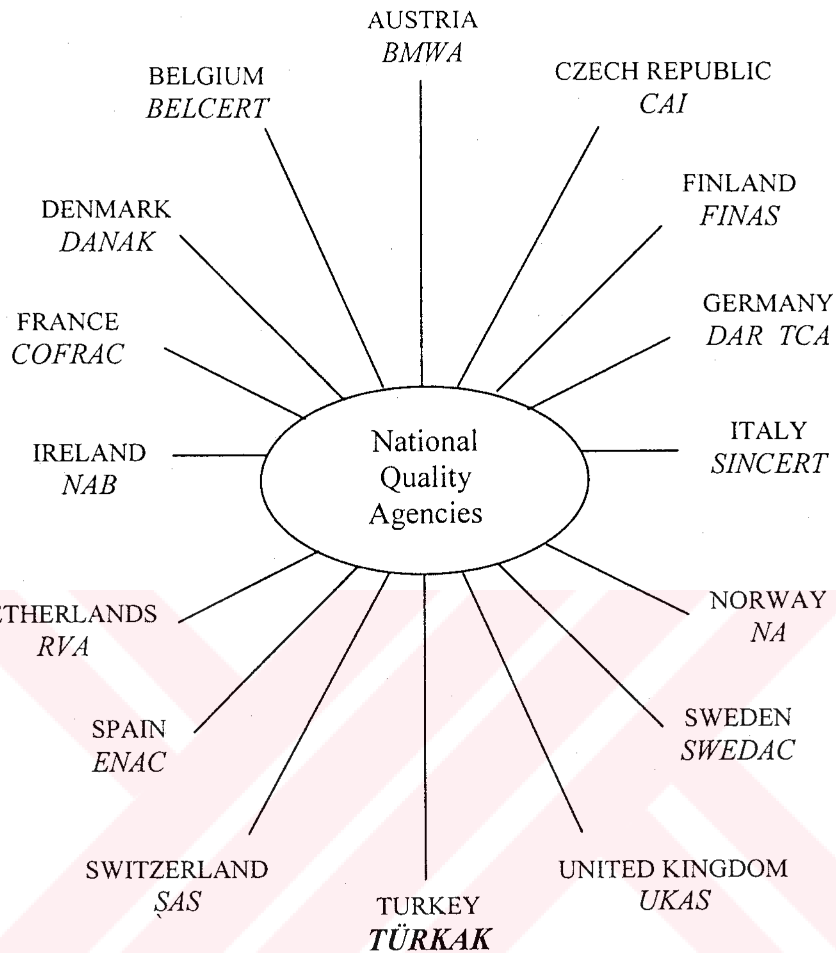


Figure 5.2. National Quality Agencies

There are three main steps in a typical certification process,

- pre-audit/ pre- assessment
- optional audit
- registration audit

The organization (the auditee / client) that applies for the certification should make a meeting with the certification body. In this meeting, the organization should inform the certification body about the standard against which the organization will be audited. If the organization can ensure that all the requirements for the certification are complete, the certification body will want the organization to present the relevant documents. Before having an ISO certification, the organization will need to develop and coordinate the appropriate documentation and procedures. There are four major documentation components (Clause, 2003):

- **Quality manual**: provides a description of the enterprise and an overview of the QMS structure
- **Procedure documents**: instructions for activities that effect quality. Defining who is responsible, when it is performed, where it occurs in the process
- **Working documents**: specific instruction for each quality related task, and may include blueprints, checklists, flowcharts etc.
- **Documentation controls**: specific regulations on handling records, forms, labels, orders etc.

The overall certification process can be seen in Figure 5.3.

If the certification body decides that the documentation and procedures are appropriate, the registration audit could be performed. Otherwise, the certification body will reject the certification application and will request the appropriate documentation and procedures for the next application. If the certification body verifies that the organizations quality systems meet the specific requirements, the organization will be ISO certificated.

On the other hand, if the certification body verifies that the organizations quality system fails to meet the specific requirements, the audited organization will be given enough time to take the needed actions. After this period, a re-audit will be performed. If the organizations quality system is found to be appropriate after the re-audit, the organization will be ISO certificated.

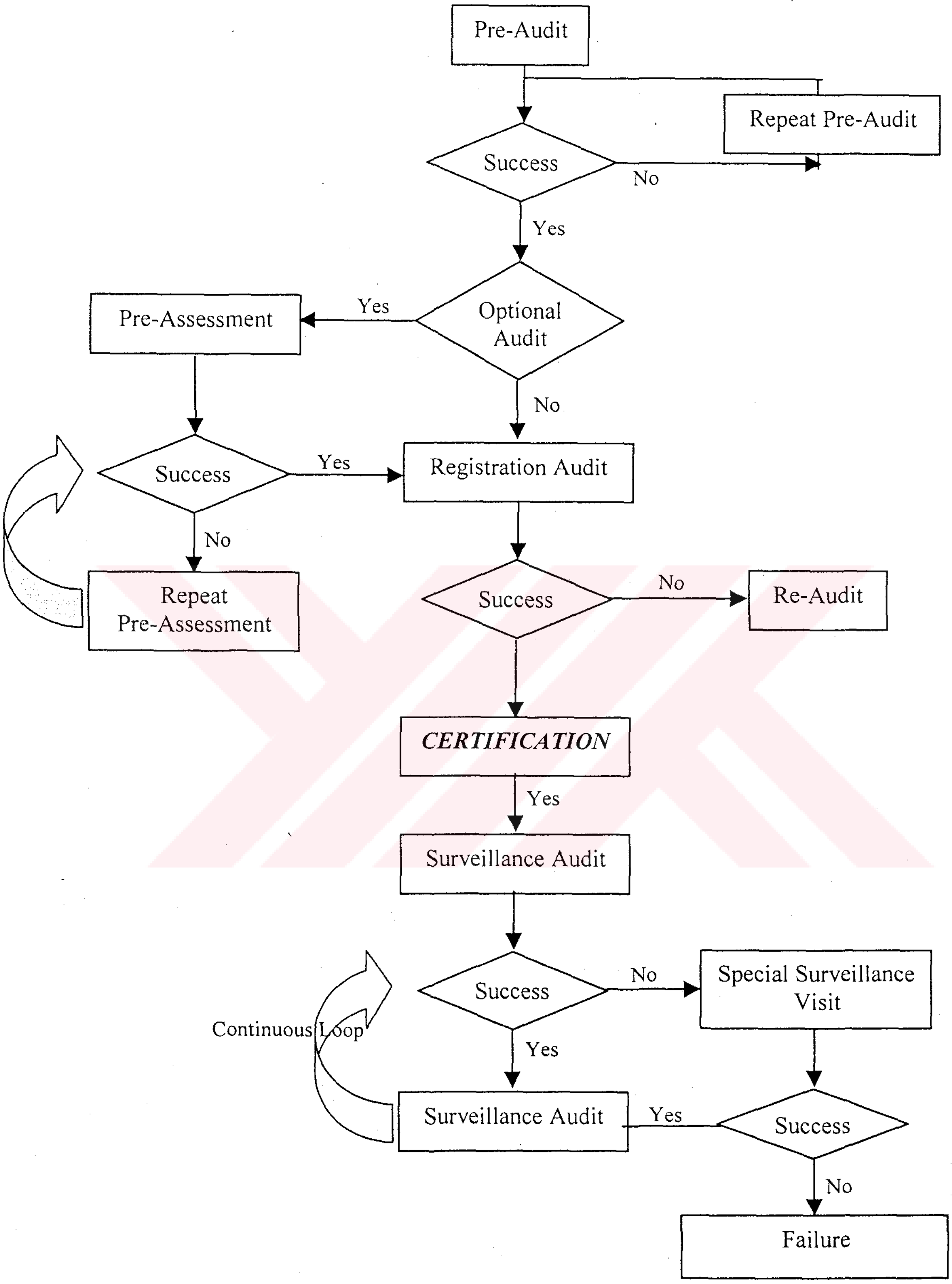


Figure 5.3. ISO certification process (Clause, 2003)

Before the registration audit, the certification body arranges a suitable date for the audit with the organization (auditee) and the relevant departments that will be audited. Moreover, the certification body should make *team formation* following the audit arrangement. When forming the QA team, the certification body should consider the required **auditor time** for an effective audit.

The **auditor time** is the amount of time required for the assessment of organizations of differing sizes and complexity over a broad spectrum of activities. The **auditor time** includes the time spent by an auditor or QA team in planning; interfacing with organization, personnel, records, documentation and processes; and report writing. The certification bodies should determine the auditor time in order to plan and schedule the audit. **International Accreditation Forum (IAF)** provides an **Auditor Time Chart (Appendix 1),** which shows the appropriate audit days for organizations with a given number of employees. However, this chart cannot be used in isolation since the size of an audit is affected by several factors like scope of the audit, logistics, complexity of the organization and its state of preparedness for audit.

5.4 Quality Audit

5.4.1 What is an audit?

A **Quality Audit (QA)** is an activity, which is carried out to assess or examine a product, the process used to produce the product or the system in which the production takes place. Besides, a quality audit aims to determine whether the subject of the audit is operating in compliance with the source documentation, or not.

ISO 11001-1992 defines QA as:

" A systematic and independent examination to determine whether quality activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives."

Figure 5.4. schematizes a typical audit process.

Cotterell (1999) describes the audit as follows;

An audit provides an independent and objective assessment of compliance with the defined system requirements.

The QA can be applied to a quality system or its specific elements in a limited manner. If the audit is applied to the whole quality system, it is called **Quality System Audit (QSA).** Types of quality audits are shown in Table 5.1.

