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DETERMINATION OF CRITERION THAT AFFECTS SUPPLIER SELECTION IN PUBLIC ADMINISTRATION SOFTWARE TENDERS AND SELECTION OF SUPPLIER

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ABSTRACT

DETERMINATION OF CRITERION THAT AFFECTS SUPPLIER SELECTION IN PUBLIC ADMINISTRATION SOFTWARE TENDERS AND SELECTION OF SUPPLIER

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In today's world, project management has gained importance depending on the project production. Public institutions expect to receive the best service by optimizing the use of their limited resources. Thus, they should carry out a careful assessment about the selection of the firm to provide the service. They also should be able to decide the criteria according to which the priorities will be determined for the alternative firms to provide the relevant service.

In this study, determination of the criteria needed to be taken into consideration for evaluating of firms' proposals and determination of firm selection under the light of determined criteria in the software tenders made by public institutions were made with the help of Multi-Criteria Decision Making Methods.

The aim of this study is to find a hybrid solution by using AHP technique to determine criteria weights in the firm selection from alternatives regarding firm selection criteria for software tenders of public institutions and by using TOPSIS technique to range these as well as to present Fuzzy TOPSIS method applied to reach a group decision in fuzzy environment where decisions are taken in atmosphere of uncertainty. First of all, the importance weights of decision criteria were determined with senior executives of the public institution, and then five firm alternatives were evaluated with the help of Multi-Criteria Decision Making Methods regarding determined decision criteria. Thus, it is seen that common decisions for firm selection can be taken by using scientific and feasible methods that supply advantages in many aspects in software tenders of public institutions.

Key Words: Multi-Criteria Decision Making, AHP, TOPSIS, Fuzzy TOPSIS

ÖZ

KAMU İDARELERİ YAZILIM İHALELERİNDE FİRMA SEÇİMİNİ ETKİLEYEN KRİTERLERİN BELİRLENMESİ VE FİRMA SEÇİMİ

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Günümüzde proje üretimine bağlı olarak proje yönetimine önem vermeye başlanmıştır. Kamu kurumları kısıtlı kaynaklarını iyi şekilde kullanarak, en iyi hizmeti vermesi beklenmektedir. Hizmeti sağlayacak firmaların seçiminde yapacakları değerlendirmede oldukça özenli olmak zorundadırlar. Kamu kurum ve kuruluşları uygulamayı düşündükleri hizmeti sağlayacak firma seçenekleri arasındaki önceliklerin hangi ölçütlere göre belirlenmesi gerektiğine karar verebilmelidir.

Çalışmada, kamu kurumlarının yaptığı yazılım ihalelerinde firma tekliflerinin değerlendirilmesinde göz önünde bulundurulması gereken kriterlerin belirlenmesi ve belirlenen kriterler ışığında firma seçiminin gerçekleştirilmesi Çok Ölçütlü Karar Verme Teknikleri yardımıyla gerçekleştirilmiştir.

Bu çalışmanın amacı, kamu kurumları yazılım ihaleleri için uygun olan firma seçim kriterlerini göz önüne alarak, alternatifler arasından yapılacak firma seçiminde, kriter ağırlıklarının belirlenmesi için AHP tekniği ve bunların sıralanması için de TOPSIS tekniği kullanarak hibrid bir çözüm oluşturmak ve belirsizlik altında kararların verildigi bulanık ortamlarda, grup kararı vermede yararlanılan Fuzzy TOPSIS yöntemini ortaya koymaktır. Yöntemlerin uygulamasında, öncelikle kamu kurumlarından üst düzey yöneticileri ile karar kriterinin önem ağırlıklarını belirlenmiş, ardından belirlenen karar kriterlerine göre beş firma alternatifi Çok Ölçütlü Karar Yöntemleri yardımıyla değerlendirilmiştir. Böylece, kamu kurumu yazılım ihalelerinde birçok açıdan avantaj sağlayan, bilimsel ve kolay uygulanabilir yöntemleri kullanılarak, firma seçimi için ortak kararların alınabileceği gösterilmektedir.

Anahtar Kelimeler: Çok Ölçütlü Karar Verme, AHP, TOPSIS, Bulanık TOPSIS

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CHAPTER I

1. INTRODUCTION

In our days, managers are to make a selection among different technologies, systems, policies and strategies in order to find solutions for their problems with the increase and complexification of the factors affecting the management and decision making process. More scientific decision making methods are needed for a rational decision making as the current decision problems are prudential, include uncertainty and ambiguity, require time and cost and have multiple criteria conditions.

Decision making, in short, can be defined as preferring one of the alternatives. In other words, different alternatives should be determined and the most effective one should be selected out from these alternatives in order to reach a goal. Within this scope, the concept that needs should be determined correctly and prioritised to ensure the optimal use of limited resources is evaluated in decision making concept.

One may encounter with the prioritisation problem at different dimensions. One of them is the assessment of projects for resource allocation to investment projects like different infrastructure, modernisation, follow-on support, R&D etc.. In any planning period, there are many project alternatives. For a successful result, a good planning and strategy assessment should be carried out on the project alternatives. As each project owner believes that his/her own project is very important, it is of paramount importance to reach agreement at the end of the project assessment and prioritisation.

Assessment of the investment project includes the studies conducted to detect the consistency and soundness of the technical, financial and economic aspects of a project. Especially, the problem of prioritising the needs is frequently encountered in the public sector where such non-physical factors as social, environmental, structural and political aspects are to be considered and the limited budgets should be used optimally.

Rapidly changing and difficult living and working conditions of today's world urges public institutions to take successful decisions. In such an environment, healthy decisions are needed to survive, obtain and sustain competitive advantage. Traditionally, while reaching a decision, data related to the decision making process are collected and a conclusion is reached by analysing the data heuristically. However, alternative behavior ways are now evaluated with the help of scientific decision making techniques for successful decisions in many cases.

Decision problems encountered in the real life are complicated in nature as multiple factors and objectives need to be evaluated together, objectives general conflict with one another, it is difficult to measure the degrees of reaching them, decisions contain uncertainties, decision processes include more than one actors, the results of the decision interest more than one parties and they are of vital importance. Thus, scientific theories and analytical methods have been developed in order to help the decision taker to overcome such problems – by also benefiting from his/her personal value judgments. Organisations using modern decision support methods gain a significant competitive advantage in the working environment which becomes more and more complicated gradually.

Decision making exists at all stages of the life. In general, it is the process of selecting the most suitable, possible one or several alternatives out of a cluster of alternatives on the basis of a criterion in line with at least one objective. Accordingly, the decision making process includes the following elements: the decision taker, alternatives, criteria, and environmental impacts, priorities of the decision taker and results of the decision. Decision making process can end up with a selection, ordering or classifying made out of the alternatives by the decision taker. At this stage, we encounter with multiple criteria decision making methods to take most accurate decision. The multiple criteria decision making methods where paired comparisons of specific criteria are usually taken as basis help decision takers with numeric data to give the truest decision (Evren and İlengin, 1992; Dağdeviren and Eren, 2001).

Drawing a gradually increasing amount of interest in the literature of methodology, the approach of Multiple Criteria Decision making contains the approaches and methods which try to reach the "best/optimal" solution meeting (satisfying) more than one criteria conflicting with one another in relation to a decision within itself.

Due to the fast changes taking place in the information technologies, planning of information systems has become an important factor affecting the success of enterprises. The most important part of the process of developing the information systems is software selection. The success of information system projects depends on the selection of the correct software in the enterprises. Correctly selected software will support the business processes of the enterprise and provide the decision taker with correct and updated information. Selecting the correct software, in turn, is only possible with a suitable selection procedure and a correct method where the software criteria prioritising the needs of the enterprise will be evaluated.

Firm selection is a difficult and complicated process that the enterprises face with. Thus, during the development phase of the information system projects in the enterprises, the main goal must be selecting the firm to provide the software which will meet the needs of the enterprise and provide the maximum benefit to the enterprise. There are numerous alternative software packages in the market for software selection. The important one is to select the package meeting the needs of the enterprise. There is no standard technique for the selection made out of alternative software packages. In the selection, such methods as benefit-cost analyses, ranking, risk analyses, scoring and analytical hierarchy method are used. There are many factors affecting the software selection decisions in the enterprises. Thus, certain priorities should be determined out of these factors. For instance, user satisfaction may be a more prioritised criterion than the system cost in an enterprise. So, user satisfaction will be come into prominence while making the software selection. On the other hand, another criterion may be of priority for another enterprise. Thus, the method to be used in the selection of the software firm must be able to evaluate the relative priority of multi-purpose criteria. The method to be selected should address the multi-purpose criteria, evaluate these abstracts and concrete criteria and be able to determine the relative priority of each criterion in accordance with one another. Besides, the method should be easy to use and flexible for a successful selection decision (Muralidhar, Santhaman and Wilson, 1990:88). When compared to the other methods given above, it is seen that multiple criteria decision making methods provide these criteria.

Analytical hierarchy method is based on the system approach. System approach, in turn, aims at evaluating the impacts of various elements of a system on the whole system and finding out their relative importance values. In other words, while a system is being examined, attempts are made to determine the physical and social structure of the components of the system, the structure of each and every component, the objective to which it serves and what the main objective of the system is. Structure and functions of a system constitute an indivisible whole. Thus, the analytical hierarchy method processes are designed to examine the structure-function combination as a whole. AHP technique to determine the weights of criteria and the TOPSIS technique has been used to sort them.

Public institutions perform the firm selection out of the alternatives by using the Fuzzy TOPSIS method, which is one of the Multiple Criteria Decision making methods, in consideration of the firm criteria suitable for the software tenders. Fuzzy TOPSIS method is based on the concept that the chosen alternative should have the shortest geometric distance from the positive ideal solution and the longest geometric distance from the negative ideal solution. In practice, five senior executives of public institutions determine the importance weights of ten decision criteria to be considered in the firm selection and then evaluate four alternative suppliers with linguistic variables according to these decision criteria. These evaluations are transformed into triangle fuzzy numbers, the steps of fuzzy TOPSIS method are implemented and a preference order is made according to the proximity coefficients calculated for the alternatives. In this way, it is indicated that a group decision can be taken for firm selection in the fuzzy environments by using fuzzy TOPSIS method, which is a scientific and feasible method providing the public institutions with numerous advantages.

At the second and third parts, a general situation analysis was carried out in relation to the public software projects. At the fourth part, however, basic concepts concerning the decision making, multiple criterion decision making and fuzzy decision making approaches were examined as the problem addressed in the study was associated with decision making. At the fifth part, AHP and Fuzzy TOPSIS techniques to be used in the project assessment were examined. This study gave a definition of the problem. Primarily, assessment of software projects and decision making in the public sector were generally addressed. Then, the last decision alternatives and evaluation criteria were presented and the data related to the problem were identified. The steps of AHP and Fuzzy TOPSIS methods, modelling and solution of the problem and the analysis of the solution were given. At the conclusion part, contributions expected from the study and assessments of the results of the application were presented.

CHAPTER II

2. CONCEPTS OF PROJECT AND PROJECT MANAGEMENT

Nowadays, solutions are sought in every area for economically and technically complicated problems. Accordingly, expectations from the relevant administrative units to solve these problems also increased. However, great difficulties were encountered in the efforts aimed at solving these complicated problems at a hierarchical structure or these efforts failed. Besides, it was seen that examining the works separately would lead to unforeseeable risks in terms of targets to be reached due to diversity or mutual interaction of works. Thus, a way of thinking and working within systems were sought to enable the division and structuring of works in order to handle complicated projects. As a result, it was seen that project is the best way so the need of concepts of the project and project technique improved for the solutions of these kinds of problems (Albayrak, 2005).

2.1 CONCEPT OF PROJECT

German Standard DIN 69901 prescribes that “unique” and “one-time” works and duties which have certain constraints in terms of time, target and resource (labour, capital and financial resources etc.) and possess organisational characteristics peculiar to them can be defined as project (Koçel, 1993).

According to Project Management Institute (2000), “a project is identified as a temporary study carried out to create a unique product or service”. The expression of “temporary” means that each project has a certain start as well as a certain end. On the other hand, the expression of “unique” refers to the fact that the product or service should be different from other products or services (Ives, 2005).

Project is a complicated study, which generally lasts in less than three years, is conducted by various organisational units, consists of interrelated works, possesses a well-identified objective as well as a certain time schedule and budget (Barutçugil, 1983).

Main characteristics which turn a group of works into a “project” are as follows (Koçel, 1993):

- Activities included in the group of works have a determined beginning and end;
- The group of works and activities included in this group are mostly performed for only once (the objective is reached with the performance of activities included in the group of works for once);
- These activities included in the group of works are never disclosed completely, there are certain ambiguities.
- Failure of completing the works on time can cause losses on the part of the enterprise;
- There are certain standards for deadline, cost and quality of each work included in the group of works;
- There are continuous changes in relation to the works and standards during the conduct of works and activities;
- Provided that the works undertaken by an enterprise bear the abovementioned characteristics, these works can be classified as “Project”.

2.2 CONCEPT OF PROJECT MANAGEMENT

When the historical development of project management is examined, it is seen that the first practices of Project Management in today’s context started during the Second World War. Restrictive and challenging effects of war years and the pressure of time factor, in particular, gave rise to the management of insolvable complicated works and processes together with organisation, planning, monitoring and control methods which were available but had not been tried until that time on the grounds of defense in order to realise certain national and military projects in the U.S.A (Peşkircioğlu, 1989).

In the project called “Mangattan Engineering Project” which was launched in 1941 with the aim of developing the first atom bomb, works of many scientists, experts, engineers, soldiers and government authorities from universities, industries, army and public sector were planned and organised in line with the overall target of project in order to fulfill a great number of complicated system tasks under the restrictive impact of time factor and as a result, an integration problem was encountered (Schwalbe, 2000).

The first project applications were conducted for military purposes as well as space-aviation purposes. Important milestones of this process included the military-purposed “Polaris Program” which was launched in the U.S.A following the Second World War and “Apollo” projects of NASA. Progressive Project Planning (PPP) which was developed by NASA, System Management (SM) developed by the American Air Forces and Program Evaluation and Review Techniques (PERT) developed by the American Naval Forces can be given as examples of such studies (Kürkçüoğlu, 2006).

Project management applications developed in the U.S.A expanded to the countries of Western Europe in the postwar era and they spread rapidly. For instance, European Space Vehicle Launcher Development Organisation (ELDO) and European Space Research Organisation (ESRO) which were later united under the name of European Space Agency and NATO assumed the responsibility to convey the applications developed in the U.S.A to Europe either partially or completely (Kürkçüoğlu, 2006).

Project management techniques which firstly emerged and evolved with the military and space-aviation projects expanded to the sectors of production, research and development, construction, agriculture and service in a short time. Project management which gained importance at the second half of the 20th century and became common and popular rapidly in many countries especially in the developed countries, in particular is defined by Project Management Institute as “the application of information, skills, tools and techniques to the project activities in order to meet the requirements of a project” (Ives, 2005).

Project management is the whole of planning, organisation, management, resource allocation and use, application, monitoring, control and evaluation activities which are maintained to reach a pre-set target in line with the time, performance and resource criteria and constraints of works defined as project (Peşkircioğlu, 1989).

Harold Kerzner defined project success as completing the project within time, cost and performance constraints. These three key factors also represent the following important characteristics of project management (Barkley and Saylor, 1994).

