RISK EVALUATION OF AN ERP IMPLEMENTATION PROJECT USING FUZZY EXTENDED AHP (FEAHP)

(BULANIKLAŞTIRILMIŞ AHP KULLANILARAK BİR ERP KURULUM PROJESİNİN RİSK DEĞERLENDİRMESİ)

by

Ece ÜNLÜYILDIZ, B.S.

Thesis

Submitted in Partial Fulfillment

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ERP implementation projects are risky projects. Risk management activities are very important for the successful implementation of these types of projects.

In this study we have examined an ERP implementation project, in automotive industry, and its potential risks which can affect the success of the project.

I would like to thank Prof. Dr. Ziya ULUKAN for leading me on my project and sharing his information and experiences with me. I would like to thank him for his patience and guidance.

I would like to thank the company and all its workers, which I carried out my study, for the peerless helps on my project.

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Ece ÜNLÜYILDIZ

May, 2007

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List of Symbols

w_{ai} : Weight of the project activity i.

$Crit_i$: Criticality of the project activity i.

$GW_2(h)$: Grade of importance of the risk items for the hth attribute.

R2(h) : Rate of risk for the hth attribute.

$\tilde{M}$: A triangular fuzzy number.

$\mu_{\tilde{M}}(x)$: Membership function of a triangular fuzzy number M.

(l, m, u): Smallest, most promising and largest possible values of a triangular fuzzy number.

$M^{l(y)}$: Left side representation of a fuzzy number.

$M^{r(y)}$: Right side representation of a fuzzy number.

a_{ij} : Fuzzy representation of pair wise comparison.

a_{ij}^{-1} : Reciprocal of a_{ij}.

M_{crisp} : Defuzzified triangular fuzzy number.

CI : Consistency index.

CR : Consistency ratio.

λ_{max} : Largest eigen value of the comparison matrix.

RI : Random index.

A : Defuzzified pair wise comparison matrix.

$\overline{R}$: A fuzzy positive reciprocal comparison matrix.

δ : Tolerance deviation.

S'_{α} : α-level cut feasible region.

S_i : Synthetic extent value with respect to the ith object.

D : Highest intersection point between μ_{M_1} and μ_{M_2}.

$d'(A_i)$: Degree of possibility of ith synthetic extent value to be greater than the others.

W' : Weight vector.

W : Normalized weight vector, which gives the priority weights of one alternative over another.

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ABSTRACT

Today one of the major sources of competitive advantage of the companies is the ability to speed up the supply chain process. This demand led to a significant development in enterprise resource planning systems (ERP).

Companies that use ERP systems can gain a competitive advantage from the way they implement the system and then exploit the resulting data. Many companies that have installed ERP have claimed to be more nimble within the marketplace than their competitors. ERP systems offer companies' automated business processes, common data, real time information and shared business practices throughout the organization.

Despite these significant benefits that ERP systems can provide, they are very expensive and time taking projects. ERP projects often represent the single largest investment in an information systems (IS) project in the histories of the companies

Companies have spent billions of dollars and used numerous amounts of man-hours installing ERP software systems. The ERP software vendor market has experienced rapid growth in the late 1990's. In 1998 there were five major software vendors offering ERP solutions to businesses worldwide. SAP is ranked by market share as the largest vendor of ERP solutions, followed by The Oracle Corp., Peoplesoft, Edwards and Baan Co.

ERP represents a major investment but the failure rates of these projects are very high. Three quarters of ERP projects were judged as unsuccessful by the implementing firms. 90% of ERP implementations end up late or over budget. Thus, failure risk of these kinds of projects is very high.

With proper focus, the risk of an ERP implementation can be mitigated. However, to do

this, risks must be identified at the earliest stages of the project planning and risk management activities should be continued throughout a project.

This research is carried out in a global automotive corporation working in partnership with all the major vehicle manufacturers to design and develop an innovative range of products. The implementer company has decided to initiate SAP/R3 software package as an ERP solution. The aim of this study is to identify the risk factors, evaluate the risk level and determine the most risky factors which affect the success of the project.