Table 5.1. Types of quality audits

Applied element	Applied audit
To processes	Process Quality Audit
To products	Product Quality Audit
To services	Service Quality Audit

Quality System Audit

The objective of QSA is to assess an organization's own quality system. They try to address who, what, where, when and how of the organization's quality system used to produce its products. Further it is a *"documented activity performed to verify, by examination and evaluation of objective evidence, that applicable elements of the quality system are suitable and have been developed, documented an effectively implemented in accordance with specific requirements."*(ANSI/ASQC A3, 1987)

Process Audit

Process audits mainly focus on the validity and overall reliability of the processes that are brought together to produce a product. These audits have two main functions; *appraisal and analysis*.

For the first, the employee's work is audited in accordance with the company manufacturing process plans, the procedures, the work instructions etc. For the second, on the other hand, the procedures and the work instructions used in the process are being audited.

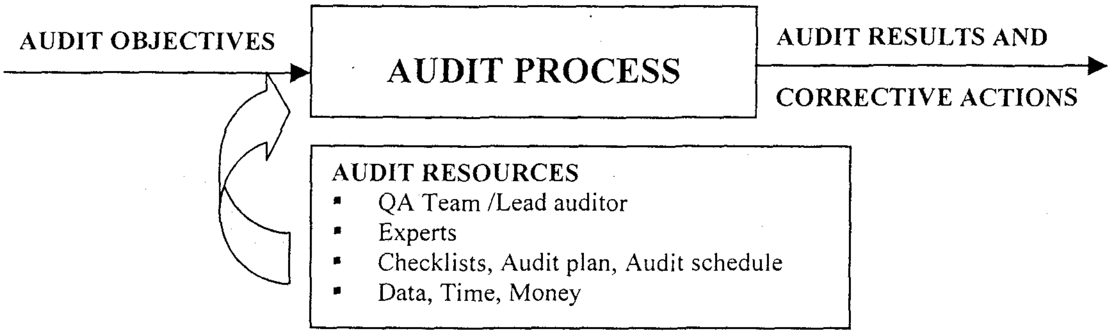


Figure 5.4. The schematic representation of a typical audit process

Product Audit

Product audit is the detailed inspection of a finished product before the delivery of the product to the customers. These audits mainly test the attributes of the product like physical appearance, dimensions, electrical properties etc.

They are generally accomplished for the following reasons (Baysinger, 2003);

- to estimate the outgoing quality level of the product or group of products,
- to ascertain if the outgoing product meets a predetermined standard level of quality for a product or product line,
- to estimate the level of quality originally submitted for inspection,
- to measure the ability of the quality control inspection function to make quality decisions,
- to determine the suitability of internal process controls.

5.4.2 Definitions for quality audits

ISO provides the definitions of the quality related terms, which are widely used in the ISO standards. Since, quality and quality auditing are discussed in this chapter, some useful definitions from **ISO 8402-1990** that are related to quality audits are presented below.

- **Auditor (quality) :** A person who has the qualifications to perform quality audits.
- **Client :** A person or an organization requesting the audit.
- **Auditee :** An organization to be audited.
- **Observation:** A statement of fact made during an audit and substantiated by objective evidence.
- **Objective evidence:** Qualitative or quantitative information, records or statements or fact pertaining to the quality of an item or service or to the existence and implementation of a quality system element, which is based on observation, measurement or test and which can be verified.

5.4.3 Audit objectives

The audits are generally designed for the purposes stated below:

- to determine the conformity or nonconformity of the quality system elements with specified requirements,
- to determine the effectiveness of the implemented quality system in meeting specific quality objectives,
- to give the organization / auditee an opportunity to improve the quality system,
- to meet regulatory requirements.

Besides there are reasons behind initiating an audit;

- to evaluate an organization's own quality system against a quality system standard,
- to evaluate a supplier where there is a desire to establish a contractual relationship,
- to verify that an organization's own quality system continues to meet specific requirements and is being implemented,
- to verify that the supplier's quality system continues to meet specific requirements and is being implemented.

5.4.4 Audit stages

Before planning an audit, the organization should make the final decision on which quality system elements, physical locations and organizational activities will be audited. While making this decision, the organization (client) should get assistance from the lead auditor. Main audit stages can be summarized as shown in Figure 5.5.

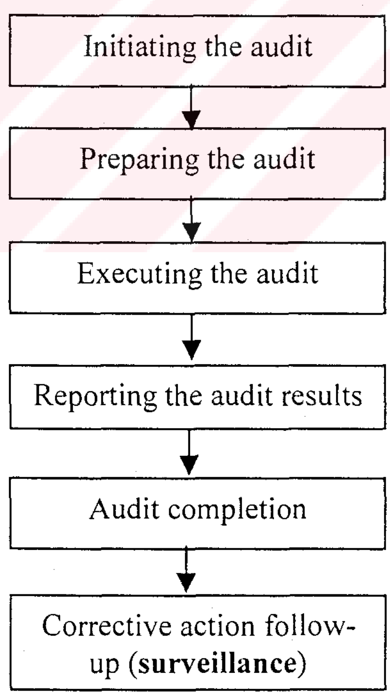


Figure 5.5 Main stages of a typical audit

A detailed flowchart of a typical audit can be seen in Figure 5.6.

Initiating the audit

At this stage, the scope and depth of the audit for meeting requirements of the organization should be carefully determined. Further, audit frequency should be determined.

When deciding on the audit frequency, *"significant changes in management, organization, policy, techniques or technologies that could affect the quality system, or changes to the system itself and the results of recent previous audits should be considered"* (ISO 10011-1, 1992).

Before planning the audit, the auditor should review the adequacy of the organization's records related to the quality system. If the auditor decides that the organization is not adequate to meet the requirements, the use of audit resources should be avoided. In this case, the audit should be carried when the organization is able to meet the requirements.

Preparing the audit

At this stage, an audit plan that is approved by both the auditors and the organization should be formed. The audit plan should be flexible enough to permit changes that occur during the audit. The plan should include (ISO 10011-1, 1992);

- the audit objectives and scope,
- identification of the individuals having significant direct responsibilities regarding the objectives and scope,
- identification of reference documents,
- identification of audit team members,
- the language of the audit,
- the date and the place where the audit is to be conducted,
- identification of the organizational units to be audited,
- the expected time and duration for each major audit activity,

- the schedule of meetings to be held with the audited organizations management,
- confidentiality requirements,
- audit report distribution and the expected date of issue.

The objections to the audit plan should be made known to the lead auditor. These objections should be solved between the lead auditor and the audited organization before the execution of the audit.

After the preparation of the audit plan, QA team assignments should be made. Each auditor should be assigned to a specific quality system element or to a functional department.

Finally, working documents, which the auditors will use must be designed. These documents include (ISO 10011-1, 1992);

- checklists used for evaluating quality system elements,
- forms for reporting audit observations,
- forms for documenting supporting evidence for conclusions reached by the auditors.

Executing the audit

The stage generally starts with the opening meeting. The purpose of this meeting is (ISO 10011-1, 1992);

- to introduce the members of the audit team to the audited organization's management
- to review the scope and the objectives of the audit
- to provide a short summary of the methods and procedures that will be used during the audit
- to establish the official communication links between the QA team and the audited organization