- Completing the project with the allocated resources: This is the cost factor of project management.
- Completing the project within the allocated program: This is the time factor of project management.
- Completing the project in line with certain criteria, standards and details: This is the performance factor of the project management.

2.3 STAGES OF PROJECT MANAGEMENT

The objective of management is to ensure efficiency and effectiveness. It is accepted that project management consists of the following five stages to this end (Tosun, 1982):

i. Planning Stage
ii. Organisation Stage
iii. Execution and orientation (chain of command) stage
iv. Coordination stage
v. Control and correction stage

Project planning stage consists of the activities related to the determination and identification of the works to be performed, determination of all kinds of necessary human, physical and financial resources as well as the establishment of the organisation structure which will enable the continuity and completion of the project (Heizer and Render, 2001).

Project organisation is the stage where human, physical and financial resources are gathered in a timely manner under a single authority. Project organisation is affected by such factors as organisational position of the project, dimension of the project and complexity of the project. Project should be organised in consideration of organisational scope of the project, functions to be affected by the project as well as the activities included in it (Ece and Kovancı, 2004).

Execution and orientation is the stage where decisions are taken as regards to how to handle the works. In the stage of project control, planning and the current state of the project are compared and probable deviations from the project targets are determined. This is the process developed by the project manager to ensure the fulfillment of time, cost and success targets prescribed at the beginning of the project (Ece and Kovancı, 2004).

A person entitled with the rights and responsibilities to put the necessary decisions into practice in line with the planned criteria and targets of the project under certain constraints should be appointed as project manager. Project manager is responsible for completing the project at the requested time with the planned budget at the pre-determined quality level. Thus, the project manager should possess the following qualifications (Turan, 1993):

- Having the basic management knowledge and management experience;
- Having the skills of leadership and motivation, communication, problem solving and decision taking.
- Having the knowledge and experience about planning, organisation, execution, coordination, control and monitoring activities.

A successful project management requires both the skills of project leadership and project management. In big projects, in particular, the project manager should possess the leadership qualifications as well as the management qualifications. However, leadership is not limited to the project management. It can be displayed by different people at different times (Ece and Kovancı, 2004).

Assigning the leadership responsibility by considering the fields of specialty at a level acceptable by the team members contributes to the success of the project positively. It is natural to experience conflicts in the project environment. While dealing with these conflicts, project manager should take action by considering that conflicts inhibit creativity (Dengiz, 2000). Project manager has a certain power relationship with various members or groups of the organisation through the project. These are top management, sub-groups (project team, secretariat etc.), personnel in conflict, functional executives, people or groups outside the organisation (client, supplier etc.). Success or failure of a project depends on to what extent the project manager is accepted by the groups. The project manager should include the client in the project and establish contacts between client and organisation. Especially, in big projects, this relationship gains even more importance and directly affects the success of the project (East and Y.Liu, 2003).

CHAPTER III

3. SOFTWARE SECTOR AND SOFTWARE PROJECTS

Software sector is a sector that all countries want to develop and most of the countries try to trigger by establishing techno parks and techno-cities. In this sector, tax reductions are applied and enterprises try to train qualified personnel.

Software sector develops softwares for built-in systems, computers and computer-like devices, all kinds of automation systems, consumers and business world, offers these softwares as projects or package product, gives training and consultancy services and provides support service for softwares.

Software projects are also needed to be conducted through professional methods as in the other projects. However, due to the sector that they belong to, they have certain different characteristics. Software projects directly affect the functioning of organisations and they are generally executed in order to increase efficiency of organisations and to maintain competitive advantage. Thus, IT project influences functioning of the whole organisation.

Most of the developed software projects are not visible and tangible projects at the beginning. Therefore, a full comprehension over the project poses certain difficulties both for the project owner and the technical team commissioned to conduct the project. Project owner can have rambling expectations from the project but the project manager should make the project visible to the project owner as much as possible and keep the expectations at a reasonable level.

Information technologies sector is a fast-growing and fast-evolving sector. Thus, projects should be prepared in a flexible manner to be able adapt to these changes. Fast change and growth are accompanied by uncertainties and risks and the project manager should be alert against such uncertainties and risks.

Software projects are expensive in comparison to the others. As technology is renewed every day, infrastructure and equipment costs change constantly in parallel to this situation.

The success of the software project can be evaluated soundly only when the product becomes operative. Hence, the selection process of the firm to realise the software project may take a relatively longer time.

3.1 SOFTWARE SECTOR IN THE WORLD

According to the 2011 data of Forbes magazine, the five biggest software firms are ranked as Microsoft, IBM, Oracle, SAP and Ericsson by their revenues from the software products. It is envisaged that the software sector will reach a turnover of 500 Billion USD in 2013.

When the distribution of 100 biggest software firms of the world by the countries is considered, it is seen that most of them were either established / launched in the U.S.A or moved their headquarters to the U.S.A.

Popularity of internet, new business models including application stores as well as the growth of the client network allow the sector to record a fast growth.

3.2 SOFTWARE SECTOR IN TURKEY

According to the 2010 report prepared by Software Industrialists Association, there are 1600 firms operating in the software sector in Turkey. 87.2 % of these firms have the status of small and medium-sized enterprise. The report indicates that Turkish information sector recorded 6.994 million USD in terms of hardware, 696 million USD in terms of software and 909 million USD in terms of service in 2010.

In the software sector, communication sector and public sector constitute the most fundamental demand. Opening to the global market and export stand out as the newly-developing fields which are desired by the sector but far from the targeted point.

Targets are much higher. Such targets as 50 % local product use in information sector, reaching the GDP of information sector to 8 % and having at least one leading firm in the global arena have been set for 2013 policy of Turkey.

To reach the export target of 500 billion USD by 2023, 10 billion USD of which will originate from the software sector, the sector should increase its export volume and dimension by 31 % cumulatively as of 2012. Even though it is a fast-growing sector in comparison to the others, some radical and dramatic changes are needed to reach these targets in the software sector.

Public administrations, falling within the scope of 2nd Article of Public Procurement Law no.4734, perform certain tasks and duties by tender apart from limits and conditions specified thereby. Public administrations applies the lowest price principle to select the most advantageous bid.

In product purchase tenders, it is not sometimes possible to select economically most advantageous bid on the basis of lowest price. On this occasion, administrations are entitled to determine the economically most advantageous bid by considering the operating and care cost, cost effectiveness, efficiency, quality and technical value in addition to the characteristics of the product subject to the tender (Public Procurement Law, 2002:40). Besides, administrations may take additional factors into account to determine the economically most advantageous bid depending on the requirements of the product subject to the tender. In tenders where the economically most advantageous bid will be determined upon consideration of factors except for the price, calculation method based on monetary values or relative weights of non-price factors and document and/or sample to be presented for the evaluation on these factors should be specified clearly in the administrative specifications (Product Purchase Tenders Practice Regulation, 2009: 60). As it is seen, law-maker allows the use of alternative techniques in the evaluation of non-price factors in the tender process.

Law-maker has imposed certain limitations in terms of the non-price factors to be determined by the administrations in the tender process. For instance, the 60th Article of Product Purchase Tenders Practice Regulation prescribes that economical and financial competence criteria and work experience document cannot be seen as non-price factor. Besides, the law-maker emphasizes that non-price factors cannot be determined on the basis of certain brands or models in a manner limiting the competition; an explanation document should be prepared by the unit or authorities making the arrangements concerning these non-price factors, monetary values or relative weights of these factors as well as the calculation method and this document should be attached to the document of tender confirmation.

In the 61st Article of the said regulation and the 11th Article of the Regulation on Amendment to the Product Purchase Tenders Practice Regulation which was issued in 2011, it is specified that necessary arrangements can be made to ensure that a price advantage can be applied in favor of the bidders who offer domestic goods in addition to the non-price factors and only local bidders can take part in the product purchase tenders where the approximate cost remains below the threshold value.

According to the 40th Article of Public Procurement Law no.4734, if more than one bidders quote the same price in a tender where the lowest price is considered as the economically most advantageous bid and they are selected as the economically most advantageous bid, the other factors except for the said price are considered and the economically most advantageous bid is selected.

3.3 FACTORS AFFECTING THE SUCCESS OF SOFTWARE PROJECTS

Standish Group defines successful information technologies project as the "projects which meet the time-, budget- and scope-related expectations and bear the characteristics and functions in conformity to the work objectives" (http://www.standishgroup.com/newsroom/chaos_2009.php). In the light of the available experiences and based on the definition, we can list the factors bringing success to the IT projects as such: top management support, user participation, experienced project manager, well-identified project targets, well-identified project scope, accurate analysis and a project management methodology appropriate for the project.

Top management support is of importance to receive an adequate amount of resources for the project, to experience an increase of trust in the project and to ensure that the project is adopted by the organisation and the output practice of the project is implemented more rapidly by the organisation. Without support of the top management, even though the project is accomplished, its probability of success remains low. Users can allocate a sufficient amount of time and effort both in the planning and implementation stages of the project only if administrators give an effective support to the project.

User participation is of great importance to design the practice to be revealed at the end of the project successfully and to obtain a high efficiency from the practice. The user who has the highest level of command over the work in question is the person most probable to know the essential characteristics of the practice as well as how the work can be performed rapidly and cost-effectively as much as possible. Thus, good relationships should be established with users and their recommendations and complaints should be taken into consideration.

An experienced project manager is a good advantage for the project. Software projects have more risks and uncertainties in comparison to the other projects. However, experience is the leading factor which contributes to the project management in face of uncertainties and risks.

Expectations of the project owner and his/her need for the project set the targets of the project. Project targets is a concrete identification of the practice to be presented at the end of the project. Targets should be well-identified in order to decide on whether the project has been completed. Lack of well-identified targets will lead to deviations in the plans of the project.

Scope is the process of defining and controlling what to include in the project as well as what to exclude from it. During this process, characteristics and functions that a product or service should possess should be clearly specified. Project scope is determined in line with project targets. Problems in determining the project scope will affect time and cost targets of the project negatively.

In software projects, analysis is to listen the work to be performed from the project owner blow-by-blow and to reflect them to the paper. All the questions should be directed to the project owner (organisation) and information should be taken about all the exceptional cases to be encountered in the project. Analysis process is difficult in the software projects. Employees of the organisation may not provide the necessary support to the analysis process on the grounds that the output of the project would make their work more difficult or there would be no need for them at the end of the project. Project manager should overcome this problem by receiving support from the top management. After the analysis process has been completed, user interfaces are created and project is stimulated in the mind of the project owner. In this process, provided that the project owner realises the wrong information conveyed in relation to the workflow in the analysis process and expresses the changes that he/she wants in the program in terms of ease of use. Making these changes before implementation contributes greatly to the project. The project owner should be consulted with regularly even after the phase of analysis and exchange of ideas should continue in relation to the course of the project.

A project management methodology selected in accordance with the project allows an optimal, efficient and disciplined management over the project. Project management methodologies are developed in the light of the studies conducted for years and the obtained experiences. Managing a project with a professional approach by not repeating the previous errors becomes possible only with an appropriate management methodology.

3.4 STEPS THAT SHOULD BE TAKEN BY PUBLIC ADMINISTRATIONS FOR SUCCESS OF THE PROJECT IN SOFTWARE PROJECTS

While organisations can carry out the IT projects in the IT departments within their bodies, they can also transfer these projects to other IT firms. In the light of the obtained experiences, the steps that should be taken by the public administrations for success of projects transferred to other firms are listed below:

- A clear identification of the software project to be undertaken,
- Assignment of experienced project leaders who will manage the project on behalf of the organisation and follow its progress, establish communication between organisation and the awarded enterprise and have a command over information technologies and work processes,
- Preparing a clear project specifications, if needed, receiving expert support in preparing the specifications,
- Assessment of project tender within the framework of clear and net criteria,
- Awarding the firm which meets the needs of organisation in the best manner instead of the firm which quotes the lowest price,
- A clear determination of project success criteria,
- A clear determination of project quality expectations,
- Development of the project in line with operating culture of the organisation,
- Preferring the products which will not cause an excessive dependency to foreign resources in the selection of software and hardware to be used in the project,

- Keeping all the communication channels within and outside the organisation open,
- While selecting the technologies to be used in the project, technologies which are appropriate for the open system architecture and can be adapted to other systems used by the organisation as well as its new practices easily should be preferred.
- Following the progress of the project in line with the plans, controlling the progress continuously,
- In big projects, project acceptance process is undertaken by a third firm specialised in the field,
- Following the project acceptance, training, maintenance and updating activities should be guaranteed by well-prepared contracts,
- Providing trainings on basic information technologies to employees who will use the practice to be presented at the end of the project,
- Preventing potential negative approach and resistance of employees to the practice for various reasons.

3.5 CHARACTERISTICS OF PUBLIC AND SOFTWARE SECTORS

In the Software Sector, the projects which lead to most problems are software projects conducted by the public sector. Repeated projects within the mechanism of state and waste of funds constitute a great and unresolvable problem even in the European Union countries. For instance, data are collected repeatedly in the public sector and lead to a great waste. Equipment costs, unnecessary staff employment, maintenance costs, license fees are added into the budgets every year and this waste cannot be prevented in any way.

In our country, the number of personnel who is competent enough to manage projects in the public sector is limited. Software companies try to accomplish project with great difficulties. Big and important software projects are managed by executives who have not been trained in the field of Information Technologies and see this field only as hobby. As the working principle is not complied with by adhering to the planning, project management can get out of control. Time pressure in the projects leads to an increase of errors by reducing the quality.

Firms which make investment in the new technologies cannot, unfortunately, compensate these investments and the principle that economically lowest bid is awarded in tenders makes it difficult to distinguish between technologies.

A platform where sector problems are discussed and solution proposals are presented is “TOBB Software Assembly” established within the body of TOBB. As a result of the studies of this assembly in which sector companies, relevant institutions and NGOs take part, the most important five problems of the sector and solution proposals have been determined and presented to the relevant Ministers in 2011 Economic Council of Turkey. These problems and solution proposals are as summarized below:

- Selection of software projects in the public software tender regulations may contain mistakes,
- The lack of incentives, risk capital and funds appropriate for the software sector,
- The lack of a National Software Agency and national software strategy within the body of Prime Ministry or Ministry of Industry,
- Tax regulations in the sector do not promote growth, enable deepening or strengthen export,
- The lack of staff specialised in Informatics within the Public Procurement Agency,
- The lack of qualified personnel in informatics,
- Public tenders for software and services are not carried out in consideration of the characteristics of the software sector. Software and software services tenders should be made through the determination of selection criteria so as to eliminate the errors in the selection of software projects.

CHAPTER IV

4. MULTI-CRITERIA DECISION MAKING (MCDM)

4.1 DEFINITION AND CONCEPTUAL FRAMEWORK

Decision making is to make selection among the alternative behavior patterns to reach a goal and to fulfill a purpose (E. Forman & M.A. Selly, Decisions by Objectives, World Scientific, 2001, p.1.). Decision making lies at the heart of vital and managerial functions. Human beings and managers should always make decisions in all stages of the life as well as in all duties they perform. Where, when and how will a work or behavior be performed and by whom? There are always several alternative behavior patterns that may be the answers of these questions. So, selecting the most appropriate one among these alternatives is the purpose of decision making. T.L.Saaty divides decision making into two categories: “heuristic” and “analytical” (T.L. Saaty, Fundamentals of Decision Making and Priority Theory, 2nd Edition, RWS., Pittsburgh, 2000, p. ix.). Heuristic decisions are not supported by data and are generally taken arbitrarily. In some simple situations, heuristic approach may be successful. However, when encountered with complicated situations requiring information, decision makers may realise that their decisions deviate from their own values. The expression of “good decision making” is used for situations where these deviations are not seen. Good decision making has been regarded as an “art” to emphasize the heuristic power of the individual.