Risks are multidimensional and include imprecise data. Due to the nature of risk, benefiting from the multi-attribute evaluation methods is more reliable. The AHP is one of the most widely used multi-criteria decision making tool. However, it does not take into account the uncertainty and imprecise data. In order to overcome this handicap, in this study Fuzzy Extended Analytical Hierarchy Process (FEAHP) approach is proposed to determine the risk level of the project.

The result of the study shows that the risk level of the SAP/R3 implementation project is very high. To reduce the level of risk by benefiting from the risk criteria priority weights, some preventive actions can be taken. Thus, relative importance of risks can enable the project managers to develop a better risk management strategy.

RESUME

Aujourd'hui une des sources principales d'avantage concurrentiel des compagnies est la capacité d'accélérer le processus de chaîne d'approvisionnements. Cette demande a mené à un développement significatif dans des systèmes de planification de ressource d'entreprise (ERP).

Les compagnies qui emploient des systèmes d'ERP peuvent gagner un avantage concurrentiel de la manière qu'elles mettent en application le système et puis exploitent les données résultantes. Beaucoup de compagnies qui ont installé ERP ont prétendu être plus agiles dans le marché que leurs concurrents. Les systèmes d'ERP offrent les processus automatisés des sociétés d'affaires, les données communes, l'information en temps réel et les procédures de gestion partagées dans toute l'organisation.

En dépit de ces avantages significatifs que les systèmes d'ERP peuvent fournir, ils sont très chers et temps prenant des projets. Les projets d'ERP représentent souvent le plus grand investissement simple dans une systèmes d’information (IS) projettent dans les histoires des compagnies.

Les compagnies ont dépensé des milliards de dollars et ont employé de nombreuses quantités d'heures-homme installant les systèmes logiciels d'ERP. Le marché de fournisseur de logiciel d'ERP a éprouvé la croissance rapide vers la fin des années 90. En 1998 il y avait cinq fournisseurs principaux de logiciel offrant des solutions d'ERP aux entreprises dans le monde entier. SAP est le chef du marché des solutions d'ERP, suivi d'Oracle Corp., de Peoplesoft, d'Edwards et de Baan Co.

ERP représente un investissement important mais les taux d'échec de ces projets sont très hauts. Trois quarts de projets d'ERP ont été jugés comme non réussis par les sociétés mettant en application. 90% de réalisations d'ERP finissent vers le haut de tard

ou plus de budget. Ainsi, le risque d'échec de ces genres de projets est très haut.

Avec le foyer approprié, le risque d'une exécution d'ERP peut être atténué. Cependant, pour faire ceci, des risques doivent être identifiés aux premières parties de la planification de projet et des activités de gestion des risques devraient être continuées dans tout un projet.

Cette recherche est effectuée à une société des véhicules à moteur globale travaillant dans l'association avec tous les fabricants principaux de véhicule pour concevoir et développer une gamme des produits innovatrice. La compagnie d'applicateur a décidé de lancer le progiciel SAP/R3 comme solution d'ERP. Le but de cette étude est identifier les facteurs de risque et d'évaluer le niveau de risque du projet.

Les risques sont multidimensionnels et incluent des données imprécises. En raison de la nature du risque, tirant bénéfice du multi attribuez les méthodes d'évaluation est plus fiable. L'AHP est un de l'outil le plus largement répandu de prise de décision de multicritère. Cependant, il ne tient pas compte de l'incertitude et des données imprécises. Afin de surmonter cet handicap, dans cette approche analytique prolongée brouillée du processus de hiérarchie d'étude (FEAHP) est proposé de déterminer le niveau de risque du projet.

Le résultat de l'étude prouve que le niveau de risque du projet de l'exécution SAP/R3 est très élevé. Pour réduire le niveau du risque en tirant bénéfice des critères de poids prioritaires de risque, quelques mesures préventives peuvent être prises. Ainsi, l'importance relative des risques peut permettre aux chefs de projet de développer une meilleure stratégie de gestion des risques.