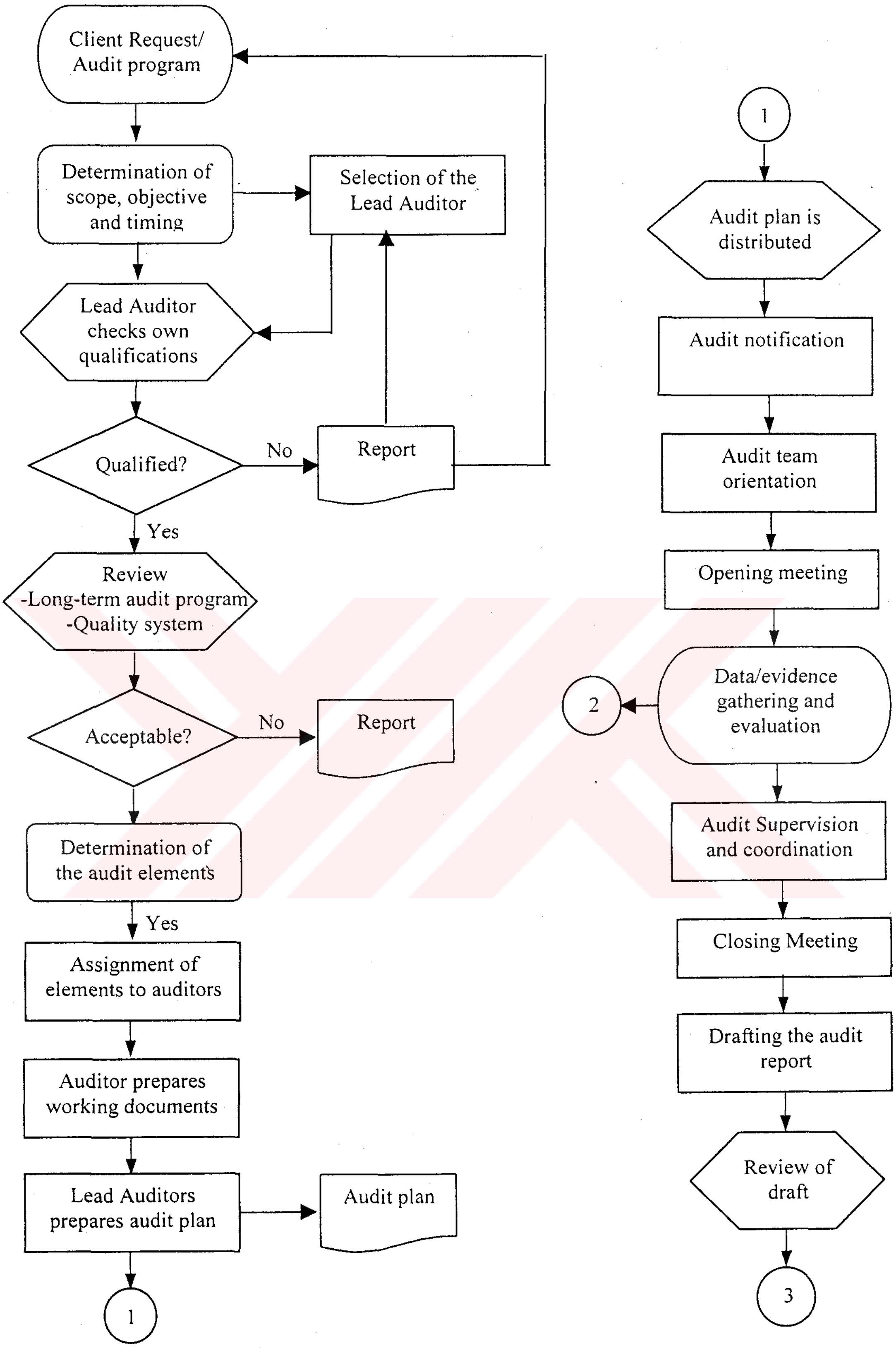


Figure 5.6. A detailed flowchart for a typical audit (Gryna, 2002)

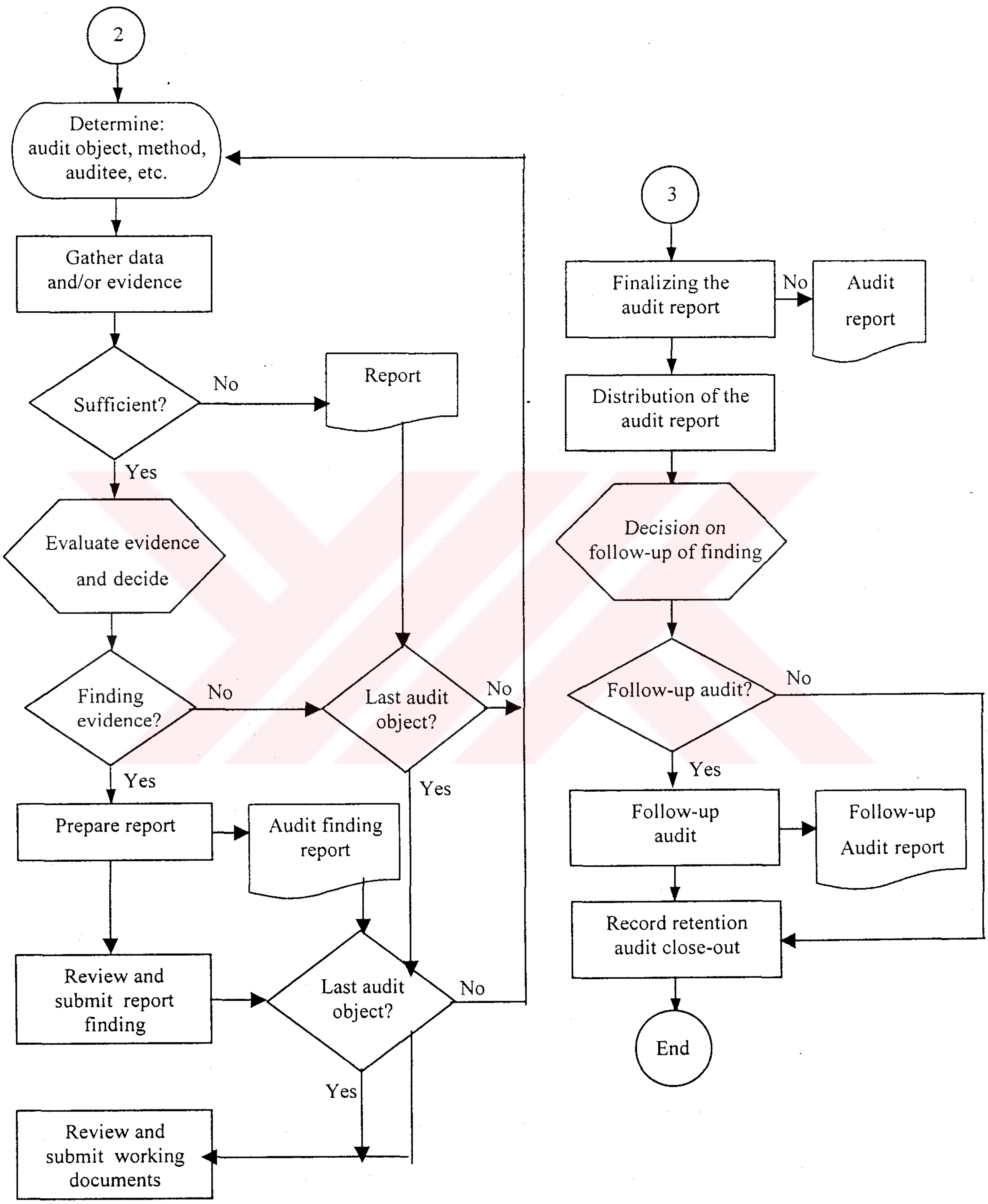


Figure 5.6. (cont.)

- to confirm that the resources and facilities needed by the QA team are available
- to confirm the date and time for closing meeting
- to clarify any unclear details of the audit plan

Following this opening meeting, the QA team should start the examination. During the examination, objective evidence should be collected through interviews, examination of the documents and observation of the activities and conditions. In this stage, all the audit observations should be documented. At the end of the examination, the QA team should discuss all the observations to determine the nonconformities, which should be clear and supported by evidence (ISO 10011-1, 1992).

At the end of the audit, the QA team should hold a closing meeting with the audited organization's management. The purpose of this meeting is to present the observations of the audit to the management. In the meeting, the lead auditor should present the audit observations and the QA team's conclusions about the quality system.

Reporting the audit results

The lead auditor should prepare the audit report. The audit report should reflect the content and the findings of the audit. It should be dated and signed by the lead auditor. The report should contain (ISO 10011-1, 1992);

- the scope and objectives of the audit
- details of the audit plan
- identification of the reference documents against which the audit was conducted
- observations of the nonconformities
- QA team's judgment of the extent of the audited organization's compliance with the applicable quality system standard and related documents
- the system's ability to achieve defined quality objectives
- the audit report distribution list.

The lead auditor should send this report to the management of the audited organization.

Audit completion

The audit is completed with the acceptance of the audit report by the audited organization.

Corrective action follow-up

Each auditor is responsible for determining and initiating corrective actions to correct nonconformity or the cause of the nonconformity found in an organization. The corrective actions and follow-up audits should be made within a period agreed by the audited organization and the auditor.

5.4.5 Types of audits

There are three basic QAs;

- First party or internal audits,
- Second party audits and
- Third party or external audits.

First party (internal) audits

These are the audits conducted by an organization upon itself by its own personnel. This type of audit is mainly directed at improving the management system, checking compliance of the organization's employee work practices, with procedures (Cotterell, 1999). Although they are subjective in nature, these audits should be recognized as effective management tools.

Second party audits

These are the audits conducted by a customer upon its suppliers to ascertain whether the supplier can meet the existing contractual requirements or not. Obviously, the supplier's quality system is a very important part of contractual requirements since it is directly

T.C. YÜKSEKÖĞRETİM KURULU
DOKÜMANTASYON MERKEZİ

(manufacturing, engineering, purchasing, quality control, etc.) and indirectly (marketing, inside and outside sales, etc.) responsible for the design, production, control and continued supportability of the product (Baysinger, 2003).

Third party (external) audits

These are the audits conducted for certification purposes, usually by certification bodies. It is an assessment of an organization's own quality system conducted by an independent, outside team of auditors. Compared to the first and the second party audits they are objective since the auditors are independent.

5.4.6 Auditors

Quality auditors are the most important quality professionals. They must have the best and most thorough knowledge of business, systems, developments, etc. They see what works, what does not work, strengths, weaknesses of standards, codes, procedures and systems (Baysinger, 2003).

Since quality auditing is an important task, auditors should be selected according to some criteria including an appropriate level of training, past experience, quality experience etc. These criteria can be seen in Figure 5.7.

Education: Auditor candidates should have completed at least secondary education (in Turkey high school education). Furthermore, they should have demonstrated competence in clearly and fluently expressing concepts and ideas both orally and written.

Training: Auditor candidates should have completed the training necessary to ensure their competence in the skills required to carry and manage audits. Training in the following areas are also required;

- knowledge and understanding of the standards against which quality system audits may be performed,

▪ assessment techniques of examining, questioning, evaluating and reporting,
▪ additional skills required for managing an audit such as planning, organizing, communicating and directing.