Today, decision making has become a “science” rather than an “art” in contrary to what was believed for long years (T.L. Saaty, Decision Making for Leaders, 3rd Edition, RWS, Pittsburgh, 2001, p.xii.). For a decision to be considered successful, it should frequently evaluate various conflicting actors and factors altogether, reach conclusions which estimate all these and preserve their validity in the course of time. Thus, approaches combining value judgements of individuals through objective and analytical methods have been developed.

Everybody tries to make “good” and “successful” decisions. However, there is no clear definition due to the subjectivity of the concept of “good”. Decision makers deal with decisions having “good results”. On the other hand, academicians and analysts argue that a decision making process which is well-constructed within the framework of scientific theory and takes all decision factors into consideration leads to a “good” decision making (M.I. Henig & J. T. Buchanan, "Solving MCDM Problems: Process Concepts", Journal of Multi-Criteria Decision Analysis, C. 5, 1996, p. 3.).

Multi-Criteria Decision Making processes came out as the whole procedures which try to help the decision maker to reach the most desired solution by evaluating the complicated decision problems in a scientific and analytical framework. Multi-Criteria Decision Making (in short MCDM), in its shortest definition, is the general name given to the solution of problems where the objective is to fulfill multiple and conflicting purposes (criteria) (S. Zionts, "MCDM-If Not A Roman Numeral Then What?", Interfaces, C. 9, S. 4, 1979, p. 94.).

MCDM is, on the part of the decision makers (individuals, organisations, managers), the attempt to solve the problems to be encountered in the daily life. However, on the other part, it is the attempt to reach solutions that will provide the highest level of satisfaction through modelling of the problem by the analyst or sometimes by the decision maker himself/herself as well as the use of methods so as to help rational decision making. On the basis of this point, MCDM both represents an approach and refers to a superior concept covering techniques or methods designed to help people to make selections suitable for their value judgements when they encounter with problems to be characterised with multiple and conflicting criteria that do not have the same dimensions (P. Bogetoft & P. Pruzan, Planning with Multiple Criteria: Investigation, Communication and Choice, Handelshojskolens Forlag, Copenhagen Business School Press, 1997, p.11.). MCDM has recently stood out as the most rapidly developing branch of Operational Research and represents a field which renews and revives the characteristics of system mentality, multi-disciplinarity and scientific approach in problem solving.

4.2 COMMON FEATURES OF MCDM PROBLEMS

There are four common features to be concluded from the above-given definitions and examples for MCDM problems. The first one of these features is that a MCDM problem has multiple purposes/qualifications. C.L. Hwang and K.Yoon expressed that each MCDM problem has multiple purposes or qualifications desired to be fulfilled and decision maker has to produce appropriate purposes related to each problem or determine the qualifications peculiar to the problem (C.L. Hwang & K. Yoon, a.g.e., 1981, p.2.).

According to the definition of M.T. Tabucanon, “A problem can be regarded as a MCDM problem only if it contains several conflicting criteria and at least two alternative (probable) solutions.”. M.T. Tabucanon, a.g.e., 1988, p.5.

M. Zeleny also makes a similar claim by saying that: “Decision making is not possible without at least two criteria” and adds that: “If only one criterion which can be measured excellently is available while evaluating the alternatives and these alternatives can be investigated effectively according to this criterion, only one measurement and research activity will be sufficient for making a selection (M. Zeleny, a.g.e., 1982, p.74-75.). In brief, Zeleny claims that a single-dimension “decision making” problem is not possible in reality. Additionally, in some occasions, one alternative can obtain all the superior scores alone in comparison to the other criteria. Therefore, a decision making activity will not occur.

Setting aside the debate concerning whether it represents real life problems, it is clear that there are many procedures put forward in relation to the solution of decision making problems which contain a single criterion and several alternatives (M.T. Tabucanon, a.g.e., p.4-5). These procedures shed light on the procedures to be implemented for the solution of MCDM problems. However, in all conditions, selection procedure is relatively simple in the solution of single-criterion decision making problem even in the presence of numerous alternatives. In short, what makes Multi-Criteria Decision Making problem complicated and difficult in addition to making it closer to the realities is the inclusion of several criteria into the problem.

Second common feature of MCDM problems is the conflicts between criteria. When numerous criteria exist within a problem, there generally exists a conflict between them. For instance, in designing cars, it is possible to cover more distance by consuming less fuel with smaller cars (the purpose of economy) but this will reduce the comfort of passenger as it will offer less interior space (C.L. Hwang & K. Yoon, a.g.e., 1981, p.2.). If complete satisfaction of one of criteria/purposes reduces or prevents the possibility of complete satisfaction of another one or others, it can be said that these criteria/purposes are conflicting (M.T. Tabucanon, a.g.e., p.5-6). With a more clear expression, an increase in the satisfaction of one of the criteria leads to a decrease in the satisfaction of another one, there is a conflict between the criteria.

Another common feature of MCDM is that it contains incommensurable units (C.L. Hwang & K. Yoon, a.g.e., 1981, p.2.). Each purpose or qualification has a different unit of measurement. MCDM problem is solved by either designing the best one out of infinitely many unpredictable alternatives or selecting the best one out of a limited set of alternatives. All criteria or dimensions are evaluated in this regard. At this point, the presence of two types of alternatives set is striking. While one of the sets contains infinitely many alternatives, the other contains a limited number of elements.

4.3 STRUCTURE AND COMPONENTS OF THE MCDM PROBLEMS

At this point, it will be useful to make short explanations about some concepts and components used within the scope of MCDM problems to ensure conceptual clearness. Output of the MCDM problem is a "Decision". This output may come out as a graded (ranked) list of the best reconciliatory solutions or alternatives. Inputs of the problem consist of an "indicator" which tells the necessity of a decision to the "decision maker" and triggers the decision making process along with the data helping to explain the "decision status".

4.4 MULTI-CRITERIA DECISION MAKING APPROACHES USED IN SUPPLIER SELECTION

Such multi-criteria decision making approaches as AHP, ANP, Data Envelopment Analysis, Fuzzy Set Theory, Mathematical Programming, SMART, ELECTRE, TOPSIS, PROMETHEE as well as the integration of these methods are commonly used in the supplier selection problem (Ho, 2008: 211).

CHAPTER V

5. RESEARCH METHODOLOGY

Prior to the Fuzzy TOPSIS method, TOPSIS method which constitutes its basis will be addressed.

5.1 RESEARCH APPROACH

5.1.1 TOPSIS Method And Its Characteristics

TOPSIS method is one of the classical MCDM methods developed by Hwang and Yoon in 1981 for the first time for solving the MCDM problems. In general, TOPSIS method is based on the principle that the selected alternative should be close to the positive ideal solution and far from the negative ideal solution as much as possible. TOPSIS method can also be identified as the technique of ranking preferences by their proximity degrees to the ideal solutions.

Positive ideal solution is defined as the solution maximizing the benefit criteria while minimizing the harm criteria whereas negative ideal solution can be identified as the solution maximizing the harm criteria while minimizing the benefit criteria (Yu-Jie Wang,Hsuan-Shih Lee, "Generalizing TOPSIS for fuzzy multi-criteria group decision making", Computers and Mathematics with Applications, C:LIII, 2007, p. 1763.). In other words, when all criteria are taken into consideration, the alternative with the best level is named as the positive ideal alternative while the alternative at the worst level is named as the negative ideal alternative (Deng Yong, "Plant location selection based on fuzzy TOPSIS", Int J Adv Manuf Technol, No:28, 2006, p. 839).

In TOPSIS method, precise numbers are used in the performance evaluations and significance weights of the criteria. Opinions of people including their selection decisions are typically ambiguous and their preferences cannot be predicted with precise numerical values. Thus, precise numbers are insufficient to model the real life conditions. A more realistic approach may be the use of linguistic values instead of numerical values. In Fuzzy TOPSIS method, this uncertainty in the real life is considered, significance weights of criteria and evaluations of alternatives according to the criteria are used by using the linguistic variables while making a group decision. Fuzzy TOPSIS method is a MCDM method developed to eliminate the uncertainty resulting from people's judgements during the decision making process in the solution of problems which contain a linguistic uncertainty and require to make a group decision (Chen, "Extensions of the TOPSIS for group decision-making under fuzzy environment", p. 4.).

5.1.2 Fuzzy TOPSIS Method And Its Characterıstıcs

As it is known, it is really difficult to make a decision under uncertainty. An environment where decisions are made under uncertainty and at the same time, objectives and limitations are not clear is called as a "fuzzy" environment. In such environments, using one of the methods developed by Zadeh (1965) on the basis of Fuzzy Sets Theory may facilitate decision making (Ecer, "A Method Helping to Make a Group Decision in Fuzzy Environments: Fuzzy Topsis and an Application", p. 78.). In this context, Fuzzy TOPSIS method was developed by extending TOPSIS method though fuzzy sets theory in order to eliminate the uncertainty resulting from human judgements during the decision making process. It is also known that decision may be taken individually or jointly in a group. Group decision means that decisions are taken by several people, different personal preferences turn into a single preference or several people take part in the decision process. Structure of Fuzzy TOPSIS method which is a MCDM method used in taking group decisions is considerably appropriate for use in fuzzy environments where uncertainty is prevailing (Ecer, "Comparison of Different Fuzzy TOPSIS Methods Used in Making Group Decisions and One Application", p. 229.). It is also expressed by Chen that a multi-criteria fuzzy decision making method is essential provided that evaluating different qualitative and quantitative criteria altogether and making a ranking based on their weights are requested (Chen-Tung Chen, "A fuzzy approach to select the location of the distribution center", Fuzzy Sets and Systems, C:CXVIII, 2001, p. 66.).

As mentioned above, the most obvious feature of the Fuzzy TOPSIS method is that the decision is a multi-criteria group decision taken under uncertainty. In other words, we can define Fuzzy TOPSIS as a method where several decision makers evaluate and rank alternatives under uncertainty according to numerous decision criteria and thus, help them make a correct decision concerning their selection.

The basic principle of FTOPSIS method is that the selected alternative is close to the Fuzzy Positive Ideal Solution and far from the Fuzzy Negative Ideal Solution as much as possible (Chen Lin, Huang, “A fuzzy approach for supplier evaluation and selection in supply chain management”, p. 291.). FTOPSIS method is a decision making tool which is used in taking group decisions in fuzzy environments, digitises the evaluations made with linguistic variables by attributing membership functions to them and allows for evaluation of alternatives with the help of its algorithm. A great majority of the supplier selection criteria consists of qualitative criteria. According to these criteria, it is more practical and correct to evaluate suppliers with such linguistic variables as “Very good”, “Good” or “Moderate” instead of numerical values. A variable consisting of values that are defined with expression or linguistically is called “linguistic variable”. Linguistic variables are significantly useful in defining complicated or under-recognized expressions (Chen, “Extensions of the TOPSIS for group decision-making under fuzzy environment”, p. 3.).

The most distinctive feature of FTOPSIS method is that it allows for decision criteria to possess different significance weights. Considering the fact that decision criteria may possess different significance weights for each decision maker, more realistic and accurate evaluations can be made. Thus, more correct and effective decisions can be taken (Ecer, “A Method Helping to Make a Group Decision in Fuzzy Environments: Fuzzy Topsis and an Application”, p. 79.).

5.1.3 Analytical Hierarchy Process (AHP) Method

Analytical Hierarchy Method (AHP) which was developed by Professor Thomas L. Saaty in the 1970s is decision-making method used in the solution of complicated problems containing several criteria. AHP allows decision makers to model the complicated problems in a hierarchical structure demonstrating the relationships between main objective of the problem, criteria, sub-criteria and alternatives. The most important feature of AHP is that it integrates both subjective and objective opinions of the decision-maker into the decision-making process. In other words, AHP is a method where knowledge, experience, individual opinions and foresights are combined reasonably. AHP has a wide usage area and is used effectively in many decision problems. For instance, Saaty (1980), Wind and Saaty (1980), Golden et al. (1989a) and Zahedi (1986) addressed many successful AHP practices performed in the fields of marketing, finance, education, public policies, economy, medicine and sports in their researches. Besides, AHP is used together with operational research techniques such as integer programming, target programming, dynamic programming in many studies (Chin et al., 1999; 347).

The analytical hierarchy method processes are based on the system approach. System approach evaluates the impacts of various elements of a system on the whole system and finds their relative importance. In other words, while a system is being examined, physical and social structure of its components, structure and objective of each component, upper objectives to which the objectives serve and main objective of the system are determined. Structure and functions of a system constitute an indivisible whole. Analytical hierarchy method processes examine this structure-function combination as a whole. Hierarchies used in the method are constituted with the aim of revealing the abovementioned structure to determine functional relationships of components of the systems as well as their impacts on the whole system (Evren, 1992: 49).

5.1.3.1 Limitations

AHP is subject to certain criticism concerning theory and practice. The scope of this criticism is summarized briefly below (Rangone, 1996: 115; Armacost et al., 1994:74; Millet, 1998: 1203; Deshmukh and Millet, 1999:99; Taylor III et al., 1998: 681).

- The phenomenon of rank reversal is an issue to be considered in AHP practices and means that when any decision alternative is added into or removed from the problem, the rank of decision alternatives changes. Discussions concerning rank reversal continue in the literature.
- Subjective nature of modeling process is considered as a limitation of AHP. This means that the methodology cannot guarantee an “absolutely true” decision.

- As the number of grades increases in a decision hierarchy, the number of paired comparisons also increases. This fact requires more effort and time to set the AHP model. Although the use of Expert Choice and other software programs reduce the needed time and effort, it is alleged that the methodology requires more time and effort in comparison to less formal methods.

5.1.3.2 Contributions

- AHP provides a practical decision making methodology which allows decision makers to determine their preferences for the target correctly.
- It has a structure/process which simplifies complicated problems.
- It promotes the understanding of decision makers concerning the definition of decision problems as well as their factors.
- It allows integration of both subjective and objective and both qualitative and quantitative information into the decision process.
- Decision makers can analyze the flexibility of final decision by making a sensitivity analysis.
- It allows decision makers to measure the consistency degree of their judgments.
- Its use in group decisions is convenient.
- Expert Choice which is a software package of AHP allows the decision maker to perform the practice in a rapid and correct manner.

5.1.3.3 Characteristics of the AHP Method

5.1.3.3.1 Axioms of AHP

Theoretical infrastructure of AHP is based on three axioms. The first one of these axioms is the reciprocity axiom. To explain it, for example, "if A is 5 times bigger than B, then B is one fifth of A".

Second one is the homogeneity axiom and means that compared elements should not differ greatly from one another and if they do, errors are seen in judgments.

The third axiom is independency axiom and means that judgments or priorities concerning the elements of a certain grade in a hierarchy should be independent from those in another grade. This expression suggests that priorities of top grade criteria do not change when a new alternative is added or removed.