ÖZET

Kurumsal kaynak planlama (ERP) sistemleri günümüzde rekabet gücünü arttırmak isteyen firmalar tarafından sıklıkla tercih edilmektedir. ERP, tedarik zincirinin güvenilirliğini ve hızını arttırması, maliyetlerde önemli ölçüde azalma sağlaması gibi nedenler ile son yıllarda oldukça talep edilir olmuştur. Bu talep ERP sistemlerinin gelişmesinde önemli rol oynamaktadır.

Firmalar rekabet güçlerini arttırmak ve bunun sonuçlarından faydalanabilmek için ERP sistemlerini tercih etmektedir. ERP sitemleri kullanıcılarına işlem otomasyonu, ortak veri kullanımı, gerçek zamanlı veriye ulaşabilme imkanı, verinin firma içi ve dışı paylaşım kolaylığı gibi birçok fayda sunmaktadır.

Bahsedilen tüm bu faydalara ancak başarılı ERP kurulum uygulamaları ile ulaşılabilir. ERP sistemi kurulumu ve başarılı bir şekilde hayata geçirilmesi oldukça maliyetli ve uzun süreli bir süreçtir. Firmaların tarihlerindeki en büyük bilgi teknolojisi (IT) yatırımları genellikle ERP projeleri olmaktadır.

1990’ lı yıllarda ERP yazılım sektöründe oldukça önemli gelişmeler olmuştur. Birçok firma bu alanda pazardaki yerini almıştır. Pazardaki en büyük ERP yazılım şirketi SAP’ dır. SAP’ ı Oracle Corp., Peoplesoft, Edwars ve Baan Co. takip etmektedir.

ERP projeleri oldukça büyük miktarlarda yatırım gerektiren ve fakat başarısızlık oranları oldukça yüksek olan projelerdir. ERP projelerinin yaklaşık dörtte üçü başarısız olarak tanımlanmıştır. Projelerin yaklaşık %90’ı zaman ve bütçe aşımı ile sonuçlanmaktadır. Bu sonuçlar dikkate alındığında ERP uygulama projelerinin başarısızlık riski oldukça yüksektir.

Bu noktada risk yönetimi projenin başarılı bir şekilde sonuçlanabilmesi için oldukça

önemli bir rol oynamaktadır. İyi bir risk yönetimi stratejisi ile riskler kontrol altına alınabilir. Bunun için olası riskler proje başlangıcında tanımlanmalı ve proje süresince risk yönetimi aktiviteleri devam etmelidir.

Çalışma birçok lider otomobil üreticisi ile ortaklaşa çalışan uluslararası bir firmada yürütülmüştür. Uygulayıcı firmada kullanılan MRPII sistemi yerine ERP sisteminin kurulması, fabrikanın tüm süreçlerinin bu sayede birleştirilmesi ve başarılı bir kurulum projesi ile ERP sisteminin sağlayacağı faydalardan yararlanılması hedeflenmektedir. Bu sebepler doğrultusunda uygulayıcı firma SAP firması tarafından geliştirilen SAP/R3 ERP çözüm yazılımını tercih etmiştir.

Hazırlanan çalışmanın amacı, riskin tanımlanması, değerlendirilmesi ve yüksek risk taşıyan faktörlerin belirlenmesi ile riskleri önleyici faaliyetlerin uygulanması için yol gösterici bir araştırma ortaya koymaktır.

Risk çok boyutlu bir kavram olarak ele alınmalıdır. Risk doğası gereği bir belirsizlik durumudur. Dolayısıyla risk değerlendirme süreçlerinde çok ölçütlü değerlendirme metotlarının kullanımı daha etkin ve doğru sonuçlara ulaşılmasını sağlayacaktır. Analitik Hiyerarşi Prosesi (AHP) oldukça sık kullanılan etkin birçok ölçütlü karar verme tekniğidir. Ancak AHP belirsizliği ve kesin olmayan durumları göz önünde bulundurmamaktadır. Çalışmada AHP' nin bu eksikliğini ortadan kaldırabilecek bir yöntem olan Bulanık Analitik Hiyerarşi Prosesi (FEAHP) kullanılmıştır.