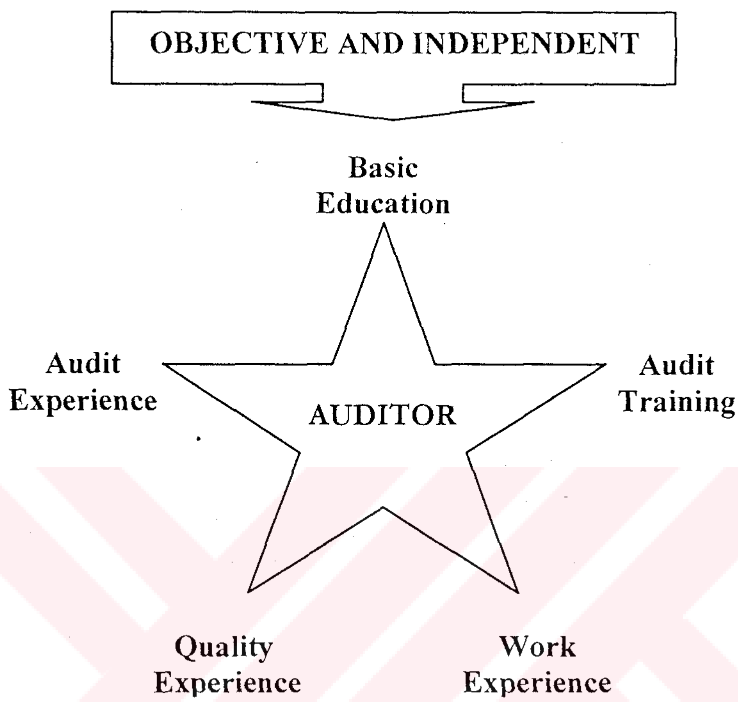


Figure 5.7. The basic properties of an auditor

Experience: Auditor candidates should have a minimum of four years' full time appropriate practical workplace experience, at least two years of which should have been in quality assurance activities (ISO 10011-2, 1992). Before working as an auditor, the candidate should have gained experience in the entire audit process (participation to minimum four audits, for a total of at least 20 days, including documentation review, actual audit activities and audit reporting) (ISO 10011-2, 1992).

Apart from the minimum requirements that are needed for an auditor, there are also some additional requirements. **ISO 10011-2 (Qualification Criteria For Quality Systems Auditing)** points out some guidelines for the auditors. These additional requirements can be listed as;

Personal Attributes: Auditor candidates should;

- be open-minded and mature
- possess sound judgment, analytic skills and tenacity
- have the ability to perceive situations in a realistic way
- understand complex operations from a broad perspective
- understand the role of individual units within the overall organization

The auditor should be able to apply these attributes in order to;

- obtain and assess objective evidence fairly,
- remain true to the purpose of the audit without fear or favor,
- evaluate constantly the effects of audit observations and personal interactions during an audit,
- treat concerned personnel in a way that will best achieve the audit purpose,
- react with sensitivity to the national conventions of the country in which the audit is performed,
- perform the audit process without deviating due to distractions,
- commit full attention and support to the audit process,
- react effectively in stressful situations,
- arrive at generally acceptable conclusions based on audit observations,
- remain true to a conclusion despite pressure to change that is not based on evidence.

Management Capabilities: The auditors should show that their knowledge and capability of using the necessary management skills is full.

Language: An auditor should not participate in an unsupported audit where he/ she could not fluently understand the language of the audit. Support in these kinds of audits could be provided by a person with the necessary technical language skills, who is not subject to pressures that could affect the performance of the audit.

American Society for Quality (ASQ) considers the following factors, which are quiet similar to ISO guidelines, when selecting auditors/ lead auditors for a particular assignment.

- The type of quality system standard against which the audit is to be conducted (for example, manufacturing, computer software, or service standards),
- The type of product or service and its associated regulatory requirements (for example, health care, insurance),
- The need for professional qualifications or technical expertise in a particular discipline, the size and the composition of the QA team, the need for skill in managing the team, and the ability to make effective use of the skills of the various QA teams.
- The personal skill needed to deal with particular client (audited organization), the required language skills, the absence of any conflict of interest, and other relevant factors.

5.4.7 The auditor's ethical responsibility

Each auditor has some *ethical responsibilities*. In performing an audit, each auditor that has given responsibility must be **independent** and **objective**. The auditors should only consider the facts into the assessment of whether conformance exists between criteria and established programs. An auditor;

- should not audit before informing the responsible members of the audited organization about the audit time,
- should not accept gifts or entertainment of a nature or degree that might possibly prejudice the audit,
- should not pass the secret organizational information that belongs to the audited organization to anyone,
- should not discuss the audited organizations performance with the people who are presently being audited,

- should avoid making false, unsupported or misleading statements that tend to injure or discredit the audited organization's reputation,
- should act in an ethical manner .

5.4.8 Selection of the" Lead Auditor" and QA team

The lead auditor for an audit should be selected by audit program management, which is composed of qualified auditors. During the selection, the following additional criteria should be considered. The candidate;

- should have acted as a qualified auditor in at least three complete audits,
- should have demonstrated the capability to communicate effectively and use the given time correctly.

The audits are conducted by auditors or in other words by a QA team. The QA team is formed by the lead auditor. The lead auditor forms the QA team based on the competence of the auditors and the needs and the expectations of the organization that will be audited. ASQ describes the relationship between the QA team and the lead auditor as follows (Baysinger, 2003):

- The lead auditor (leader of the audit team) should serve as a supervisor and should always be willing to recognize good work and offer constructive criticism for improvement in performance.
- The lead auditor must demonstrate through actions how the QA team should act.
- The lead auditor should require the team to comply fully with the rules, regulations and customs of the organization under audit.
- The lead auditor must objectively resolve any (including personal ones) conflict that occurs between the audited organization and the QA team.

According to IAF, the QA team, formed in each case needs an understanding of the issues relating to the **size, complexity, field of activity and business considerations** of the organization being audited, and what factors, general to the sectors in which the organization operates, are essential to ensure that certificates issued are credible. Each QA team should have a general understanding and background in the field in which the certification body operates.

In document R 40.02 (Guidelines for lead auditors and auditors of the Quality Management System), TÜRKAK states that an auditor / technical expert should be selected to the audits according to their field of activity. The classification of the auditors / technical experts according to the field of activity is given in Table 5.2.

The QA team can vary in number according to the size of the organization being audited. However, the size of a QA team can be in between **2-4 members** including the lead auditor. If needed, a technical expert can also be included to the QA team. The lead auditor should consider the following when selecting the members of the QA team (Goestch and Davis, 2002);

Table 5.2. Field of activity for the auditors (TÜRKAK, 2001)

GROUP	FIELD OF ACTIVITY
A	Agriculture and fishery
	Nutrients, drink and tobacco
	Hotels and restaurants
B	Rubber and plastic products
	Metal products
	Basic metals and finished metal products
	Electrical and optical instruments
	Ship construction
	Repairment of vehicles, motorbikes,
	Production of other transportation vehicles (motorbike, bicycle etc.)
C	Paper and paper products
	Publishing companies

Table 5.2. (cont.)

C	Typography
D	Mining companies
	Concrete, cement, lime, stucco etc.
	Non-metal metallic products
	Construction
	Architecture and other engineering services
E	Wood and wood products
F	Textile and Textile products
	Leather and leather products
G	Production of coke and refined oil products
	Chemicals, chemical products and fibrous products
H	Electricity procurement
	Fuel gas procurement
I	Education
J	Public management
	Financial business: leasing
	Transportation, Storage
	Communication
-	Nuclear fuel
-	Drug
-	Machine and instrument
-	Production and research of air and space transportation vehicles
-	Unclassified production
-	Recycling
-	Gross and retail trade
-	Real-estate
-	Information technology
-	Engineering services
-	Other services
-	Health and social affairs
-	Other social services

- competence of candidate auditors,
- the type of the organization, processes, activities, or functions being audited,

- the number, language skills and expertise of the auditors,
- any potential conflict of interest between QA team members and the organization being audited,
- requirements of the audited organization, and of certification and accreditation bodies.

When forming the QA team, understanding the audited organization's needs is an important issue. A survey of auditors and the audited organizations in financial services industry has investigated five attributes of the audit and the auditor: **professionalism**, **business knowledge**, **risk perspective**, **audit planning** and **conduct**, and **reporting audit results** (Gryna, 2002). The results of the survey showed that the audited organizations pointed out that professionalism (objectivity, knowledge of the area being audited) is three times more important that auditors did. On the other hand, auditors pointed out that risk perspective (coverage of key areas, audit in sufficient detail) as three times more important that the audited organization.

In the light of the above discussion, it can be concluded that an auditor can be evaluated according some skills (Baştürk, 2002; Canikyan, 2002). These skills can be summarized as follows;

- **Business Knowledge (BK),** includes the knowledge about the type of the organization, processes, activities, or functions being audited.

- **Communication Skills (CS),** includes language, communication skills and the relevance of questions during the audit.

- **Auditing Skills (AS),** includes skills related to audit planning, conduct, reporting audit results, time management etc.

- **Expertise of the Auditors (EA),** includes competence and the experience of the auditor in the field of auditing.

5.5 Discussions and Conclusion

There is no doubt that, ISO 9000 adaptation and certification is an important process for many organizations. Although having an ISO certificate does not mean reaching total quality, efforts related to the ISO adaptation should be seen as a key that opens the door to total quality

As stated in section 5.3, organizations implement ISO 9000 for various purposes. In Turkey, the main reason beyond the certification is using ISO 9000 certificate as a tool to open up to new markets.

In Turkey, ISO 9000 certificates can be taken from national and foreign certification bodies. The most popular of these certification bodies is **TSE**. TSE gives certification services on eleven main points. These points serve the cities within its region. Each points forms an audit plan considering the suitable applications for the certification. After the formation of the audit plan, the most suitable lead auditors and the auditors that works in that region are assigned to the audits, which should be conducted according to the plan. Although the system works without any significant problem, TSE do not have a well-defined procedure for assigning auditors and forming QA teams.

In this thesis, an attempt is made to develop a model for the formation of a QA team.