5.1.3.3.2 Development of the Hierarchy / Division

The first step of AHP, division is the process of dividing a decision problem into sub-problems in a hierarchical order so as to ensure a better understanding and assessment. In brief, it refers to the establishment of decision hierarchy. Main target is located on the top of the decision hierarchy. A lower grade consists of criteria which will affect the quality of the decision. If these criteria have features to affect the main target, other grades can be added into the hierarchy. Bottom part of the hierarchy includes decision alternatives. The number of grades in the decision hierarchy depends on the complexity of the problem as well as its detail degree (Zahedi, 1986:97; Millet, 1998: 1199).

Comparative judgments or paired comparisons constitute the second basic step of AHP. The term of paired comparison refers to comparison of two factors/criteria and is based on the judgement of decision maker. Paired comparisons are designed to set priority distributions of decision criteria and alternatives. To be clearer, elements in the hierarchy are compared as pairs to determine their relative importance to the elements in the upper grade (Wind and Saaty, 1980; 644; Rangone, 1986: 108).

5.1.3.3.3 Synthesis

After paired comparison matrices are developed, priority (relative importance) of each comparison element is calculated. This section of AHP is called as “synthesis”. Linear algebra techniques are used in the establishment of priority vectors. The phase of synthesis includes calculation and normalization of the biggest eigen value as well as the corresponding eigen vector. There are certain methods used for this purpose. However, in the normalization method used commonly in the literature, elements of each column are divided by the total of that column. Row total of the obtained values is taken; this total value is divided by the number of elements in the row (Saaty, 1980: 19; Evren and Ülengin, 1992: 59). In this way, priority vectors are found for each criterion.

5.1.3.3.4 Final Decision

Last phase of AHP is the solution of decision problem. In this phase, a composite priority vector is formed to serve as the rank of decision alternatives in fulfilling the main target of the problem. To form this vector, weighted average of priority vectors set for each variable is calculated (Zahedi, 1986: 96). The obtained final priorities can be named as decision alternative scores and represent the intensity of judgment perceptions concerning the alternative preferences of decision makers.

5.1.3.3.5 Consistency

An important matter for the quality of final decisions is the consistency of judgments formulated by the decision maker during the paired comparison process. Consistency is considered as a prerequisite of rational thinking. However, in practice, it is almost impossible to become completely consistent. New information can be learned only if a certain degree of inconsistency is allowed. AHP does not require an excellent consistency. It allows inconsistency but measures inconsistency at each judgment. A consistency ratio proposed by Saaty is used to measure the consistency of paired comparison judgments (Saaty, 1980: 21).

5.1.3.3.6 Group Decision

AHP allows the assessment of judgments of several individuals in the paired comparison process. This is a critical issue. When it is assumed that all members of a group will make judgments for all criteria, these judgments should be combined to present reconciliation. There are some methods recommended in the literature in this respect. These are as follows (Saaty, 1980: 19; Rangone, 1996: 110; Liberatore et al., 1997: 604; Zakarian and Kusiak, 1999:88; Armacost et al., 1994: 74).

- Group members reach reconciliation through discussion.
- A facilitator is assigned to path way to reconciliation out of judgment of members.
- Supplementing both judgments through a mathematical expression (for instance, geometrical mean).

The most common one of these methods is to achieve reconciliation through geometrical mean.

5.1.3.3.7 Sensitivity Analysis

After the alternatives are ranked, the results of the established model should be reviewed. The review will point out to the necessary corrections to be made in relation to the judgments or hierarchical structure. An important component of this review is to assess how sensitive the ranks of alternatives and final decision are towards changes in the judgments.

5.1.4 Expert Choice Software Package

Expert Choice (EC) software package has been developed by Expert Choice firm as the software program of Analytical Hierarchy Method. EC is decision support tool used in the analysis of complicated problems. It allows decision makers to view the decision problem in a hierarchical structure in a very simple and easy manner, to make the necessary paired judgments and to calculate the relative priorities automatically with the eigen value approach. While performing paired comparison, the decision maker can prefer any one of verbal, digital or graphical comparison alternatives. Besides, it is a program which is suitable for individual analysis or group-based analysis. Throughout the world, a great number of private firms and public administrations employ Expert Choice software in various fields (Expert Choice Tutorials, 2000:6).

5.2 RESEARCH DESIGN

5.2.1 Use Of Fuzzy TOPSIS Method In Supplier Selection in Public Software Tenders

In this study, the most appropriate supplier out of potential software suppliers will be selected through the FTOPSIS method developed by Chen (2000). In line with the algorithm of the method, significance weights of criteria matrix and fuzzy decision matrix are formed after the decision criteria of decision makers as well as their evaluations for alternatives according to the decision criteria are transformed into triangular fuzzy numbers. Afterwards, fuzzy decision matrix normalized following a series of calculations and weighted normalized fuzzy decision matrix is obtained. Distances of each alternative from fuzzy ideal solutions are calculated with the help of weighted normalized fuzzy decision matrix and priority ranking is made for alternatives with proximity coefficients found for each alternative.

5.2.2 Use of AHP Method in Supplier Selection in Public Software Tenders

Analytical Hierarchy Process (AHP) developed by Saaty is a multi-criteria decision making technique based on the paired comparison process which is present in the nature of human beings (Özdemir, 2003). This is a decision making mechanism which has never been taught to human beings but is adopted by them instinctively in face of a decision making problem (Saaty, 2000). Instinctive mechanism also considers the qualitative criteria in the decision process inherently. Thus, what strengthens AHP is that such factors which are difficult or impossible to address in other methods but affect decisions can be dealt with in AHP.

AHP has especially gained popularity in the field of multi-criteria decision making. It can determine the best alternative by assessing many alternatives in terms of several criteria. AHP can be applied to the individual and group decisions (Lai et al., 2002). What distinguishes AHP method from other methods is that it can configure multi-criteria and multi-period problems hierarchically (Saaty, 2000). While only quantitative factors were considered for decision making in the previous methods, both qualitative and quantitative factors which are important for decision making are taken into consideration owing to this process. Furthermore, analytical hierarchy process is a strong method to help decision maker take a healthy decision. This method includes paired comparison of elements through matrix according to a criterion determined at each level of the hierarchy as well as scaling of weights accordingly. This weighting is transformed into a large eigen vector problem and concluded with a normalized weights vector. These relative weights facilitate determination of a priority in the allocation of resources (Evren and Ülengin, 1992).

Another positive feature of AHP is that it allows group participation in decision making or problem solution. Actually, AHP regards opinions, judgments and facts accepted by the other people as the real appearance of the problem.

Even though group participation is a prerequisite for validation of the decision, the increase of group size can lead to difficulties in practice (Hasgül, 2004). Owing to the method, individuals integrate their information into the model either scientifically or instinctively to achieve a common solution. However, these information undergoes a logical process only through this method.

5.3 DATA COLLECTION

The first stage of the supplier evaluation period is to determine the criteria to be used in the evaluation. Various criteria which vary according to the conditions of the enterprise and affect the supplier selection decision are taken into consideration while making the supplier selection. Thus, supplier selection is a multi-criteria decision making problem.

Supplier criteria are used to measure the characteristics of the supplier with whom an enterprise works. Supplier criteria may contain certain important sub-criteria including financial power, management, technical capacity and quality systems of a supplier. Product performance criteria are those used to measure the functional characteristics of the purchased goods. It may contain such sub-criteria as quality, reliability, speed, capacity, care, durability, transport. As to service performance criteria, they are used to measure post-sales services and may contain such sub-criteria as client support, follow-up/monitoring and professionalism. Cost criteria constitute one of the most important criteria in supplier evaluation and selection. Transport cost, purchase cost, taxes etc. may be included in this group of criteria.

Traditional supplier evaluation methods would consider only financial criteria in the decision making process (Sung Ho Ha , Ramayya Krishnan, "A Hybrid Approach To Supplier Selection For The Maintenance of A Competitive Supply Chain", Expert Systems with Applications, C:XXXIV, 2008,p. 1304.). However, ensuing methods revealed that price criterion is not sufficient alone for supplier evaluation and selection and some other criteria should also be considered along with it. One of the most comprehensive studies concerning the determination of supplier criteria is the study carried out by Dickson in 1966 with 273 purchase manager and specialists selected out of USA and Canada National Society of Purchase Managers. At the end of this study, Dickson identified 23 basic criteria to consider in supplier evaluation and selection. This study of Dickson will shed light on the studies to be conducted in the future. These criteria are still used in many studies. The three most important criteria determined by Dickson which are quality, delivery and price have preserved their significance in almost all studies (H. Ahmet Akdeniz, Timur Turgutlu, "Supplier Selection On Retail: Analysis With Two Multi – Criteria Evaluation Methodologies", Review of Social, Economic & Business Studies, C:IX, No:10). In ensuing years, 23 criteria of Dickson (1966) were developed and expanded with the advent of new business requirements.

In literature, there are many studies which deal with the problem of supplier selection. When the studies concerning supplier selection are examined, it is seen that, following the study of Dickson, researchers started to use various criteria in the studies on supplier selection. Weber et al. examined the studies which had been conducted in the literature in relation to supplier selection from 1966 to 1990 and detected that price, delivery time and quality were the most common criteria. In a similar study, Wilson also addressed the importance of selection criteria and determined that criteria included quality, service, price and delivery time, respectively. Verma and Pulman stated in their study that the criterion of flexibility has also gained importance recently in supplier selection in addition to the abovementioned criteria.

In his study, Dickson interviewed with 273 purchase specialist and managers and determined 23 criteria which are of importance in supplier evaluation were determined via questionnaires. Quality, delivery, performance history, warranty and assurance policy and production equipments were determined as the most important criteria, respectively. Weber et al. (1991) examined 74 articles which had been carried out in the literature on supplier selection from 1966 to 1990. It was detected that net price became the most frequently discussed criteria in the literature with 61 articles. It was followed by the Delivery with 44 articles and Quality with 40 articles (Akdeniz and Turgutlu, 2007: 3).

5.4 DATA ANAYSIS

5.4.1 Identification of Criteria and Alternatives

Dickson's study and meetings with experts became decisive in determination of the criteria identified in this study. Firstly, 22 criteria had been determined. A questionnaire was developed with these criteria and it was applied to different top managers of 5 different public administrations. It's shown in Appendix A. The results of the questionnaire were calculated in a statistical software programme named MINITAB. Mean weight values were received from MINITAB. The highest mean weight values were ranked. Thus, the first 10 criteria were determined to use in AHP and TOPSIS techniques.

1. Technical competence of the offered software: The software should offer a structure enabling integrity in such processes as entering, deleting and updating data and its technical characteristics should meet the needs of the enterprise completely. The software should be adaptable to changes, if necessary, to meet the special requirements.
2. Number of staff of the firm and expertise of the key personnel: Qualifications and fields of expertise of the software project team should be specified.
3. Turnover of the firm in the last year: This is the display of firm's income statement showing the total turnover in the last year.
4. Meeting the pre-determined procedure, privacy and reliability criteria: Software should be in competent with the local and sectoral legislation in the environment where the enterprise is located and also should answer easily to the changes in these legislations.
5. Contracts previously undertaken by the firm in line with similar terms of reference: This is the total price of projects indicating the work amount undertaken and accomplished by the firm in relation to the offered software.
6. Quality standard certificates of the firm: These are the documents showing the quality level of the software of the firm.
7. Price quoted by the firm: The criterion of cost includes the costs related to the software, training and communication.
8. Eagerness of the firm for the business: The firm is expected to be able to perform its business in conformity with the technical competence of the software as well as to have eagerness to perform it.
9. Duration of the firm's operation in the software sector: This shows how much the firm has operated in the field of software.
10. Warranty/maintenance period offered by the firm: This is the period when the software is adapted to the characteristics of the public administration and installed within the public administration.

5.4.2 Application Steps of the Hybrid Analytical Hierarchy Process Method And TOPSIS Model

Analytical Hierarchy Process (AHP) is a mathematical theory developed by Thomas L. Saaty from Pennsylvania University in the mid-1970s to be used for measurement and decision making (Saaty and Niemira, 2006: 1). AHP was commonly studied in the literature and was used in almost all applications related to the multiple decision making (Ho, 2008: 211). It can be argued that the reason of its popularity relies on its ease of understanding.

Application steps of the AHP method is as follows:

1st Step, Establishing the Hierarchic Structure:

A decision hierarchy is created starting from the top with the aim of making a decision. Criteria take place at the middle level while alternatives are found at the lowest level (Saaty, 2008: 85).

2nd Step, Determination of Dual Comparison Matrices (A) and Superiorities:

After the objective, criteria and sub-criteria are determined; the dual comparison matrix given in the following expression (n x n) is established to determine the importance degrees of criteria and sub-criteria (Saaty, 1990: 12). The decision maker compares criteria or alternatives dyadically for criteria matrix or alternative matrix.

$$A = \begin{bmatrix} 1 & a_{21} & a_{31} & \cdots & a_{n1} \\ 1/a_{21} & 1 & a_{32} & \cdots & a_{n2} \\ 1/a_{31} & 1/a_{32} & 1 & \cdots & a_{n3} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 1/a_{n1} & 1/a_{n2} & 1/a_{n3} & \cdots & 1 \end{bmatrix}_{nxn}$$

Relative importance of each criterion included in the following equation in terms of its contribution to the objective and superiority of each objective in terms of the criteria are determined through the dual comparison method according to the judgments of the executors in **Table 1**.

Table 1 AHP Importance Scale (Saaty, 1990: 15)

Numeric	Value Definition
1	Elements are equally important or the executor remains indifferent between them.
3	The 1st element is slightly more important than the 2nd one or slightly more preferred.
5	The 1st element is much more important or preferred than the 2nd one.
7	The 1st element is highly more important or preferred than the 2nd one.
9	The 1st element is extremely more important or preferred than the 2nd one.
2, 4, 6, 8	Intermediate values

3rd Step, Determination of Eigenvector (Vector of Relative Importance):

Subsequent step following the dual comparison matrices is the calculation of the eigenvector showing the importance of each element in the relevant matrix in relation to the others (Sipahioğlu, 2008: 5). Nx1 dimension eigenvector of the matrix is determined as follows:

When it is: i=1, 2, 3, …, n and j=1, 2, 3, …, n ;

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \qquad w_i = \frac{\sum_{j=1}^{n} b_{ij}}{n}$$

In order to determine the percentage importance distributions of criteria, column vectors in the form of W = [wi]n x 1 should be calculated. W column vector is obtained through the arithmetic mean of the line elements of the matrix which are established by the bij values specified in the above-given equation.

4th Step, Calculation of the Consistency of the Eigen value:

The consistency rate (CR) is calculated for each dual comparison matrix and this rate can be 0,10 at maximum. A consistency rate higher than 0,10 shows an inconsistency in the judgments of the decision maker. In this case, the judgments should be improved. To obtain the CR value, firstly the biggest eigenvector of A matrix (λmax) needs to be calculated.

When it is: i=1,2,3,…,n and j=1,2,3,…,n,

$$D = \lfloor a_{ij} \rfloor_{nxn} \times [w_i]_{nx1} = [d_i]_{nx1}$$

$$\lambda_{max} = \frac{\sum_{i=1}^{n} \frac{d_i}{w_i}}{n}$$

Another value needed to calculate the consistency rate is random index. The data including the RI values which consist of constant numbers and are determined according to the n value are given in the following **Table 2**. The calculation of CR value in line with this information is specified in the following equation.

$$CR = \frac{\lambda - n}{(n - 1) \cdot RI}$$

Table 2 Random Index Data (Güner, 2005: 42)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0,58	0,9	1,12	1,24	1,32	1,41	1,45	1,49

5th Step, Obtaining the General Result of the Hierarchic Structure: The previous four phases are calculated for the whole hierarchic structure. At this phase, superiority column vectors at the size of mx1 created by each one of the *n* criteria found in the hierarchic structure are united and DW decision matrix at the size of m x n is formed. R result vector is achieved through the multiplication of the obtained matrix with the inter-criteria W superiority vector.