Çalışmanın sonuçlarına göre ele alınan SAP/R3 yazılımı kurulum projesi oldukça yüksek seviyede risk içermektedir. Çalışma sonucunda elde edilen risk kriterleri ağırlık vektörleri hangi risk faktörünün bu projenin olası başarısızlığında daha çok rol oynayacağını göstermesi açısından önemlidir. Bu sayede proje yöneticileri elde edilen risk ağırlıklarını değerlendirerek riski azaltmaya yönelik daha etkin bir risk yönetim stratejisi geliştirebilirler.

1. INTRODUCTION

Many firms around the world have been implementing ERP (enterprise resource planning) systems since the 1990's to have a uniform information system in their organizations and to re-engineer their business. ERP aims to integrate individual functional systems such as manufacturing, finance, procurement and distribution. The systems allow companies to replace their existing information systems and also help to standardize the flow of management. A successfully implemented ERP system has the advantages of reduced cost, rapid implementation, high system quality and improved competitiveness. ERP implementation is not only a software installation effort it must be managed as a program of wide-ranging organizational change initiatives.

In the past few years many organizations have initiated enterprise-wide/ERP projects using such packages as SAP, Oracle, Peoplesoft and Baan. SAP and its R/3 solution is the dominant leader in ERP systems and have almost one-third the market share. SAP/R3 applications are a range of software modules. They can be used either alone or combined to form business solutions. ERP projects often represent the single largest investment in an information system (IS) project in the histories of these companies and, in many cases, the largest single investment in any corporate wide project. ERP represents a major investment but the failure rates of these projects are very high. Three quarters of ERP projects were judged as unsuccessful by the implementing firms. 90% of ERP implementations end up late or over budget. According to these results we can say that ERP implementation projects are fraught with risk. An ERP project is not just a software implementation project; rather, it is a major change initiative. With proper focus, the risk of an ERP implementation can be mitigated. However, to do this, the risks must be identified and managed.

Managing risk is an integral part of good management and fundamental to achieving good business and project outcomes. Projects will be different in size, duration, objectives, complexity and some other dimensions. It is not important how different or unique a project is; every project contains some degree of uncertainty and there is no risk-free project. Risk should be considered at the earliest stages of project planning, and risk management activities should be continued throughout a project.

This study mainly focuses on the identification and evaluation phases of the project risk management process. The possible risks and their characteristics that may affect the success of SAP/R3 software package implementation project are identified from early research studies and experiences of SAP experts.

Risks are multidimensional; they should be evaluated with respect to more than one criterion to get more reliable results. The Analytic Hierarchy Process (AHP) is one of the most widely used multiple criteria decision-making tools. Once the structuring is completed, the AHP is surprisingly simple to apply and it can effectively handle both qualitative and quantitative data.

Risk is essentially uncertainty. Because of its nature, risk includes imprecise and vague data. AHP uses crisp data and does not take into account the uncertainty. Fuzzy set theory is especially powerful when there is an unavailability of precise or complete information. Thus, fuzzy set theory can be a valid supporting tool to overcome the handicaps of AHP in fuzzy environment.

In this research fuzzy extended Analytic Hierarchy Process (FEAHP) method is proposed for risk evaluation of an ERP implementation project. Finally an illustrative real life application is presented for the utilization of FEAHP in risk evaluation.

2. ENTERPRISE RESOURCE PLANNING

2.1. The Evolution of ERP Systems

The focus of manufacturing systems in the 1960’s was on inventory control. Companies could afford to keep lots of ‘‘just-in-case’’ inventory on hand to satisfy customer demand and still stay competitive. Consequently, techniques of the day focused on the most efficient way to manage large volumes of inventory. Most software packages (usually customized) were designed to handle inventory based on traditional inventory concepts.