CHAPTER 6

INTELLIGENT TEAM FORMATION FOR QUALITY CERTIFICATION AND APPLICATIONS

6.1 Introduction

In this chapter, the *team-formation problem* and the *fuzzy team formation model* is explained and applications of the model are presented. The model is applied to three different problems.

As explained before, the purpose of team formation is to form the right team for a particular task. The problem is to form teams according to the skill requirements and deadline of each task. Figure 6.1 demonstrates the definition of the problem for QA teams. In the figure, each box demonstrates an audit. In each box, the required skills and the levels of skill requirements are shown. Here, BK is the acronym for Business Knowledge, CS is the acronym for Communication Skills, AS is the acronym for Auditing Skills and EA is the acronym for Expertise of the Auditor.

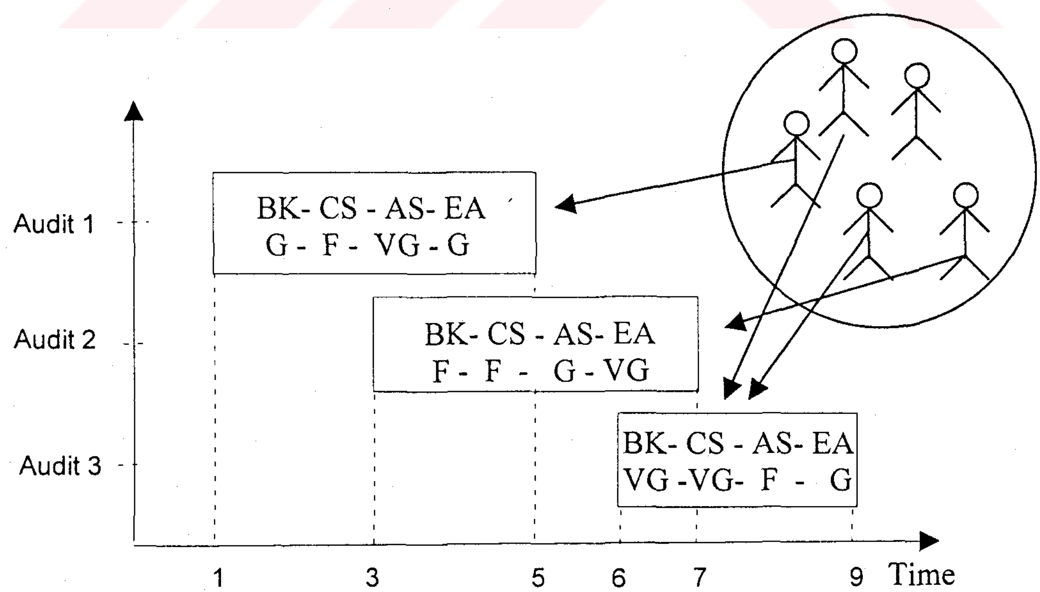


Figure 6.1 Demonstrated definition of the problem.

6.2 The Fuzzy Team Formation Model

The model developed for the *team formation* problems contains fuzzy objectives functions and hard-crisp constraints. The mathematical model for the *team formation* problem is as follows;

$$\widetilde{\max}\,\Omega \qquad \text{(Objective Function 1- Suitability Objective)} \tag{6.1}$$

$$\widetilde{\max}\,\beta \qquad \text{(Objective Function 2 - Team Size Objective)} \tag{6.2}$$

subject to

$$\sum_{i=1}^{cn} c_i x_{ij} \le p_j \qquad \forall j \tag{6.3}$$

$$\sum_{i=1}^{cn} x_{ij} < M \qquad \forall j \tag{6.4}$$

$$\sum_{i=1}^{cn} x_{ij} FT_j < ST_l \qquad \forall j,l \qquad j=1,\ldots,tn-1,\ \ l=j+1,\ldots,tn \tag{6.5}$$

$$\sum_{i=1}^{cn} st_i x_{ij} \le ST_j \qquad \forall j \tag{6.6}$$

$$\sum_{i=1}^{cn} FT_j x_{ij} \le ft_i \qquad \forall j \tag{6.7}$$

$$x_{kj} + x_{mj} < 2 \qquad \forall j,k \quad , \quad \forall m : m \in S_k \tag{6.8}$$

$$x_{ij} \in \{0,1\} \qquad \forall i,j \tag{6.9}$$

where

$$x_{ij} = \begin{cases} 1 & \text{If the candidate } i \text{ is assigned to team } j, \\ 0 & \text{otherwise,} \end{cases}$$

$$\Omega = \min\{\sigma\} \tag{6.10}$$

$$\beta = \min\{\gamma\} \tag{6.11}$$

$$\sigma = \{C_{ij} x_{ij}\} \qquad \forall i,j \qquad \begin{matrix} i=1,\ldots,cn \\ j=1,\ldots,tn \end{matrix} \tag{6.12}$$

$$\gamma = \left\{ \sum_{i=1}^{cn} x_{ij} \right\} \quad \forall j \qquad j=1,\dots,tn \tag{6.13}$$

$$\mu_\Omega = \begin{cases} 0 & \sigma < a \\ 1-(b-\sigma)/(b-a) & a \le \sigma < b \\ 1 & \sigma \ge b \end{cases} \tag{6.14}$$

$$\mu_\beta = \begin{cases} 1-(c-\gamma)/\alpha & c-\alpha \le \gamma < c \\ 1 & c \le \gamma \le d \\ 1-(\gamma-d)/t & d < \gamma \le d+t \\ 0 & \text{otherwise} \end{cases} \tag{6.15}$$

In the mathematical modeling of the *fuzzy team formation* problem the following notation is used:

cn: is the number of candidate team members that will be assigned to teams

tn: is the number of teams that will be formed

C_{ij}: is the skill suitability of candidate team member i to the team j

c_i: is the salary requirement of candidate team member i,

p_j: is the budget of the audit j (team j),

st_i: is the starting date of the available working time for the candidate team member i,

ft_i: is the finishing date of the available working time for the candidate team member i,

FT_j: is the due date of the audit j (team j)

ST_j: is the starting date of the audit j (team j)

Ω: is the minimum suitability value in the solution string

β: is the minimum team size value in the solution string

S_k: set of candidate team member k, which cannot work with candidate team member m

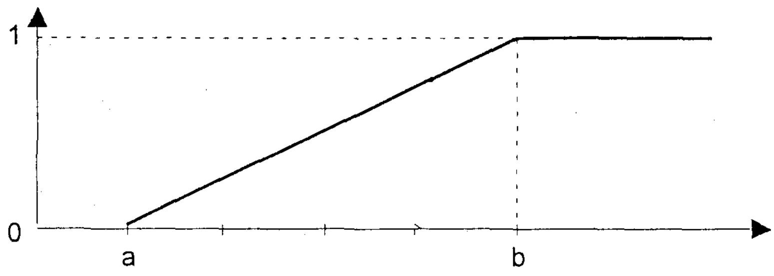


Figure 6.2 The membership function of the first objective function

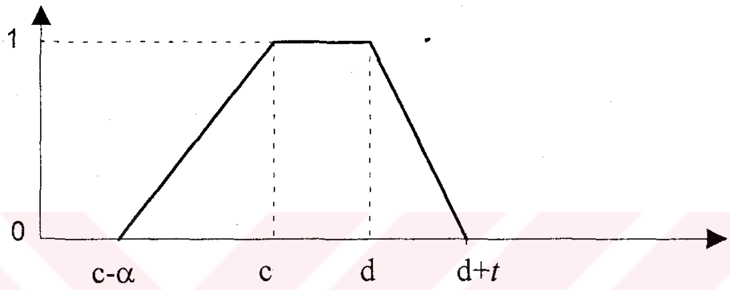


Figure 6.3 The membership function of the second objective function

In the above formulation, the Suitability Objective (the first fuzzy Objective Function) tries to maximize the suitability of the team members for each audit/task whereas the Team Size Objective (the second fuzzy Objective Function) tries to optimize the size of each team under the hard-crisp constraints. Here, Equation 6.14 and 6.15 are the membership functions of the Objective Function 1 and 2, (they are graphically illustrated in Figure 6.2 and Figure 6.3) respectively. The variables, which are used in Figure 6.2, Figure 6.3, Equation 6.14 and Equation 6.15; a, b, c, d, α and t are user defined values. For the solution, following values are used;

a=0.36,	d=7,
b=2.5,	α=4 and
c=5,	t=2.

Constraint set 6.3 ensures that the total salary requirements of the assigned candidate team members should not exceed the budget of each team. Constraint set 6.4 shows that a team member of a team could not work for more than a specified number (M) of teams. Here, the user determines the value of M according to the problem. Constraint set 6.5 is special to the problems, which includes the formation of a QA team. If there is an intersection in the schedules of the planned audits, this constraint ensures that an appropriate candidate doesn't assign to two overlapping audits. Because, an auditor cannot conduct two coinciding audits simultaneously. However, for the formation of other kind of teams such as a project team, this constraint should be ignored. Because, a member of a project team can work for more than one project.

Constraint sets 6.6 and 6.7 ensure the assignment of the candidate team members whose work schedule is suitable for the team. Finally, Constraint set 6.8 prevents the formation of an undesired team, which contains candidates team members k and m, which do not have good relationships with each other. This means that candidates k and m could not assigned to the same team. Again, the user determines the candidate team members, which should not assigned to the same team.

To efficiently solve the model, Simulated Annealing, which is a good heuristic technique is used for the solution. In Section 6.2.2, the SA algorithm is explained and in Section 6.3.2. the pseudo-code of the solution algorithm is presented. The algorithm is coded in C++ programming language.

For the solution of the *fuzzy team formation* model, Zimmerman's max (min) approach, which is presented in Section 3.4, is used.