When it is: i=1,2,3,…,m and j=1,2,3,…,n,

$$DW = \lfloor w_{ij} \rfloor_{mxn}$$

$$R = DW \times W$$

AHP method was used in order to obtain the weights of selection criteria. Expert Choice program was used for the application of the AHP method.

As shown in **Figure 1**, the proposed firm selection scheme can be divided into three main functions: "collecting info" which collects the decision criteria, "criteria weighting" which processes criteria weighting using AHP methods based on Expert Choice which is a software package of AHP allows the decision maker to perform the practice in a rapid and correct manner, and "alternatives ranking" which finalizes the process of firm selection using TOPSIS method.

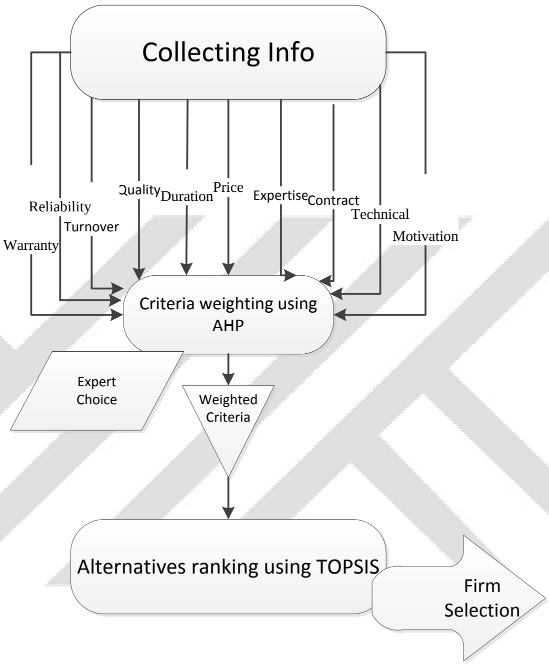

Figure 1 Hybrid AHP and TOPSIS based firm selection

At Expert Choice program, criteria were identified and the hierarchic structure given in the **Figure 2** was formed with the aim of selecting the best supplier. Weights of criteria used for TOPSIS for sorting criteria. Five candidate firms were evaluated through the criteria (Dickson G. W., 1966, Anderson et al., 1997; Chan and Chan, 2004; Liu and Hui, 2005; Narasimahn, 1983) used in the firm selection.

After the hierarchic structure is formed, the subsequent step is to create the dual comparison matrices. Here, while the dual comparison matrices are formed, the answers given by the experts to compare each criterion with another are processed into the matrix. These answers received from the experts were entered into Expert Choice program and the importance degrees of these criteria were obtained. While importance degrees of these criteria were obtained, inconsistency rates of expert judgments were controlled. If the inconsistency rates of the expert had turned out to be higher than 0.1, the judgments should have been reviewed.

The **Figure 2** gives the comparisons of the criteria with one another. The consistency rate of the dual comparison matrix is 0.05.

	Price	Duration	Employee	Quality	Contract	Turnover	Technical	Willing	Security	Varanty
Price		1,0	7,0	7,0	5,0	3,0	9,0	3,0	7,0	7,0
Duration			6,0	2,0	2,0	3,0	7,0	1,0	5,0	3,0
Employee				3,0	5,0	7,0	3,0	6,0	2,0	2,0
Quality					1,0	7,0	5,0	3,0	5,0	1,0
Contract						5,0	5,0	1,0	5,0	2,0
Turnover							9,0	3,0	7,0	5,0
Technical								8,0	2,0	5,0
Willing									7,0	3,0
Security										3,0
Varanty	Incon: 0,05									

Figure 2 Framework of the criteria

Comparisons of the firms on the basis of criteria, their relative priorities and inconsistency rates are indicated in the following tables. As the inconsistency rates of all matrices are below 0.10, we can say that the assessments are reliable. In the **Figure 3**, the values obtained after all the comparisons and showing the relative priorities of the suppliers are given. Accordingly, the most important criterion is the technique (0.296). On the other hand, the criterion with the lowest importance rate is price (0.015).

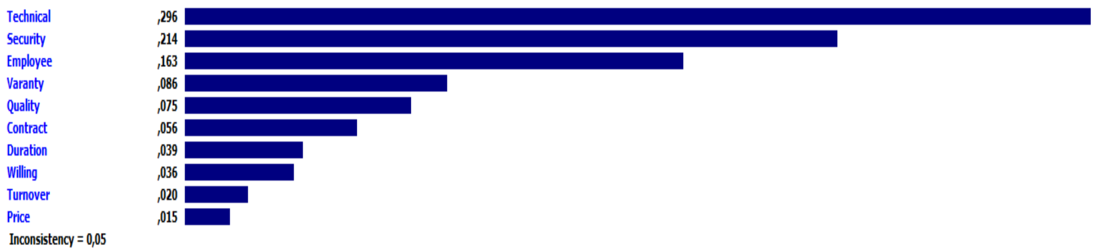

Figure 3 Comparisons of the criteria

The values which were obtained after all the comparisons and show the relative priorities of the firms are included in the **Figure 4.** Accordingly, the selection order is as such: Company A (0.363), Company B (0.214), Company C (0.211), Company D (0.122) and Company E (0.089).

Figure 4 Score Orders of Firms

Considering the order of the firms obtained according to the price criterion in the **Figure 5**, it is seen that the relative priority degrees of Company D, Company A, Company E, Company B and Company C are 0.505, 0.222, 0.143, 0.089 and 0.042, respectively. The consistency rate of the matrix is 0.04.

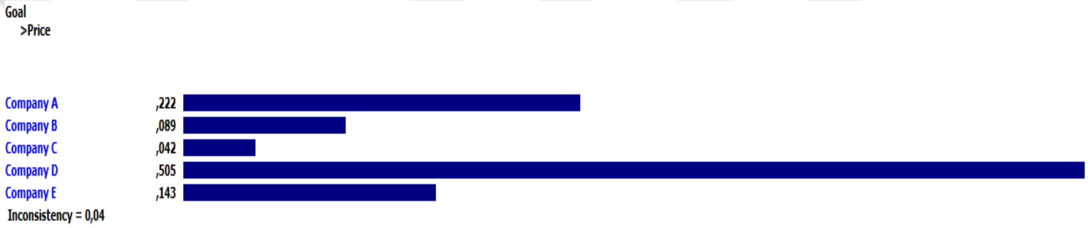

Figure 5 Comparison of the Firms on the Basis of the Price Criterion

Considering the order of the firms according to the criterion assessing the duration of the firm to work in the software sector in the **Figure 6**, it is seen that the relative priority degrees of Company B, Company C, Company D, Company A and Company E are 0.241, 0.241, 0.241, 0.241 and 0.034, respectively. The consistency rate of the matrix is 0.00.

Figure 6 Comparison of the Firms on the Basis of Working in Software Sector

Considering the order of the firms according to the criterion related to the number of expert employees in the firm in the **Figure 7**, the relative priority degrees of Company A, Company B, Company C, Company D and Company E are 0.372, 0.347, 0.151, 0.088 and 0.041, respectively. The consistency rate of the matrix is 0.03.

Figure 7 Comparison of the Firms on the Basis of the Criterion related to the Employees

Considering the order of the firms according to the criterion related to the quality certifications that the firms have in the **Figure 8**, it is seen that the relative priority degrees of Company A, Company C, Company B, Company E and Company D are 0.478, 0.320, 0.112, 0.059 and 0.030, respectively. The consistency rate of the matrix is 0.07.

Figure 8 Comparison of the Firms on the Basis of the Quality Certifications

Considering the order of the firms according to the criterion related to the size of the contracts undertaken by the firm so far in the **Figure 9**, it is seen that the relative priority degrees of Company B, Company C, Company D, Company A and Company E are 0.231, 0.231, 0.231, 0.231 and 0.077, respectively. The consistency rate of the matrix is 0.00.

Figure 9 Comparison of the Firms on the Basis of the Criterion related to the Size of the Contracts Undertaken by the Firms

Considering the order of the firms according to the criterion associated with the turnover amounts of firms **in the Figure 10**, it is seen that the relative priority degrees of Company B, Company A, Company C, Company D and Company E are 0.358, 0.358, 0.160, 0.088 and 0.036. The consistency rate of the matrix is 0.06.

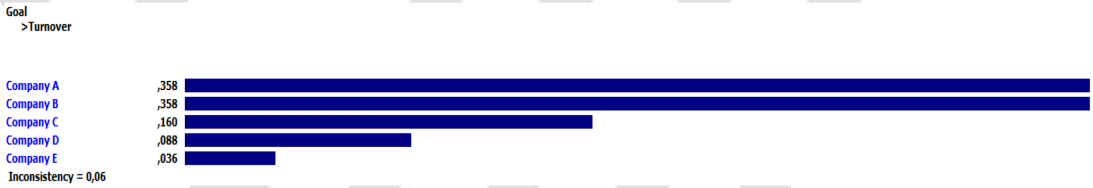

Figure 10 Comparison of the Firms on the Basis of the Criterion related to the Turnover Amounts

Considering the order of the firms according to the criterion related to the technical competence of the software in the **Figure 11**, it is seen that the relative priority degrees of Company A, Company B, Company C, Company D and Company E are 0.539, 0.182, 0.168, 0.074 and 0.037. The consistency rate of the matrix is 0.03.

Figure 11 Comparison of the Firms on the Basis of the Criterion related to the Technical Competence of the Software Proposed by them

Considering the order of the firms according to the criterion evaluating the willingness to do business in the **Figure 12**, it is seen that the relative priority degrees of Company B, Company C, Company A, Company E and Company D are 0.234, 0.234, 0.234, 0.194 and 0.103, respectively. The consistency rate of the matrix is 0.03.

Figure 12 Comparison of the Firms on the Basis of the Criterion related to the Willingness to Do Business

Considering the order of the firms according to the criterion related to the privacy in the **Figure 13**, it is seen that the relative priority degrees of Company A, Company C, Company B, Company E and Company D are 0.417, 0.274, 0.147, 0.098 and 0.064, respectively. The consistency rate of the matrix is 0.02.

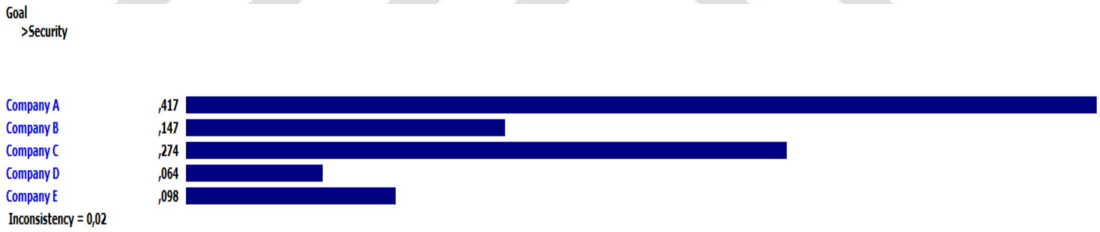

Figure 13 Comparison of the Firms on the Basis of the Criterion related to the Privacy

Considering the order of the firms according to the criterion associated with the warranty period proposed by the firms in the **Figure 14**, it is seen that all the firms have equal priority degrees as they all propose the same period and the consistency rate of the firm is 0.00.

Figure 14 Comparison of the Firms on the Basis of the Warranty Period Proposed by them

5.4.3 Application Steps of the Fuzzy TOPSIS Method

As it is known, it is rather difficult to decide under uncertainty. An environment where a decision is taken under uncertainty and objectives and limitations are not obvious is called as fuzzy. In such environments, decision-taking can be facilitated by benefiting from the methods based on Fuzzy Clusters Theory developed by Zadeh (1965). In this respect, FTOPSIS was developed to eliminate uncertainties resulting from human judgments in the decision-taking process by extending TOPSIS method with the fuzzy cluster theory.

It was determined that the decision as regards to the most appropriate supplier; should be given through FTOPSIS which is an effective and practicable method being able to criticise many criteria. In this study, FTOPSIS was implemented with the algorithm developed by Chen (Chen, 2000, p: 1-9). The steps taken in line with the algorithm of the method are as follows:

The algorithm of FTOPSIS can be summarized as follows step by step in line with the given data (Chen, 2000, p: 6):

Step 1: Determining the jury consisting of the decision takers, alternatives and selection criteria,

Step 2: Evaluating the decision criteria of decision-takers as well as alternatives according to the decision criteria through linguistic variables,

Step 3: Determining the importance weights of criteria,

Step 4: Forming the fuzzy decision matrix and normalized fuzzy decision matrix,

Step 5: Forming the weighted normalized fuzzy decision matrix,

Step 6: Determining the fuzzy positive and negative ideal solutions,

Step 7: Calculating the distances from the fuzzy ideal solutions,

Step 8: Calculating the proximity coefficients,

Step 9: Ordering alternative suppliers

Step 1: One of the most important stages of FTOPSIS method is to determine the hierarchical structure properly. Hierarchical structure of the decision problem was determined to be as follows in line with the examinations. The hierarchical structure of the decision problem which indicates the supplier alternatives Ai = (A1,A2,A3,A4,A5) and decision criteria through which decision-takers will evaluate these alternatives Ci = (C1,C2,C3,C4,C5,C6,C6,C7,C8,C9,C10) is as follows.

Step 2: In order to assess the importance weights of decision criteria, linguistic variables ranging from the lowest level to the highest level as well as their numerical equivalents are displayed as triangular fuzzy numbers in the **Table 3**.

Table 3 Linguistic expressions used in the assessment of decision criteria and their equivalents as triangular fuzzy numbers

Very Poor (VP)	(0.0,0.0,0.1)
Poor (P)	(0.0,0.1,0.3)
Medium Poor (MP)	(0.1,0.3,0.5)
Fair (F)	(0.3,0.5,0.7)
Medium Good (MG)	(0.5,0.7,0.9)
Good (G)	(0.7,0.9,1.0)
Very Good (VG)	(0.9,1.0,1.0)

Source: Chen, C. T. (2000). Extensions of the TOPSIS for Group Decision-Making under Fuzzy Environment. Fuzzy Sets and Systems, 114, p. 5.

Linguistic variables used by the decision takers to assess the alternatives according to the decision criteria from very bad to very good and their numerical equivalents as triangular fuzzy numbers are displayed in the **Table 4**.

Table 4 Linguistic expressions used to assess alternatives and their equivalents as triangular fuzzy numbers

Very Low (ML)	(0,0,1)
Low (L)	(0,1,3)
Medium Low (ML)	(1,3,5)
Medium (M)	(3,5,7)
Medium High (MH)	(5,7,9)
High (H)	(7,9,10)
Very High (VH)	(9,10,10)

Source: Chen, C. T. (2000). Extensions of the TOPSIS for Group Decision-Making under Fuzzy Environment. Fuzzy Sets and Systems, 114, p. 5.