In the 1970’s, it became increasingly clear that companies could no longer afford the luxury of maintaining large quantities of inventory. This led to the introduction of material requirements planning (MRP) systems. MRP represented a huge step forward in the materials planning process. For the first time, using a master production schedule, supported by bill of material files that identified the specific materials needed to produce each finished item, a computer could be used to calculate gross material requirements. Using accurate inventory record files, the available quantity of on-hand or scheduled-to-arrive materials could then be used to determine net material requirements. This then prompted an activity such as placing an order, canceling an existing order, or modifying the timing of existing orders. For the first time in manufacturing, there was a formal mechanism for keeping priorities valid in a changing manufacturing environment. The ability of the planning system to systematically and efficiently schedule all parts was a tremendous step forward for productivity and quality.

Yet, in manufacturing, production priorities and materials planning are only part of the problem. Capacity planning represents an equal challenge. In response, techniques for capacity planning were added to the basic MRP system capabilities. Tools were developed to support the planning of aggregate sales and production levels (sales and operations planning), the development of the specific build schedule (master production scheduling), forecasting, sales planning and customer order promising (demand management), and high-level resource analysis (rough-cut capacity planning). Scheduling techniques for the factory floor and supplier scheduling were incorporated into the MRP systems. When this occurred, users began to consider their systems as company-wide systems. These developments resulted in the next evolutionary stage that became known as closed loop MRP.

In the 1980's, companies began to take advantage of the increased power and affordability of available technology and were able to couple the movement of inventory with the coincident financial activity. Manufacturing resources planning (MRP II) systems evolved to incorporate the financial accounting system and the financial management system along with the manufacturing and materials management systems. This allowed companies to have a more integrated business system that derived the material and capacity requirements associated with a desired operations plan, allowed input of detailed activities, translated all this to a financial statement, and suggested a course of action to address those items that were not in balance with the desired plan [1].

By the early 1990's, continuing improvements in technology allowed MRP II to be expanded to incorporate all resource planning for the entire enterprise. Areas such as product design, information warehousing, materials planning, capacity planning, communication systems, human resources, finance, and project management could now be included in the plan. Hence, the term, ERP was coined. And ERP can be used not only in manufacturing companies, but in any company that wants to enhance competitiveness by most effectively using all its assets, including information.

2.2.Definitions of ERP Systems

The definition of ERP software has been defined by various authors but with not many differences.

Gable [2] defines ERP system as comprehensive package software solutions seek to integrate the complete range of a business processes and functions in order to present a holistic view of the business from a single information and IT architecture.

Slight differently, Rosemann [3] defines it as customizable, standard application software which includes integrated business solutions for the core processes (e.g. production planning and control, warehouse management) and the main administrative functions (e.g., accounting, human resource management) of an enterprise [4].

Heizer and Render [5] define an ERP system as: ‘‘an information system for identifying and planning the enterprise-wide resources needed to take, make, ship and account for customer orders’’.

Another definition is provided by Aladwani [6]: ‘‘ERP system is an integrated set of programs that provides support for core organizational activities such as manufacturing and logistics, finance and accounting, sales and marketing, and human resources’’ [7].

In another recent paper, according to Berchet and Habchi [8], the ERP system could be defined as follows:

The ERP system is a tool assembling and integrating all data and management skills which represent the firm’s activity, in a unique database: from finance to human resources, going through the elements of the supply chain that permanently links the production to purchasing and sales.

The ERP system is also a tool composed of applicative modules (one per ordinary analytical function of the firm) able to dialog between each other according to a conventional exchange protocol thanks to the unique base and the uniqueness of the processed data. Then each module receives information coming from the other modules and sends its own data to the other modules.

2.3.ERP Systems

ERP allows the corporate management of a business, and aims to integrate individual functional systems such as manufacturing, finance, procurement and distribution. The systems allow companies to replace their existing information systems and also help to standardize the flow of management information and have been regarded as the next step in the evolution of MRPII. The MRPII model actually forms the basic core of ERP and uses similar modules, however some ERP systems do contain certain modules that were not originally used within MRPII such as computer aided design (CAD), distribution resource planning (DRP), tool management systems (TMS), and product data management (PDM).