In the *fuzzy team formation* problem, there are two fuzzy objectives and a set of hard constraints. To simplify the formulation, Suitability Objective is represented as OBJ_1 and Team Size Objective is denoted as OBJ_2. The membership function for the OBJ_1 is μ_{OBJ1} and for the OBJ_2 is μ_{OBJ2}. Then, according to Zimmerman's max (min) approach, the fuzzy decision D, which has membership function μ_D can be represented as follows;

$$\mu_D = \mu_{OBJ1} \wedge \mu_{OBJ2} = min\ \{\mu_{OBJ1}, \mu_{OBJ2}\}$$

To reach the optimal fuzzy decision, denoted as D*, the decision, which is more favorable than others, should be found. By using the Zimmerman's approach, the optimal decision can be as follows;

$$\mu_D^* = max\ \mu_D$$

In the light of the above explanations, the program works as follows:

The program generates a solution satisfying the hard constraints. Afterwards, the program finds the minimum suitability value (σ) of the team member in the solution string and calculates the membership value of the OBJ1 (μ_{OBJ1}) according to the Equation 6.13. Then, the algorithm finds the minimum team size (γ) in the solution string and calculates the membership value of the OBJ2 (μ_{OBJ2}) according to Equation 6.14. According to Zimmerman's approach, the minimum of these membership values is the decision at this step. This value can be accepted as the fitness value of the solution string. In the program, the fitness of the next neighborhood solution is checked and the maximum of these fitness values is selected. By accepting the maximum of these fitness values, the program tries to reach the optimal solution. Up to the maximum number of iteration, the cycle is terminated and the optimal decision is found.

6.3 Simulated Annealing Algorithm

Simulated annealing (SA) is a stochastic neighborhood search method that is developed for the combinatorial optimization problems (Baykasoğlu et.al., 2001). It is introduced by Kirkpatrick in 1982 as **"an analogy to the statistical mechanics of annealing in solids"** (Rutenbar, 1989). SA techniques use an analogous set of "controlled cooling" operations for nonphysical optimization problems, in effect transforming a poor, unordered solution into a highly optimized, desirable solution (Rutenbar, 1989). SA differs from iterative algorithm in that it doesn't stuck in local optimum but rather reach global optimum. SA does so, by accepting neighborhood solutions worse than current solution with a probability. This **acceptance probability** is related to the **temperature**, which decrease during the process. As the temperature decreases, the acceptance probability decreases too. This means that as the temperature decreases, the probability of accepting worse neighborhood solutions decreases.

6.3.1 Basic components of the SA algorithm

SA algorithm has some basic components. These components are as follows:

Configuration: This represents the possible problem solution, which is searched. A configuration in this study is represented as a matrix having the size ($cn \times tn$). Figure 6.4 represents a sample configuration with ten candidates and two teams.

1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0

Team 1 **Team 2**

Figure 6.4 Representation of the solution vector for the SA

Neighborhood move: In order to reach all feasible configurations, a move from the current solution to the neighborhood solution must be performed. In this study, a neighborhood solution is obtained by mutating (illustrated in Figure 6.5) the current solution. The procedure is as follows:

Step 1. Select a location in the configuration randomly.

Step 2. If the value in this location is equal to 1, change it to 0 or vice versa.

1	0	**1**	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0

1	0	**0**	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0

Figure 6.5 Neighborhood move

Objective Function: Objective function is used to measure how good a configuration is. As it can be seen from the proposed model, there exist two objective functions. Suitability Objective (OBJ1) tries to maximize the minimum suitability of candidate team member i in the configuration and Team Size Objective (OBJ2) tries to maximize the minimum team size. For this purpose, membership functions of these fuzzy objective functions μ_{OBJ1} *and* μ_{OBJ2} are calculated and the minimum of these values is accepted as the fitness (decision) of the solution string.

Cooling Schedule: to reach a good solution from a random or initial solution some parameters related to the annealing must be determined. For this purpose, a high starting temperature (T_{in}) and rules to determine when the current temperature should be lowered (length of the markov chain at each iteration - *LCM*), by how much the temperature should be lowered (rate of cooling - α) and when annealing should be terminated (maximum number of iterations - el_{max}) are needed. In this work, α is 0.987, el_{max} is 1000, and T_{in} is 1.000.000.

Acceptance of a solution: The neighborhood solution is accepted if the objective function (in this work fitness) improves, otherwise the solution is accepted with a probability depending on the temperature, which is set to allow the acceptance of a large proportion of generated solutions at the beginning (high temperature). Then, the temperature is modified (lowered) to decrease the probability of acceptance (Baykasoğlu et. al., 2001). Suppose that *i* and *j* are two solutions with objective function values f_i and f_j respectively. Then the neighborhood solution j is accepted according to the following acceptance probability:

$$P_{accept} = \begin{cases} 1 & \text{if } f_j \leq f_i \\ e^{-((f_j - f_i)/T)} & \text{if } f_j > f_i \end{cases} \qquad (6.16)$$

Termination: When the previously determined parameters are reached, the algorithm terminates (for example, maximum number of iterations, reaching the final temperature etc.). In this study, termination criteria is determined as the maximum number of iterations.

6.3.2 The SA algorithm for " *Fuzzy Team Formation*" problem

The pseudo code of the proposed SA algorithm for the *Fuzzy Team Formation* problem which is adopted from Baykasoğlu et. al. (2001) is as follows;

```
Step 1. Generate the initial solution (which satisfies the constraints). Calculate the fitness value fitness_0;
      solution= fitness_0;;
Step 2. Parameter initialization;
      2.1. Set the annealing parameters;
            T_in;   // Initial temperature //
            el_max; // maximum number of iterations //
            α;      // rate of cooling //
      2.2. Initialize the iteration counter;
            el=0;
Step 3. Annealing Schedule;
      3.1. Inner loop initialization;
            il=0;
      3.2. At every temperature achieve equilibrium. Execute inner loop until the condition in 3.2.5 is met;
            3.2.1. il=il+1;
            3.2.2. Generate a neighborhood solution (which satisfies the constraints). Calculate the fitness value fitness_il;
            3.2.3. ε= fitness_il - fitness_il-1;
            3.2.4. IF (ε<= 0) OR Random(0,1)<=e^(-ε/T_el)
                  THEN accept the new solution, Solution= objective_il;
                  ELSE reject the new solution;
                  Solution =fitness_il-1;
            3.2.5. IF (il>=2)
                  THEN terminate inner loop and GOTO step 3.3
                  ELSE continue inner loop and GOTO step 3.2.1
      3.3. el=el+1;
      3.4. T_el+1= α*T_el;
      3.5. IF (el>=el_max)
            THEN terminate inner loop and GOTO step 4
            ELSE continue inner loop and GOTO step 3.1
Step 4. Terminate the best solution, Solution and stop.
```

The algorithm starts working with the generation of an initial solution that satisfies the hard-constraints. The fitness of the initial solution is obtained by choosing the minimum of the membership values μ_{OBJ1} *and* μ_{OBJ2}. Later, a neighborhood solution is generated from the initial solution as explained in Section 6.3.1. After the calculation of the fitness of the neighborhood solution, the fitness values are compared. If the fitness value is found to improve ($\varepsilon \leq 0$), then the neighborhood solution is accepted as the current solution. Otherwise, the neighborhood solution is accepted with a probability or rejected. At every temperature, a determined number of neighborhood moves (il) are produced until equilibrium at this temperature is reached. Since, the acceptance probability is dependent on temperature, at high temperatures the probability of accepting the bad solution is higher. As the temperature decreases, the probability of accepting bad solution also decreases. When the algorithm reaches the maximum number of iterations (el_{max}), the algorithm stops. The optimal solution configuration and its fitness value are terminated.

6.3.3 Notes on the program developed

For the solution of the *fuzzy team formation* model, some inputs are needed. Firstly, the user must determine the desired number of teams that will be formed and input this information. In order the program to form teams, a data file about the candidate team members (auditors) must be formed. This database should include relevant data about the candidate team members such as their available working days, levels of their skills represented by linguistic variables and their salary requirements. Having this database, the user can determine the number of candidate team members, which is desired to include in the *team formation* process.

After entering the desired number of candidate team members and the desired number of teams, the user should enter the budget value for each audit. The index for candidate team members such as candidate team member k and m who don't have good relations should also entered. The value of the variable M, which shows the number of teams that a candidate can assigned should be entered. Finally, the levels of the required skills for each team should be entered in the form of linguistic variables.

The program matches the skills levels of the candidate team members with the levels of the required skills for each team and calculates the suitability coefficients for the Suitability Objective. The solution is reached under hard constraints by the proposed SA algorithm. Finally, the program gives the fitness of the solution and the configuration of the solution as output and stops.

6.4 Applications

In this section, some applications of the *team formation* problem for QA teams are presented. These applications are supplied to show how the program and the model work. As explained previously, in the model two fuzzy objective functions (Suitability Objective and Team Size Objective) and a set of hard constraints are employed and the fitness of the solution is obtained by the Zimmermann's max (min) approach.

6.4.1 Application 1

T.C. YÜKSEKÖĞRETİM KURULU DOKÜMANTASYON MERKEZİ

Suppose that, in a regional quality agency, there are seven auditors and two planned audits that should be conducted. The lead auditors are responsible for the formation of each team and candidate 1 and candidate 2 cannot work in the same team. The relevant data about the auditors and audits can be seen in Table 6.1 and Table 6.2.