Decision-takers evaluate the importance weights of criteria by using the linguistic variables given in the above **Table 5**. The following table indicates the results of how the decision-takers have evaluated the decision criteria through linguistic variables. These linguistic ratings, employed by specialists to represent the fuzzy performance under certain criteria, are very good (VG), good (G), medium good (MG), fair (F), medium poor (MP), poor (P) and very poor (VP).

Table 5 Importance Weights of Criteria By Using The Linguistic Variables

Criteria		**Decision-Takers**				
		DT1	**DT2**	**DT3**	**DT4**	**DT5**
C1	Price quoted by the firm	G	MG	MG	G	G
C2	Time during which the firm worked in the field of software	G	G	VG	MG	G
C3	Number of personnel of the firm and expertise of the key personnel	VG	G	VG	G	VG
C4	Quality standard certificates owned by the firm	G	VG	MG	MG	MG
C5	The size of projects undertaken by the firm in line with a similar terms of reference	G	MG	VG	MG	VG
C6	Turnover amount of the firm in the last year	G	MG	MG	MG	MG
C7	Technical competence of the proposed software	G	VG	VG	VG	VG
C8	Motivation of the firm to undertake this business	MG	VG	VG	G	M
C9	Meeting the predetermined procedures, safety and confidentiality criteria	MG	G	MG	G	MG
C10	Warranty and maintenance duration proposed by the firm	MG	MG	MG	MG	G

Assessment results are transformed into triangular fuzzy numbers in order to use them in the necessary steps for creating the importance weights in **Table 6** for the criteria.

Table 6 Importance Weights of Criteria By Using The Fuzzy Variables

Criteria	Decision-Takers				
	DT1	DT2	DT3	DT4	DT5
C1	0.7,0.9,1.0	0.5,0.7,0.9	0.5,0.7,0.9	0.7,0.9,1.0	0.7,0.9,1.0
C2	0.7,0.9,1.0	0.7,0.9,1.0	0.9, 1.0,1.0	0.5,0.7,0.9	0.7,0.9,1.0
C3	0.9, 1.0,1.0	0.7,0.9,1.0	0.9, 1.0,1.0	0.7,0.9,1.0	0.9, 1.0,1.0
C4	0.7,0.9,1.0	0.9, 1.0,1.0	0.5,0.7,0.9	0.5,0.7,0.9	0.5,0.7,0.9
C5	0.7,0.9,1.0	0.5,0.7,0.9	0.9, 1.0,1.0	0.5,0.7,0.9	0.9, 1.0,1.0
C6	0.7,0.9,1.0	0.5,0.7,0.9	0.5,0.7,0.9	0.5,0.7,0.9	0.5,0.7,0.9
C7	0.7,0.9,1.0	0.9, 1.0,1.0	0.9, 1.0,1.0	0.9, 1.0,1.0	0.9, 1.0,1.0
C8	0.5,0.7,0.9	0.9, 1.0,1.0	0.9, 1.0,1.0	0.7,0.9,1.0	0.3,0.5,0.7
C9	0.5,0.7,0.9	0.7,0.9,1.0	0.5,0.7,0.9	0.7,0.9,1.0	0.5,0.7,0.9
C10	0.5,0.7,0.9	0.5,0.7,0.9	0.5,0.7,0.9	0.5,0.7,0.9	0.7,0.9,1.0

Decision-takers evaluate the supplier alternatives according to each one of the criteria by using the linguistic variables indicated in the table which demonstrates the Linguistic Expressions used in Assessing the Alternatives and their Equivalents as Triangular Fuzzy Numbers. The following **Table 7** demonstrates the results of how the decision-takers have evaluated the alternatives according to each one of the criteria by using the linguistic variables. The linguistic weights for representing the importance of criteria are very high (VH), high (H), medium high (MH), medium (M), medium low (ML), low (L) and very low (VL).

Table 7 Decision-takers' assessments for alternatives with linguistic variables

Criteria	Alternatives	Decision-takers				
		DT1	DT2	DT3	DT4	DT5
C1	A1	H	VL	H	MH	ML
	A2	ML	L	ML	MH	H
	A3	L	ML	L	ML	VL
	A4	VH	MH	VH	H	VL
	A5	MH	H	MH	MH	L
C2	A1	H	VL	H	H	H
	A2	H	L	H	H	H
	A3	H	ML	H	H	H
	A4	H	MH	H	H	H
	A5	VL	H	L	MH	L
C3	A1	H	VL	VH	VH	H
	A2	H	L	H	VH	H
	A3	ML	ML	H	H	MH
	A4	L	MH	L	MH	ML
	A5	VL	H	L	ML	L
C4	A1	VH	VL	H	VH	VH
	A2	ML	ML	ML	MH	MH
	A3	MH	L	MH	H	H
	A4	VL	H	VL	L	L
	A5	L	MH	L	ML	ML
C5	A1	H	VL	H	H	H
	A2	H	L	H	H	H
	A3	H	ML	H	H	H
	A4	H	MH	H	H	H
	A5	ML	H	L	ML	MH
C6	A1	MH	VL	VH	H	H
	A2	MH	L	VH	H	H
	A3	ML	ML	H	MH	MH
	A4	L	MH	MH	ML	ML
	A5	L	H	ML	L	L

Table 7 (Cont.) Decision-takers' assessments for alternatives with linguistic variables

C7	A1	H	VL	VH	VH	H
	A2	H	ML	H	MH	H
	A3	MH	L	H	H	H
	A4	ML	H	ML	MH	H
	A5	VL	MH	ML	MH	ML
C8	A1	MH	MH	MH	MH	H
	A2	MH	MH	MH	MH	MH
	A3	MH	MH	MH	MH	L
	A4	MH	MH	MH	ML	MH
	A5	MH	MH	MH	MH	L
C9	A1	H	MH	MH	H	VH
	A2	H	MH	MH	H	ML
	A3	H	MH	MH	H	H
	A4	H	MH	MH	H	VL
	A5	H	MH	MH	H	L
C10	A1	VH	MH	MH	H	MH
	A2	VH	MH	MH	H	MH
	A3	MH	MH	MH	H	MH
	A4	ML	MH	MH	H	MH
	A5	VL	MH	MH	H	MH

Assessment results were transformed into triangular fuzzy numbers in the following **Table 8** in order to use them in the necessary steps for creating the fuzzy decision matrix.

Table 8 Expression of Assessment Results of Alternatives as Triangular Fuzzy Numbers

Criteria	Alternatives	Decision-takers				
		DT1	DT2	DT3	DT4	DT5
C1	A1	(7,9,10)	(0,0,1)	(7,9,10)	(5,7,9)	(5,7,9)
	A2	(1,3,5)	(0,1,3)	(1,3,5)	(5,7,9)	(7,9,10)
	A3	(0,1,3)	(1,3,5)	(0,1,3)	(1,3,5)	(0,0,1)
	A4	(9,10,10)	(5,7,9)	(9,10,10)	(7,9,10)	(0,0,1)
	A5	(5,7,9)	(7,9,10)	(5,7,9)	(5,7,9)	(0,1,3)
C2	A1	(7,9,10)	(0,0,1)	(7,9,10)	(7,9,10)	(7,9,10)
	A2	(7,9,10)	(0,1,3)	(7,9,10)	(7,9,10)	(7,9,10)
	A3	(7,9,10)	(1,3,5)	(7,9,10)	(7,9,10)	(7,9,10)
	A4	(7,9,10)	(5,7,9)	(7,9,10)	(7,9,10)	(7,9,10)
	A5	(0,0,1)	(7,9,10)	(0,1,3)	(5,7,9)	(0,1,3)
C3	A1	(7,9,10)	(0,0,1)	(9,10,10)	(9,10,10)	(7,9,10)
	A2	(7,9,10)	(0,1,3)	(7,9,10)	(9,10,10)	(7,9,10)
	A3	(1,3,5)	(1,3,5)	(7,9,10)	(7,9,10)	(5,7,9)
	A4	(0,1,3)	(5,7,9)	(0,1,3)	(5,7,9)	(1,3,5)
	A5	(0,0,1)	(7,9,10)	(0,1,3)	(1,3,5)	(0,1,3)
C4	A1	(9,10,10)	(0,0,1)	(7,9,10)	(9,10,10)	(9,10,10)
	A2	(1,3,5)	(1,3,5)	(1,3,5)	(5,7,9)	(5,7,9)
	A3	(5,7,9)	(0,1,3)	(5,7,9)	(7,9,10)	(7,9,10)
	A4	(0,0,1)	(7,9,10)	(0,0,1)	(0,1,3)	(0,1,3)
	A5	(0,1,3)	(5,7,9)	(0,1,3)	(1,3,5)	(1,3,5)
C5	A1	(7,9,10)	(0,0,1)	(7,9,10)	(7,9,10)	(7,9,10)
	A2	(7,9,10)	(0,1,3)	(7,9,10)	(7,9,10)	(7,9,10)
	A3	(7,9,10)	(1,3,5)	(7,9,10)	(7,9,10)	(7,9,10)
	A4	(7,9,10)	(5,7,9)	(7,9,10)	(7,9,10)	(7,9,10)
	A5	(1,3,5)	(7,9,10)	(0,1,3)	(1,3,5)	(5,7,9)
C6	A1	(5,7,9)	(0,0,1)	(9,10,10)	(7,9,10)	(7,9,10)
	A2	(5,7,9)	(0,1,3)	(9,10,10)	(7,9,10)	(7,9,10)
	A3	(1,3,5)	(1,3,5)	(7,9,10)	(5,7,9)	(5,7,9)
	A4	(0,1,3)	(5,7,9)	(5,7,9)	(1,3,5)	(1,3,5)
	A5	(0,1,3)	(7,9,10)	(1,3,5)	(0,1,3)	(0,1,3)

Table 8 (Cont.) Expression of Assessment Results of Alternatives as Triangular Fuzzy Numbers

C7	A1	(7,9,10)	(0,0,1)	(9,10,10)	(9,10,10)	(7,9,10)
	A2	(7,9,10)	(1,3,5)	(7,9,10)	(5,7,9)	(7,9,10)
	A3	(5,7,9)	(0,1,3)	(7,9,10)	(7,9,10)	(7,9,10)
	A4	(1,3,5)	(7,9,10)	(1,3,5)	(5,7,9)	(7,9,10)
	A5	(0,0,1)	(5,7,9)	(1,3,5)	(5,7,9)	(1,3,5)
C8	A1	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)	(7,9,10)
	A2	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)
	A3	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)	(0,1,3)
	A4	(5,7,9)	(5,7,9)	(5,7,9)	(1,3,5)	(5,7,9)
	A5	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)	(0,1,3)
C9	A1	(7,9,10)	(5,7,9)	(5,7,9)	(7,9,10)	(9,10,10)
	A2	(7,9,10)	(5,7,9)	(5,7,9)	(7,9,10)	(1,3,5)
	A3	(7,9,10)	(5,7,9)	(5,7,9)	(7,9,10)	(7,9,10)
	A4	(7,9,10)	(5,7,9)	(5,7,9)	(7,9,10)	(0,0,1)
	A5	(7,9,10)	(5,7,9)	(5,7,9)	(7,9,10)	(0,1,3)
C10	A1	(9,10,10)	(5,7,9)	(5,7,9)	(7,9,10)	(5,7,9)
	A2	(9,10,10)	(5,7,9)	(5,7,9)	(7,9,10)	(5,7,9)
	A3	(5,7,9)	(5,7,9)	(5,7,9)	(7,9,10)	(5,7,9)
	A4	(1,3,5)	(5,7,9)	(5,7,9)	(7,9,10)	(5,7,9)
	A5	(0,0,1)	(5,7,9)	(5,7,9)	(7,9,10)	(5,7,9)

Step 3: Table of Importance Weights of Decision Criteria is a matrix consisting of importance weights of decision criteria. The following formula is used to obtain this matrix.

$$\tilde{w}_j = \frac{1}{K}[\tilde{w}_j^1(+)\tilde{w}_j^2(+)\cdots(+)\tilde{w}_j^K],$$

$$\tilde{x}_{ij} = \frac{1}{K}[\tilde{x}_{ij}^1(+)\tilde{x}_{ij}^2(+)\cdots(+)\tilde{x}_{ij}^K]$$

The average of five decision takers' assessments for each decision criteria as triangular fuzzy number is taken and importance weights are calculated to obtain an assessment for each decision criteria. Thus, in **Table 9** of Importance Weights of Decision Criteria is created.

Table 9 Importance Weights of Decision Criteria

Criteria		Weights
C1	Price quoted by the firm	(0.62,0.82,0.96)
C2	Time during which the firm worked in the field of software	(0.7,0.88,0.98)
C3	Number of personnel of the firm and expertise of the key personnel	(0.82,0.96,1)
C4	Quality standard certificates owned by the firm	(0.62,0.8,0.94)
C5	The size of projects undertaken by the firm in line with a similar terms of reference	(0.7,0.9,0.96)
C6	Turnover amount of the firm in the last year	(0.54,0.74,0.92)
C7	Technical competence of the proposed software	(0.9,0.98,1)
C8	Motivation of the firm to undertake this business	(0.66,0.82,0.92)
C9	Meeting the predetermined procedures, safety and confidentiality criteria	(0.58,0.78,0.94)
C10	Warranty and maintenance duration proposed by the firm	(0.54,0.74,0.92)

Step 4: Fuzzy Decision Matrix is constituted by benefiting from the results of the assessment of alternatives according to the decision criteria.

After constituting the Fuzzy Decision Matrix, it is considered that each decision criterion has a different importance weight and the weighted normalized fuzzy decision matrix is expressed as follows:

$$\tilde{V} = [\tilde{v}_{ij}]_{m \times n}, \quad i = 1, 2, \ldots, m, \quad j = 1, 2, \ldots, n,$$

The elements of this matrix are calculated as follows:

$$\tilde{v}_{ij} = \tilde{r}_{ij}(\cdot)\tilde{w}_j$$

Considering that each decision criterion has a different importance weight for decision-takers, the Weighted Normalized Fuzzy Decision Matrix is formed with the help of the Normalized Fuzzy Decision Matrix and Criterion Weights Table by using the above-given formulas.

The average of decision-takers' assessments for each alternative according to each decision criterion is taken respectively and a Fuzzy Decision Matrix is created so as to include one assessment for each alternative according to each decision criterion. Normalized Fuzzy Decision Matrix is constituted as a requirement of linear normalization method. Fuzzy Decision Matrix is indicated in the **Appendix E**.

In this study, as all criteria are benefit criteria, the biggest one of the 3rd components of fuzzy numbers in each column of Fuzzy Decision Matrix is taken into consideration and this value is divided into all column values in that column. The maximum value of the 3rd components of fuzzy numbers in all columns in the Fuzzy Decision Matrix is 9.8. Thus, all values are divided into 9.8 and Normalized Fuzzy Decision Matrix is obtained. The values in the table obtained as a result of normalization vary between [0 – 1]. Normalized Fuzzy Decision Matrix is indicated in the **Appendix E.**

Step 5: The Weighted Normalized Fuzzy Decision Matrix is obtained by multiplying the values given to the criteria for each alternative in the Normalized Fuzzy Decision Matrix with the importance weight of the criterion found in the respective column. Weighted Normalized Fuzzy Decision Matrix is indicated in the **Appendix E**.

Step 6: They are positive triangular fuzzy numbers normalized according to the weighted normalized fuzzy decision matrix and range between [0 – 1].