Table 6.1 The data about the auditors

Candidate Auditors (cn=7)	*Business Know.*	*Comm. Skills*	*Auditing Skills*	*Auditing Expertise*	*Can work in between*	*Salary request per audit*
1	VG	F	G	F	1-10	160
2	G	VG	VG	VG	3-8	175
3	VG	G	P	F	1-6	148
4	P	VG	G	VG	2-8	200
5	F	F	VG	G	5-9	190
6	VG	F	G	VG	2-6	185
7	VG	VG	F	G	4-10	160

Table 6.2 The data about the audits

Audit (tn=2)	*Business Know.*	*Comm. Skills*	*Auditing Skills*	*Auditing Expertise*	*Should conducted in between*	*Audit cost*
1	G	F	VG	G	2-5	1000
2	F	F	G	VG	4-7	1000

When the *team formation* model is run, the algorithm forms the teams. Results are illustrated in Table 6.3. Here, the solution algorithm tries to maximize the fitness value of the solution, which is the intersection of the membership values of both fuzzy objective functions. As it can be seen from the results, candidate 1 and candidate 2 is assigned to different teams. Because, the lead auditor does not want these two people in the same team.

Further, the model doesn't assign an auditor to both teams. Since, as it can be seen from Table 6.2, there is an intersection in the audit schedules. This means that an auditor cannot be included in two overlapping audits at the same time. Since, an auditor could not conduct two audits simultaneously, each team should be composed of different team members. For this application, M value in the constraint that limits the assignment of a team member more than a specified number (M) of teams is chosen as one.

Table 6.3 Solution - the formed teams

Audit (tn=2)	*Formed teams*
1	1,3,6
2	2,4,7

Figure 6.6 shows the convergence of the obtained fitness values from the program. After 600 iterations, the fitness value converges to 0.5. In this application, membership function values of the objective functions and solution are as follows;

Objective Function 1 : 0.75
Objective Function 2 : 0.5
Solution : 0.5
Computational time : 25 min

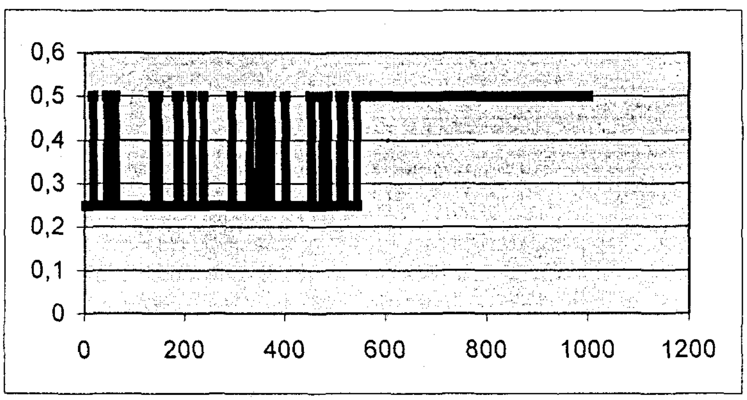


Figure 6.6 Convergence of the results

6.4.2 Application 2

In this example, there are three audits that should be conducted and eight candidate team members. The lead auditors are responsible for the formation of each team and candidate 1 and candidate 2 cannot work in the same team. The data about the auditors and the audits can be seen in Table 6.4 and Table 6.5 respectively.

Table 6.4 The data about the auditors

Candidate Auditors (cn=8)	*Business Know.*	*Comm. Skills*	*Auditing Skills*	*Auditing Expertise*	*Can work in between days*	*Salary request per audit*
1	VG	F	G	F	1-9	160
2	G	VG	VG	VG	2-8	175
3	VG	G	P	F	1-7	148
4	P	VG	G	VG	3-8	200
5	F	F	VG	G	4-6	190
6	VG	F	G	VG	1-12	185
7	VG	VG	F	G	5-10	160
8	G	F	G	VG	2-9	152

Table 6.5 The data about the audits

Audit (tn=3)	*Business Know.*	*Comm. Skills*	*Auditing Skills*	*Auditing Expertise*	*Should conducted in between days*	*Audi Cost*
1	G	F	VG	G	1-5	1000
2	F	F	G	VG	3-7	1000
3	VG	VG	F	G	6-9	1000

When the algorithm is run for the data that are illustrated in Table 6.4 and Table 6.5, the teams are formed as in Table 6.6. As it can be seen from the results, candidate 1 and candidate 2 is assigned to different teams. Because, the lead auditor again does not want these two people in the same team.

Similar to the previous example, the model doesn't assign a suitable auditor to more than one team although the schedule of the first and the third audit does not intersect. Because, M value in the constraint that limits the assignment of a team member more than a specified number (M) of teams, is again chosen as 1. This limits the assignment of a candidate to more than one team although it is possible. In this application, membership function values of the objective functions and solution are as follows;

Objective Function 1 : 0.92
Objective Function 2 : 0.25
Solution : 0.25
Computational Time : 155 min

Table 6.6 Solution-the formed teams

Audit (tn=3)	*Formed teams*
1	1,6
2	2,4
3	7,8

6.4.3 Application 3

The data for the application 3 is the same as application 2. However, the difference between these two examples is that application 2 is solved for (M=1) whereas application 3 is solved for (M=2). When the solution algorithm is run for (M=2), the teams are formed as in Table 6.7. In this application, membership function values of the objective functions and solution are as follows;

Objective Function 1 : 0.75
Objective Function 2 : 0.5
Solution : 0.5
Computational Time : 188 min

Table 6.7 Solution-the formed teams

Audit (tn=3)	Formed teams
1	1,3,6
2	2,4,8
3	1,6,7

In this application, the solution improves when compared to the application 2. In application 2, the value of M (M=1) restricts the assignment of suitable candidates to possible teams. However, in application 3, there is not such restriction. Since M=2 , suitable candidates are assigned to more than one team if the schedule of the team is satisfied.

6.5 Conclusion

In this section, the mathematical formulation of the model, the working principle of the solution algorithm, the data about the computer program and applications are presented.

The model provides satisfactory results and the program reaches optimal solution for each application. In Application 1 two teams, in Application 2 three teams and in Application 3 three teams are formed by the program.

CHAPTER 7

DISCUSSION AND CONCLUSIONS

7.1 Introduction

In this thesis, a *fuzzy model* for the *team formation* problem is proposed. Discussion and conclusions related to this study will be presented in this chapter. A future work for the researchers is also included.

7.2 Discussion

7.2.1 The need for the present work

There are only few works about *team formation* in the literature. The most outstanding study in this subject is Zakarian and Kusiak's (1999) *team formation* model. However, this study suggests a solution only for design teams. Similar to this work, Boon and Sierksma's (2003) model offers a solution for the formation of volleyball and soccer teams and de Korvin et. al.(2002) suggests a model for projects teams. In summary, in the literature there exists no general model for the *team formation problem*.

Besides, in spite of their wide use, none of the models in the literature provides a solution for the formation of quality related teams.

The scope of this work is to provide a general model for the solution of *team formation* problem and form **QA** teams of appropriate size and members (and other teams such as; project or decision teams) in an **intelligent** way.

7.2.2 The structure of the present work

As mentioned before, the *team formation* problem is a real-world problem, which contains subjectivity, imprecise information and vague human evaluations. Due to this fact, FL, which is an artificial intelligence tool, is employed.

For the solution, the coefficients of the Suitability Objective (Objective Function 1) are determined by using fuzzy ratings method, which is used in case of lack of objective and reliable information. Following this step, Team Size Objective (Objective Function 2) and crisp constraints sets are formed.

Different from the rest of the *team formation* models in the literature, the proposed model takes into account **team size** and some hard crisp constraints like the **budget of the formed team**, **schedule (time constraint)** and **interpersonal relationships** between team members.

Interpersonal relationships among team members are one of the important factors in *team formation.* In order to model this issue, team members who don't have good personal relationships assigned to different teams.

Besides, time constraints and salary requirements of the team members are considered when forming teams. Team size constraint is also taken into account, but due to their nature, **QA teams** are composed of maximum three team members.

A computer program in C++ programming language is developed to solve the fuzzy model using Simulated Annealing algorithm. The developed program is a flexible and intelligent program since the user can change the parameters of the SA algorithm and the *team formation* problem easily.

7.3 Contributions and Concluding Remarks

When compared to the other models in the literature, the *fuzzy team formation model* is a more intelligent and flexible model. The user (lead auditor, project manager etc.) can determine the number of teams, the number of skills that will be evaluated and the number of candidate team members easily. The model is able to construct good teams that have the appropriate size and team members. It should also be noted that there is not a published work on the literature on forming QA teams using analytical models like the one used in this research.

7.4 Future Works

The current *team formation* model is a detailed model, which reflects the different aspects of the problem. However, the model and the computer program employed for the solution can be improved. The computational time for the program can be reduced by employing effective annealing schedules and using better data structures. Moreover, the effects of the Simulated Annealing parameters can also be investigated further.

In the model, the triangular fuzzy numbers are used to represent the linguistic variables since it is easy to use triangular fuzzy numbers. The effects of using different types of fuzzy numbers like trapezoidal fuzzy numbers have not been considered in this study. However, the research on these effects is ongoing.

The influences of the soft factors like leadership, motivation, brainstorming and training to the *team formation* can also be included in the fuzzy model. Moreover, by an appropriate importance scale, these factors can be included in the model.

Besides, the model can be arranged and extended for the formation of other types of teams like sports teams.