According to the model of Chen (2000) which is implemented in the present study, Fuzzy Positive Ideal Solution (A*) and Fuzzy Negative Ideal Solution (A-) will be n=10 for the decision problem with 10 criteria. Thus, as a consequence of the following equations;

$$A^* = (\tilde{v}_1^*, \tilde{v}_2^*, \ldots, \tilde{v}_n^*),$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \ldots, \tilde{v}_n^-),$$

A* will be as follows:

A*=[(1,1,1),(1,1,1),(1,1,1),(1,1,1),(1,1,1),(1,1,1),(1,1,1),(1,1,1),(1,1,1),(1,1,1)]

Step 7: In order to calculate the distances of alternatives from the Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS), firstly the distances of values of alternatives for the criteria in the Weighted Normalized Fuzzy Decision

Matrix from the FPIS and NPIS are calculated through the formula envisaged by the method of Vertex. This formula is as follows:

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

Later on, as per the following formula:

$$d_i^* = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^*), \quad i = 1, 2, \ldots, m,$$

$$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-), \quad i = 1, 2, \ldots, m,$$

The distances of an alternative from FPIS and FNIS for all criteria are added and this value indicates the distance of that alternative from FPIS and NPIS (di*, di-).

In this study, for each alternative in the Weighted Normalized Fuzzy Decision Matrix, the sum of the separate distances of that alternative's matrix values in the 10-criteria column from FPIS gives the distance of that alternative from FPIS (di*). Likewise, for each alternative, the sum of the separate distances of that alternative's matrix values in the 10-criteria column from FNIS provides the distance of the alternative from the FNIS (di-).

Distances of alternatives from FPIS for all criteria are indicated in the **Table 10**.

Table 10 Distance between Ai (i=1, 2, 3, 4, 5) and A for each criterion

Criteria	d(A1,A*)	d(A2,A*)	d(A3,A*)	d(A4,A*)	d(A5,A*)
C1	0,581232754	0,65094679	0,858710487	0,466282303	0,535921372
C2	0,415267226	0,405037898	0,384194609	0,332495685	0,676978694
C3	0,286331694	0,330778156	0,453310283	0,639373783	0,725822019
C4	0,409144738	0,638411798	0,497717405	0,802578276	0,746481924
C5	0,413712213	0,403106154	0,381899939	0,329228143	0,609026507
C6	0,50408637	0,493629217	0,583968433	0,681660393	0,759721008
C7	0,401226774	0,432182391	0,452502505	0,512354109	0,661334332
C8	0,435322659	0,460293444	0,538639284	0,516031267	0,538639284
C9	0,48884153	0,490752524	0,504962793	0,521747456	0,51102595
C10	0,448708205	0,448708205	0,485351605	0,533430819	0,564247394

Distances of alternatives from FNIS for all criteria are indicated in the **Table 11**.

Table 11 Distance between Ai (i=1, 2, 3, 4, 5) and A- for each criterion

Criteria	d(A1,A-)	d(A2,A-)	d(A3,A-)	d(A4,A-)	d(A5,A-)
C1	0,498031722	0,394249164	0,182115387	0,564244244	0,514683196
C2	0,645600969	0,668617152	0,700524624	0,770066465	0,367100446
C3	0,789781328	0,724892137	0,612606016	0,417421862	0,313442459
C4	0,634858784	0,435442809	0,577675523	0,230459283	0,315081068
C5	0,643545641	0,666224524	0,698100395	0,767598526	0,451484724
C6	0,559355503	0,580988257	0,498226871	0,390230623	0,295601238
C7	0,655819007	0,66382164	0,632560406	0,572311757	0,403491358
C8	0,648479934	0,624580937	0,530494859	0,560274322	0,530494859
C9	0,669693849	0,599564421	0,661903825	0,547700201	0,570169361
C10	0,648162451	0,648162451	0,618249826	0,558110396	0,507636533

For the 1st alternative found at the Weighted Normalized Fuzzy Decision Matrix, the distance of each criterion from (1, 1, 1) is calculated. Distances calculated for all criteria are added. The obtained result corresponds to the distance of the 1st alternative from A* (d1*). The same procedure is repeated for 5 alternatives. di* values are calculated for 5 alternatives. Likewise, the distance of each criterion from (0, 0, 0) is calculated for the 1st alternative. Distances calculated for all criteria are added. The obtained result corresponds to the distance of the 1st alternative from A- (d1-). The same procedure is repeated for 5 alternatives and di- values are calculated for 5 alternatives. The results of these calculations are seen in the **Table 12**.

Table 12 di* and di- values of alternatives

Alternatives	di*	di-
A1	4,383874164	6,393329189
A2	4,753846577	6,006543493
A3	5,141257344	5,712457733
A4	5,335182235	5,378417679
A5	6,329198485	4,269185241

Ai: i. Alternative, di*: i. Distance of alternative from FPIS, di-: i. Distance of alternative from FNIS

Step 8: After distances from FPIS and FNIS are calculated, proximity coefficients of all alternatives are calculated through the following formula:

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-}, \quad i = 1, 2, \ldots, m$$

Proximity coefficients of all alternatives are as follows, respectively:

Table 13 Proximity Coefficients of Alternatives

Alternatives	CCi
A1	0,593227
A2	0,558209
A3	0,526314
A4	0,502018
A5	0,402815

Step 9: The priority order of alternatives is obtained by sorting the proximity coefficients in descending order. As the proximity coefficients are sorted as CC1>CC2>CC3>CC4>CC5 in a descending order, preference order of alternatives is determined to be A1, A2, A3, A4 and A5.

Table 14 Proximity Coefficients of Alternatives and Sorting Table

Alternatives	Cci	Sorting
A1	0,593227	**1**
A2	0,558209	**2**
A3	0,526314	**3**
A4	0,502018	**4**
A5	0,402815	**5**

Ai: i. Alternative, CCi : i. Proximity coefficient of the alternative

CHAPTER VI

6. CONCLUSION & RECOMMENDATIONS

The study aimed at ensuring that an assessment is made about the firms, objective and scientific decisions are taken instead of subjective decisions and a fast decision making process including the specialized personnel working at different positions is created.

Public institutions encounter with numerous problems that can be characterized by conflicting criteria in the project management. The studies conducted in the area of Multiple Criteria Decision Making in the literature of Methodology or in the field of Multi-Attribute Decision Making/Analysis in cases where explicit and countable alternatives are in question at the beginning provide effective approaches and methods to help the decision takers in solving these multi-dimensional problems.

Making a selection out of the multi-attribute decision making techniques is a multi-attribute decision making problem at the same time. Specific problems can be encountered in the application of each multi-attribute decision making technique and the obtained results may differ. For the problem of making selection out of the alternative firms to realize the public software projects, AHP technique is preferred *as it facilitates the modeling of complex problems, it is suitable for the problem, it is easy to understand its theoretical background, it is easy to use, it is suitable for group decision making, it is commonly used and there are a vast number of software tools*. With this technique, both qualitative and quantitative criteria faced in the problems can be modeled together. Besides, dependence of the final decision on the personal opinions is reduced through paired comparisons. TOPSIS technique has been used for sorting criteria.

In order to better express the *verbal uncertainty* in the paired comparison judgments, fuzzy TOPSIS was used out of fuzzy methods as solution technique. When compared to other fuzzy AHP approaches, fuzzy TOPSIS method *has relatively more simple steps, allows for assessment of the lacking paired comparisons, is similar to the*

TOPSIS technique and has been commonly applied in the literature and thus, fuzzy TOPSIS method was preferred out of the fuzzy multiple criteria decision making approaches.

AHP and fuzzy TOPSIS techniques were applied to determine the criteria and select the firm to develop the software that the public institutions need. As the firm selection is the composition of many criteria and most of these criteria are non-physical, fuzzy set theory was used in the measurement. The results obtained with the AHP technique were evaluated in order to contribute to the analysis of the obtained results. Fuzzy TOPSIS results also gave the same order and importance weights did not change the order of the firms in both solutions.

Multiple criteria decision making methods constitute one of the topics on which the researchers have recently focused. In this study, scholarship student selection was made by using the multiple criteria decision making methods. The selection was made on the basis of AHP, a multiple criteria decision making method, and fuzzy TOPSIS, one of the fuzzy methods. Usage, analysis and visually advantages provided by the AHP technique and also Expert Choice program came into prominence in this study. It was seen that the ease of use and clearness of this program reduced the time loss which allegedly results from paired comparisons in the AHP technique.

The criteria identified in this study were determined by benefiting from the study of Dickson and the meeting held with the experts. Firstly, twenty-two criteria were determined. Dickson (1996) interviewed 273 buying specialists and managers, thus ten criteria which were used in the questionnaires applied in the study and affected the firm selection in software projects were determined by benefiting from 23 criteria included in the questionnaire, which has an important place in supplier assessment, as well as from the experiences of the interviewed experts. A questionnaire was prepared with these criteria, which was applied to senior executives of five different public institutions. The results of the questionnaire were calculated through a statistics software program called MINITAB. Mean weight values were also gained in MINITAB. The highest mean weight values were put in order. The first 10 criteria were created in order to be used in AHP and Fuzzy TOPSIS techniques.

When the proximity coefficients for five alternative firms included in the application, it is seen that A1 ranks first with the highest proximity coefficient. Besides, it is striking that proximity coefficients of the alternatives has a narrow range (0.50 – 0.59) and there are some alternatives with very close proximity coefficients (A3 and A4). In such cases where the qualities of alternatives are very similar and thus, taking a decision is difficult, FTOPSIS method facilitates the decision making process.

While expanding the group to answer the questionnaire, the factors to be considered include the expertise areas of individuals, their familiarity to an interest in the topic, their abilities to think analytically, whether they are authorised and responsible, timing and workload. In this study, the questionnaire was answered by five senior executives from five public institutions. It is clear that an unnecessarily high number of assessments and those made by inappropriate individuals can not yield realistic and useful results.

For sound and proper assessments, the questionnaires should be filled in correctly and completely. At the same time, information security and confidentiality gain a particular importance in the questionnaire applications carried out in the public institutions. The participants want to guarantee information security for the opinions and assessments that they will put forward. Thus, the objective of the study should be clearly explained to the participants. Researcher watched over the participants while they are filling in the questionnaire in order to emphasize that filing in the parts related to the application objective, methodology, arguments and information forms correctly, clearly, convincingly and in detail will certainly give prominence to their offers among other project alternatives.

In the present study, targets and criteria affecting the assessment of firm selection in the public software tenders, which has not been addressed in detail yet, were modeled in a hierarchical structure. More importantly, re-determining the criterion structure according to the obtained criteria importance weights will provide great advantages.

As project assessment was taken as basis in this study, it will be possible to use the results for future projects of the public institutions. Furthermore, the techniques used in this study can also be used in the solution of such many decision making problems as personnel performance assessment, R&D project investment assessment, supplier selection, technology selection and construction investment prioritization. As multiple criteria decision making methods can be applied to the supplier selection problem in various sectors, it is also possible that they are used in other fields including human resources management, marketing management, management and organisation, where assessments are made with variables, alternatives are evaluated according to numerous decision criteria and a group decision is required.

The importance weights of decision criteria used in the study in line with the opinions of the decision takers were listed in descending order as follows: technical competence, security, personnel expertise, warranty period, quality certifications, size of contract, duration of working, motivation, turnover and the price.

These criteria were determined on the basis of Dickson's supplier evaluation criteria related to the software sector and after the opinions of experts are taken. Statistical method was used in order to ensure the use of these criteria in determining the firm to provide the software. In the light of the information obtained from research and examinations, questions were asked to the executives working in the public institutions about the criteria to be addressed for software selection. The relevant questionnaire is given in Appendix A. The executives were made to answer the questions related to the software and firm separately and then these data were analysed statistically. In this analysis, criterion alternatives were classified and the closest ones were included in one group. These analyses were carried out though a common software, called MINITAB. In line with the data obtained from MINITAB statistical program, the closest criteria and those that would be used in the application were determined.

After the AHP analysis model was established, the phase of collecting data to achieve results started. A questionnaire was developed to this end. With the questionnaire applied on the executives in the public institutions, data were recorded in the software of Expert Choice. The weights of criteria were determined by following the steps of AHP. These weights were used so as to put the firm alternatives in order and make the selection in TOPSIS. The order was put forward for firm selection through a hybrid model consisting of AHP and TOPSIS. Accordingly, the coefficients are as follows in descending order: Company A, B, C, D and E.

Another questionnaire was also prepared in accordance with the linguistic evaluation, which is the basic principle of TOPSIS method. This questionnaire, which was applied on the same group as well, composed of two parts. Criteria were evaluated in the first part of Fuzzy TOPSIS questionnaire. The first part of the questionnaire and the answers of the decision takers can be reviewed via Appendix C. The second part of the questionnaire was intended to evaluate each alternative for each criterion. The second part of the questionnaire and the answers given by the decision takers can be examined through Appendix D. Calculations made for the steps of Fuzzy TOPSIS method were carried out in Excel. When the results of Fuzzy TOPSIS method are examined, the order of the firms turns out to be Company A, B, C, D and E. The results obtained with the methods applied in this study were the same.

Alternatives are the firms which develop software for public institutions and take part in the public tenders. Thus, five firms which already work with the public institutions and are intended to be included in the study were interviewed. Information was collected about the criteria determined to be used in the study. Executives of public institutions made use of this information while determining the weights of the criteria. Pursuant to the agreement made with the firms, this information is not presented in the thesis to maintain confidentiality.

At the end of the interviews, the criteria that should be considered in the problem of selecting the firm to supply the software and alternatives were determined and therefore, the hierarchical structure of the problem was established.

When proximity coefficients of five supplier alternatives included in the study are examined, it is seen that Company A ranks first with the highest proximity coefficient value. It is followed by Company B, C, D and E.

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APPENDIX A. QUESTIONNAIRE FOR CRITERIA

Date: ..../......../..........

Dear Authority;

This questionnaire aims at collecting data to determine the firm selection criteria in the public software tenders for the thesis study that I carry out in the Management Master's Programme of the Faculty of Economics and Administrative Sciences of Çankaya University. Thus, your answers will be kept confidential. I want to thank you for sparing time and participating in our questionnaire.

1. Your position?

( ) Officer ( ) Expert ( ) Branch Director ( ) Head of Department ( ) General Director ( ) Other

State if other (…………………………………….)

2. Your age?

( ) 25-29 ( ) 30-34 ( ) 35-39 ( ) 40-44 ( ) 45-49 ( ) 50 and over

3. How long have you been working in the public sector?

( ) 5-9 ( ) 10-14 ( ) 15-19 ( ) 20-24 ( ) 25-29 ( ) 30 and over

4. Your education level?

( ) Vocational High School ( ) Bachelor's Degree ( ) Master's Degree ( ) Doctorate ( ) Other

State if other (…………………………………….)

APPENDIX A. (CONT.) QUESTIONNAIRE FOR CRITERIA

5. What are the priority degrees of the factors that you consider while you are selecting the firm to provide the software product that you will select?