APPENDIX 1. Auditor Time Chart

Number of Employees Note 1	Auditor Time for Initial Audit (auditor days) Notes 2+3	Additive and Subtractive Factors	Total Auditor Time
1-10	2		
11-25	3		
26–45	4		
46-65	5		
66-85	6		
86-125	7		
126-175	8		
176-275	9		
276-425	10		
426-625	11		
626-875	12		
876–1175	13		
1176–1550	14		
1551-2025	15		
2026-2675	16		
2676-3450	17		
3451-4350	18		
4351-5450	19		
5451-6800	20		
6801 –8500	21		
8501-10700	22		
> 10700	Follow progression above		

APPENDIX 2. Auditor Information and Evaluation Form

Photograph

AUDITOR INFORMATION AND EVALUATION FORM

1. PERSONAL INFORMATION

Name of the Auditor:		
Standard Knowledge:		
Date of Birth:		Place of Birth:
Male ( )	Female ( )	Citizenship:

Work Address:		
City:	Country:	Postal Code:
Tel:	E-mail:	

2. AUDIT INFORMATION: Please tick one box per topic.

	Poor	Fair	Good	Very Good
BUSINESS KNOW.				
COMMUNICATION SKILLS				
AUDITING SKILLS (audit planning and conduct, reporting audit results etc.)				
EXPERTISE				

Available Work Time:		
Day:	Month:	Year:
Salary Request:		

REFERENCES

ANSI/ASQC A3, (1987), Quality Management and Quality Assurance – Vocabulary

Atin, M. H., (1999), Bulanık doğrusal programlama, Ms. Thesis, İstanbul, Yıldız Technical University.

Baştürk, A., (2002), Special communication with the General Secretary of Turkish Accreditation Agency, Gaziantep.

Baykasoğlu, A., Gindy, N.N.Z., (2001), A simulated annealing algorithm for dynamic layout problem, *Computers and Operations Research,* **28**, 1403-1426

Baykasoglu, A., Gindy, N.N.Z., Cobb, R.C., (2001), Capability based formulation and solution of multiple objective cell formation problems using simulated annealing, *Integrated Manufacturing Systems: The International Journal of Manufacturing Technology Management*, **12-4**, 258-274

Baysinger, S.,(2003), *Characteristics of audits* http://www.qualityamerica.com/knowledgecente/articles/CQApg15-18.html

Bellman, R.E., Zadeh L.A., (1970), Decision-making in a fuzzy environment, *Management Science*, **17**, 141-164

Blair, G.M., (1991), Groups that work, *IEE Engineering Management Journal*, **1**/5, 219-223

Bojadziev, G., Bojadziev, M. (1998), *Fuzzy Sets and Fuzzy Logic applications: Advances in fuzzy systems-Applications and Theory*, 5, 209-227

Boon, B.H., Sierksma G., (2003), Team formation: Matching quality supply and quality demand, *European Journal of Operational Research*, **148**, 277-292

BS 4778 (1987), Quality – Vocabulary

Butterfield, J., Pendegraft, N., (1996), Gaming techniques to improve the team-formation process, *Team Performance Management*, **2/4**, 11-20

Canikyan, A., (2003), Special communication with the lead auditor of Moody's International Certification LTD, Gaziantep.

Castka, P., Bamber, C.J., Sharp, J.M., Belohoubek, P., (2001), Factors affecting successful implementation of High Performance Teams, *Team Performance Management*, **7**, 123-134

Chen, Y.H.(1996), Fuzzy ratings in mechanical engineering design-application to bearing selection, *Proc. Instn. Mech. Engrs.*, **210**, 49-53

Clark, N., (1994), *Team building*, McGraw-Hill Training Series, UK.

Clause, R., (2003), *Introduction to ISO 9000 & Quality Management systems when Quality counts in agriculture.*

Cotterell,A., (1999), *Management system auditing*, http://www.angelfire.com/nb/hazsub/AUDITING.html

Dereli, T., Baykasoglu, A., (2000), The Use of Artificial Intelligence Techniques in Design and Manufacturing: A Review, *Journal of Polytechnic*, **3(2),** 27-60.

Dereli, T., Baykasoğlu, A., (2003), Takım Yönetimi, *submitted to Kalder Forum*

De Korvin, A., Shipley, M.F., Kleyle, R., (2002), Utilizing fuzzy compatibility of skill sets for team selection in multi-phase projects, *Journal of Engineering and Technology Management*, **19**,307-319

Dubois, D., Prade, H., (1978), Operations on fuzzy numbers, *Int. J. Systems Sci.,* **9-6**, 613-626

Dyer, W.G. (1994), *Team building-Current issues and new alternatives*, Addison-Wesley Publishing Company

Goestch, D.L., Davis S.B.,(2002), *Understanding and implementing ISO 9000:2000*, Prentice Hall

Gryna, F. M., (2002), *Quality Planning and analysis*, McGraw-Hill

ISO 11001-1, (1992), Guidelines for auditing quality systems, Part 1 - Auditing

ISO 11001-2, (1992), Guidelines for auditing quality systems, Part 2 – Qualification Criteria for Quality Systems Auditors

ISO 11001-3, (1992), Guidelines for auditing quality systems, Part 3 – Management of Audit Programmes

ISO 8402-1986, Quality – Vocabulary.

Joy-Matthews, J., Gladstone, B., (2000), Extending the group: a strategy for virtual team formation, *Industrial and Commercial Training*, **32/1**, 24-29

Karapetrovic,S., Willborn, W., (2001), Audit system: concepts and practices, *Total Quality Management*, **12/1**, 13-28

Karsak, E.E., (2000), A Fuzzy Multiple Objective Programming approach for Personnel Selection, *IEEE*, 2007-2012.

Katzenbach, J.R., Smith, D.K. (1993) *The Wisdom of Teams: creating the high-performance organization*, New York, Harper Business.

Kaufmann, A., Gupta, M.M., (1985) *Introduction to Fuzzy Arithmetic: Theory and Applications,* Van Nostrand Reinhold, New York.

Kezsbom, D., (1995), Making a Team Work: Techniques for building successful cross-Functional teams, *Industrial Engineering*, January 39-41

Kinlaw, D.C. (1991), *Developing superior work teams*, San Diego, California, Lexington Books

Kirkpatrick, S., Gelatt, C.D., Vecchi, M.P., (1983) Optimization by Simulated Annealing, *Science*, **220,** number 4598, 671-680.

McClurg, L.N., (2001), Team Rewards: How far have we come?, *Human Resource Management*, Spring, 73-86

MIT Human Resource Practices Development Team (1999). *Evolution of the Report on Project Team Formation at MIT ,*(web.mit.edu/reeng/www/hrpd/reports)

Nair, R., Tambe, M., Marsella, S., (2002), Team formation for Reformation, *Proceedings of the AAAI Spring Symposium on Intelligent Distributed and Embedded Systems.* Stanford, CA.

Ölçer, F. (1999), *İşletmelerde takım çalışması ve Türkiye'deki sanayi işletmelerinde uygulanması üzerine bir araştırma,* Ph.D. Thesis, Adana, Çukurova University

Ross, T., (1995), *Fuzzy logic with engineering applications,* McGraw-Hill

Rutenbar, R.A.,(1989) , Simulated annealing algorithms: an overview, *IEEE circuits and devices magazine*, January, 19-26

Salas, E., Dickinson, T.L., Converse, S.A. and Tannenbaum, S.I (1992) Toward an understanding of team performance and training, in *team: their training and performance*, Swezey, W. and Salas E. (eds), Norwood, Ablex, NJ.

Scholtes, P.R., Joiner B.L., Streibel B.J. (1996), *The team handbook*, Madison, Joiner Associates

Smith, K.A., (2000), *Project management and Teamwork*, USA, McGraw-Hill

Soliman, F., Gide, E., (1998), Intelligent manufacturing management through 'Team Building',*Proceedings of 2nd International Symposium on Intelligent Manufacturing Systems*, August 6-7, 823-833, Sakarya University, Sakarya.

Sommerville, J., Dalziel, S., (1998), Project Teambuilding- the applicability of Belbin's team role self-perception inventory, *International Journal of Project Management*, **6/3**, 165-171

Stamatis, D.H., (2003), *Understanding ISO 9000 and implementing basics to quality,* http://courses.nus.edu.sg/course/socsja/Organizations/Org00-0/stamatisR.html

Stough, S., Eom, S., Buckenmyer, J., (2000), Virtual Teaming: a strategy for moving your organization into the new millennium, *Industrial Management & Data Systems*, **100/8**, 370-378.

Tambe, M., (1997), Towards flexible teamwork, *Journal of Artificial Intelligence Research*, **7**, 83-124

TURKAK (Turkish Accreditation Agency) Document R 40.02, (2001). *Guidelines for lead auditors and auditors of the Quality Management System*

TURKAK (Turkish Accreditation Agency), Accreditation law no: 4457, 19

Web, Understanding quality assurance concepts (2000), A health team training on quality assurance by Sentrong

Von Altrock, C., (1995), *Fuzzy Logic and Neuro-Fuzzy Applications Explained*, Prentice Hall, New Jersey.

William, R., (2003), *Self Directed Work Teams: A competitive advantage, web*

www.foodagrosys.com/iso.htm, (2003), *Quality management system auditing*

www.knowab.cu.uk/wbw2c.html, (2003)

Yaakob, S.B., Kawata, S., (1999), Workers' placement in an industrial environment, *Fuzzy Sets and Systems*, **106**, 289-297

Zadeh, L.A., (1965), Fuzzy Sets, *Information and Control*, **8**, 338-353

Zadeh, L.A., (1975), The concept of a linguistic variable and its application to approximate reasoning, *Information Science*, **8**, 199-249

Zakarian, A., Kusiak A., (1999), Forming teams: an analytical approach, *IIE Transactions*, **31**, 85-97

Zimmermann, H.J., (1976), Description and optimization of fuzzy systems, *International Journal of General Systems*, **2**, 209-215.