(1: Lowest priority, 2: Low priority, 3: Medium priority, 4: High priority, 5: Highest priority)

Criteria	1 (Lowest)	2 (Low)	3 (Medium)	4 (High)	5 (Very high)
1. Price quoted by the firm					
2. Methodology to be applied by the firm					
3. Number of the projects undertaken by the firm					
4. How long the firm has been working in the software sector					
5. Personnel number of the firm					
6. Whether the firm has quality standard certificates					

APPENDIX A. (CONT.) QUESTIONNAIRE FOR CRITERIA

7. Whether the personnel of the firm has national and international certification records (SPK, PMI, LEED, BREAM vb.)					
8. Size of contract realized by the firm in accordance with a similar terms of reference					
9. Turnover of the firm in the last year					
10. Suitability of the firm to the determined procedures					
11. Capability of the firm to comply with the delivery schedule of the software					
12. Technical competence of the offered software					
13. Warranty period offered by the firm					
14. Reputation and market position of the firm					
15. Motivation of the firm to do business					
16. Location advantage of the firm					

APPENDIX A. (CONT.) QUESTIONNAIRE FOR CRITERIA

17. Expertise of the key personnel of the firm					
18. Extendible nature of the software offered by the fim					
19 Being open to innovations					
20. Institutional or individual memberships of the firm to national and international associations of the sector (PMI, ULI, ICSC, DUD, GYODER, AMPD vb.)					
21. Meeting confidentiality and reliability criteria					
22. Highness of the number of recurrent clients					

APPENDIX B. QUESTIONNAIRE FOR AHP

	VH	H	M	L	Neutral	L	M	H	VH	
Price	9	7	5	3	1	3	5	7	9	Working duration of the firm
Price	9	7	5	3	1	3	5	7	9	Personnel number and expertise
Price	9	7	5	3	1	3	5	7	9	Having quality standard certificates
Price	9	7	5	3	1	3	5	7	9	Size of contact realized by the firm
Price	9	7	5	3	1	3	5	7	9	Turnover
Price	9	7	5	3	1	3	5	7	9	Technical competence of the software

APPENDIX B. (CONT.) QUESTIONNAIRE FOR AHP

Price	9	7	5	3	1	3	5	7	9	Motivation to do business

Price	9	7	5	3	1	3	5	7	9	Meeting confidentiality and reliability criteria

Price	9	7	5	3	1	3	5	7	9	Maintenance and warranty periods

Working duration of the firm	9	7	5	3	1	3	5	7	9	Personnel number and expertise

Working duration of the firm	9	7	5	3	1	3	5	7	9	Having quality standard certificates

APPENDIX B. (CONT.) QUESTIONNAIRE FOR AHP

Working duration of the firm	9	7	5	3	1	3	5	7	9	Size of contact realized by the firm

Working duration of the firm	9	7	5	3	1	3	5	7	9	Turnover

Working duration of the firm	9	7	5	3	1	3	5	7	9	Technical competence of the software

Working duration of the firm	9	7	5	3	1	3	5	7	9	Motivation to do business

Working duration of the firm	9	7	5	3	1	3	5	7	9	Meeting confidentiality and reliability criteria

Working duration of the firm	9	7	5	3	1	3	5	7	9	Maintenance and warranty periods

APPENDIX B. (CONT.) QUESTIONNAIRE FOR AHP

Personnel number and expertise	9	7	5	3	1	3	5	7	9	Having quality standard certificates

Personnel number and expertise	9	7	5	3	1	3	5	7	9	Size of contact realized by the firm

Personnel number and expertise	9	7	5	3	1	3	5	7	9	Turnover

Personnel number and expertise	9	7	5	3	1	3	5	7	9	Technical competence of the software

Personnel number and expertise	9	7	5	3	1	3	5	7	9	Motivation to do business

APPENDIX B. (CONT.) QUESTIONNAIRE FOR AHP

Personnel number and expertise	9	7	5	3	1	3	5	7	9	Meeting confidentiality and reliability criteria

Personnel number and expertise	9	7	5	3	1	3	5	7	9	Maintenance and warranty periods

Having quality standard certificates	9	7	5	3	1	3	5	7	9	Size of contact realized by the firm

Having quality standard certificates	9	7	5	3	1	3	5	7	9	Turnover

Having quality standard certificates	9	7	5	3	1	3	5	7	9	Technical competence of the software

APPENDIX B. (CONT.) QUESTIONNAIRE FOR AHP

Having quality standard certificates	9	7	5	3	1	3	5	7	9	Motivation to do business

Having quality standard certificates	9	7	5	3	1	3	5	7	9	Meeting confidentiality and reliability criteria

Having quality standard certificates	9	7	5	3	1	3	5	7	9	Maintenance and warranty periods

Size of contact realized by the firm	9	7	5	3	1	3	5	7	9	Turnover

Size of contact realized by the firm	9	7	5	3	1	3	5	7	9	Technical competence of the software

APPENDIX B. (CONT.) QUESTIONNAIRE FOR AHP

Size of contact realized by the firm	9	7	5	3	1	3	5	7	9	Motivation to do business

Size of contact realized by the firm	9	7	5	3	1	3	5	7	9	Meeting confidentiality and reliability criteria

Size of contact realized by the firm	9	7	5	3	1	3	5	7	9	Maintenance and warranty periods

Turnover	9	7	5	3	1	3	5	7	9	Technical competence of the software

Turnover	9	7	5	3	1	3	5	7	9	Motivation to do business

APPENDIX B. (CONT.) QUESTIONNAIRE FOR AHP

Turnover	9	7	5	3	1	3	5	7	9	Meeting confidentiality and reliability criteria

Turnover	9	7	5	3	1	3	5	7	9	Maintenance and warranty periods

Technical competence of the software	9	7	5	3	1	3	5	7	9	Motivation to do business

Technical competence of the software	9	7	5	3	1	3	5	7	9	Meeting confidentiality and reliability criteria

Technical competence of the software	9	7	5	3	1	3	5	7	9	Maintenance and warranty periods

APPENDIX B. (CONT.) QUESTIONNAIRE FOR AHP

Motivation to do business	9	7	5	3	1	3	5	7	9	Meeting confidentiality and reliability criteria

Motivati on to do business	9	7	5	3	1	3	5	7	9	Maintenance and warranty periods

Meeting confidentiality and reliability criteria	9	7	5	3	1	3	5	7	9	Maintenance and warranty periods

Motivati on to do business	9	7	5	3	1	3	5	7	9	Maintenance and warranty periods

APPENDIX C. QUESTIONNAIRE FOR FUZZY TOPSIS - PART I

Criteria		Decision Takers (DT)				
		DT1	DT2	DT3	DT4	DT5
C1	Price quoted by the firm	H	MH	MH	H	H
C2	How long the firm has been working in the software sector	H	H	VH	MH	H
C3	Personnel number of the firm and expertise of the key personnel	VH	H	VH	H	VH
C4	Whether the firm has quality standard certificates	H	VH	MH	MH	MH
C5	Size of contract realized by the firm in line with a similar terms of reference	H	MH	VH	MH	VH
C6	Turnover of the firm in the last year	H	MH	MH	MH	MH
C7	Technical competence of the offered software	H	VH	VH	VH	VH
C8	Motivation of the firm to do business	MH	VH	VH	H	M
C9	Meeting confidentiality and reliability criteria and the procedures	MH	H	MH	H	MH
C10	Warranty and maintenance periods offered by the firm	MH	MH	MH	MH	H
Very high, High, Moderately high, Moderate, Moderately Low						

APPENDIX D. QUESTIONNAIRE FOR FUZZY TOPSIS - PART II

Criteria		Alternatives	Decision Takers				
			DT1	DT2	DT3	DT4	DT5
C1	Price quoted by the firm	A1	G	VB	G	MG	MG
		A2	MB	B	MB	MG	G
		A3	B	MB	B	MB	VB
		A4	VG	MG	VG	G	VB
		A5	MG	G	MG	MG	B
C2	How long the firm has been working in the software sector	A1	G	VB	G	G	G
		A2	G	B	G	G	G
		A3	G	MB	G	G	G
		A4	G	MG	G	G	G
		A5	VB	G	B	MG	B
C3	Personnel number of the firm and expertise of the key personnel	A1	G	VB	VG	VG	G
		A2	G	B	G	VG	G
		A3	MB	MB	G	G	MG
		A4	B	MG	B	MG	MB
		A5	VB	G	B	MB	B
C4	Whether the firm has quality standard certificates	A1	VG	VB	G	VG	VG
		A2	MB	MB	MB	MG	MG
		A3	MG	B	MG	G	G
		A4	VB	G	VB	B	B
		A5	B	MG	B	MB	MB
C5	Size of contract realized by the firm in accordance with a similar terms of reference	A1	G	VB	G	G	G
		A2	G	B	G	G	G
		A3	G	MB	G	G	G
		A4	G	MG	G	G	G
		A5	MB	G	B	MB	MG

APPENDIX D. (CONT.) QUESTIONNAIRE FOR FUZZY TOPSIS - PART II

C6	Turnover of the firm in the last year	A1	MG	VB	VG	G	G
		A2	MG	B	VG	G	G
		A3	MB	MB	G	MG	MG
		A4	B	MG	MG	MB	MB
		A5	B	G	MB	B	B
C7	Technical competence of the offered software	A1	G	VB	VG	VG	G
		A2	G	MB	G	MG	G
		A3	MG	B	G	G	G
		A4	MB	G	MB	MG	G
		A5	VB	MG	MB	MG	MB
C8	Motivation of the firm to do business	A1	MG	MG	MG	MG	G
		A2	MG	MG	MG	MG	MG
		A3	MG	MG	MG	MG	B
		A4	MG	MG	MG	MB	MG
		A5	MG	MG	MG	MG	B
C9	Meeting confidentiality and reliability criteria as well as the procedures	A1	G	MG	MG	G	VG
		A2	G	MG	MG	G	MB
		A3	G	MG	MG	G	G
		A4	G	MG	MG	G	VB
		A5	G	MG	MG	G	B
C10	Warranty and maintenance periods offered by the firm	A1	VG	MG	MG	G	MG
		A2	VG	MG	MG	G	MG
		A3	MG	MG	MG	G	MG
		A4	MB	MG	MG	G	MG
		A5	VB	MG	MG	G	MG
Very Good, Good, Moderately Good, Moderately Bad, Bad, Very Bad							

APPENDIX E. FUZZY DECISION MATRIX

Fuzzy Decision Matrix

Alternatives	Criteria									
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	(2.8,6.4,7.8)	(5.6,7.2,8.2)	(6.4,9.6,8.2)	(6.8,7.8,8.2)	(5.6,7.2,8.2)	(5.6,7.0,8.0)	(6.4,7.6,8.2)	(5.4,7.4,9.2)	(3.8,8.4,9.6)	(6.2,8.0,9.4)
A2	(2.8,4.6,6.4)	(5.6,7.4,8.6)	(6.0,7.6,8.6)	(2.6,4.6,6.6)	(5.6,7.4,8.6)	(5.6,7.2,8.4)	(5.4,7.4,8.8)	(5.0,7.0,9.0)	(5.0,7.0,8.6)	(6.2,8.0,9.4)
A3	(0.4,1.6,3.4)	(5.8,7.8,9.0)	(4.2,6.2,7.8)	(4.8,6.6,8.2)	(5.8,7.8,9.0)	(3.8,5.8,7.6)	(5.2,7.0,8.4)	(4.0,5.8,7.8)	(3.4,8.2,9.6)	(5.4,7.4,9.2)
A4	(6.0,7.2,8.0)	(6.6,8.6,9.8)	(2.2,3.8,5.8)	(1.4,2.2,3.6)	(6.6,8.6,9.8)	(2.4,4.2,6.2)	(4.2,6.2,7.8)	(4.2,6.2,8.2)	(4.8,6.4,7.8)	(4.6,6.6,8.4)
A5	(4.4,6.2,8.0)	(2.4,3.6,5.2)	(1.6,2.8,4.4)	(1.4,3.0,5.0)	(2.8,4.6,6.4)	(1.6,3.0,4.8)	(2.4,4.0,5.8)	(4.0,5.8,7.8)	(4.8,6.6,8.2)	(4.4,6.0,7.6)

Normalized Fuzzy Decision Matrix

Alternatives	Criteria									
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	(0.29,0.65,0.80)	(0.57,0.73,0.84)	(0.65,0.98,0.84)	(0.69,0.80,0.84)	(0.57,0.73,0.84)	(0.57,0.71,0.82)	(0.65,0.78,0.84)	(0.55,0.76,0.94)	(0.39,0.86,0.98)	(0.63,0.82,0.96)
A2	(0.29,0.47,0.65)	(0.57,0.76,0.88)	(0.61,0.78,0.88)	(0.27,0.47,0.67)	(0.57,0.76,0.88)	(0.57,0.73,0.86)	(0.55,0.76,0.90)	(0.51,0.71,0.92)	(0.51,0.71,0.88)	(0.63,0.82,0.96)
A3	(0.04,0.16,0.35)	(0.59,0.80,0.92)	(0.43,0.63,0.80)	(0.49,0.67,0.84)	(0.59,0.80,0.92)	(0.39,0.59,0.78)	(0.53,0.71,0.86)	(0.41,0.59,0.80)	(0.35,0.84,0.98)	(0.55,0.76,0.94)
A4	(0.61,0.73,0.82)	(0.67,0.88,1.00)	(0.22,0.39,0.59)	(0.14,0.22,0.37)	(0.67,0.88,1.00)	(0.24,0.43,0.63)	(0.43,0.63,0.80)	(0.43,0.63,0.84)	(0.49,0.65,0.80)	(0.47,0.67,0.86)
A5	(0.45,0.63,0.82)	(0.24,0.37,0.53)	(0.16,0.29,0.45)	(0.14,0.31,0.51)	(0.29,0.47,0.65)	(0.16,0.31,0.49)	(0.24,0.41,0.59)	(0.41,0.59,0.80)	(0.49,0.67,0.84)	(0.45,0.61,0.78)

APPENDIX E. (CONT.) FUZZY DECISION MATRIX

Normalized Weighted Fuzzy Decision Matrix

Alternatives	Criteria									
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	(0.18,0.54,0.65)	(0.40,0.65,0.82)	(0.54,0.94,0.84)	(0.43,0.64,0.79)	(0.40,0.66,0.80)	(0.31,0.53,0.75)	(0.43,0.64,0.84)	(0.36,0.62,0.86)	(0.22,0.67,0.92)	(0.34,0.60,0.88)
A2	(0.18,0.38,0.54)	(0.40,0.66,0.86)	(0.50,0.74,0.88)	(0.16,0.38,0.63)	(0.40,0.68,0.84)	(0.31,0.54,0.79)	(0.36,0.62,0.90)	(0.34,0.59,0.84)	(0.30,0.56,0.82)	(0.34,0.60,0.88)
A3	(0.03,0.13,0.28)	(0.41,0.70,0.90)	(0.35,0.61,0.80)	(0.30,0.54,0.79)	(0.41,0.72,0.88)	(0.21,0.44,0.71)	(0.35,0.59,0.86)	(0.27,0.49,0.73)	(0.20,0.65,0.92)	(0.30,0.56,0.86)
A4	(0.38,0.60,0.67)	(0.47,0.77,0,98)	(0.18,0.37,0.59)	(0.09,0.18,0.35)	(0.47,0.79,0.96)	(0.13,0.32,0.58)	(0.28,0.52,0.80)	(0.28,0.52,0.77)	(0.28,0.51,0.75)	(0.25,0.50,0.79)
A5	(0.28,0.52,0.67)	(0.17,0.32,0.52)	(0.13,0.27,0.45)	(0.09,0.24,0.48)	(0.20,0.42,0.63)	(0.09,0.23,0.45)	(0.16,0.33,0.59)	(0.27,0.49,0.73)	(0.28,0.53,0.79)	(0.24,0.45,0.71)