ERP uses internet technologies to integrate the flow of information from internal business functions as well as information from customers and suppliers. The system uses a relational database management system, within client/server network architecture, to capture valuable management data. The key principle behind the system involves entering the data from a series of modular applications only once. Once stored, the data automatically triggers the update of all related information within the system. The systems can support virtually all areas of an organization, across business units, departmental functions and plants. The development of an ERP system within a large manufacturing organization requires the integration of working practices and the information systems.

Companies that use ERP can gain a competitive advantage from the way they implement the system and then exploit the resulting data. Many companies that have installed ERP have claimed to be more nimble within the marketplace than their competitors with hard-to-change custom made systems.

ERP systems offer companies the following three major benefits:

- Business processes are integrated and automated,
- Common data and business practices are shared throughout the organization,

- Information is generated in real time, timely access to management information [9].

Companies have spent billions of dollars and used numerous amounts of man-hours installing elaborate ERP software systems. The ERP software vendor market has experienced rapid growth in the late 1990's. In 1998 there were five major software vendors offering ERP solutions to businesses worldwide.

SAP is ranked by market share as the largest vendor of ERP solutions who earned over $5 billion in revenue. The Oracle Corp. was the second largest with $2.4 billion in sales. In third place PeopleSoft who earned $1.3 billion. In fourth place was J.D. Edwards with $979 million. And finally in fifth place was the Baan Co. with $743 million in sales [10].

2.4.Systems, Applications and Products (SAP)

In 1972, five former IBM employees -Dietmar Hopp, Hans-Werner Hector, Hasso Plattner, Klaus Tschira, and Claus Wellenreuther - launch a company called Systems, Applications, and Products in data processing in Mannheim, Germany. Their aim was to produce standard software application programs that could integrate with each other to form a business solution. SAP has been dedicated to produce products that improve the return on information gathered by an organization. The company began its life with the name 'Systemanalyse Und Programmentwicklung' and eventually became known as SAP.

SAP's first product known as R/2 was built and prototyped for a subsidiary of ICI. The system they produced was simply known as system 'R', which stands for 'Real-time' processing. This system was fully integrated and could be used on the IBM mainframe. The R/2 solution was launched in 1979 and was developed for a computer mainframe environment, at the time it was perceived as the most comprehensive system available to businesses in the world, and it received great interest from industries in the 1980's.

By the middle of the decade, SAP founds its first sales organization outside Germany, in Austria. The company makes its first appearance at the CeBIT computer fair in Hanover, Germany. Revenues reached DM 100 million (around $52 million), earlier than expected. SAP saw the future potential for the delivery of information to the end-user via the PC, so SAP reinvented and developed their product further by developing a business solution for the client/server architecture environment; this became known as R/3 and was released in 1992. In the 1990's SAP and its R/3 solution became the dominant ERP solution, and also became one of the world's biggest software houses.

SAP R/3 applications are a range of software modules. They can be used either alone or combined to form business solutions. SAP state that their R/3 applications offer comprehensive functionality for all standard business needs within an enterprise. SAP R/3 uses a programming language called advanced business application programming (ABAP).

SAP R3's 12 application modules are: financial accounting, treasury, controlling, enterprise controlling, investment management, production planning, materials management, quality management, project system, human resource management, sales and distribution, and plant maintenance and service management [9].

Both R/2 and R/3 solutions are truly integrated suites of application software modules for business process from manufacturing to back-office functions such as order processing. In a typical legacy system environment for order taking, many functional systems linked by interfaces [11]. In an SAP environment, as shown in Figure 2.1, the need for interfaces eliminated, greatly simplifying the task of reconciliation and audit.

As the decade draws to a close, SAP Company announced the mySAP.com strategy. mySAP.com links e-commerce solutions to existing ERP applications, using state-of-the-art Web technology. By 2005, 12 million users work each day with SAP solutions. There are now 100,600 installations worldwide, more than 1,500 partners, over 25 industry-specific business solutions, and more than 38,000 customers in 120 countries [12].

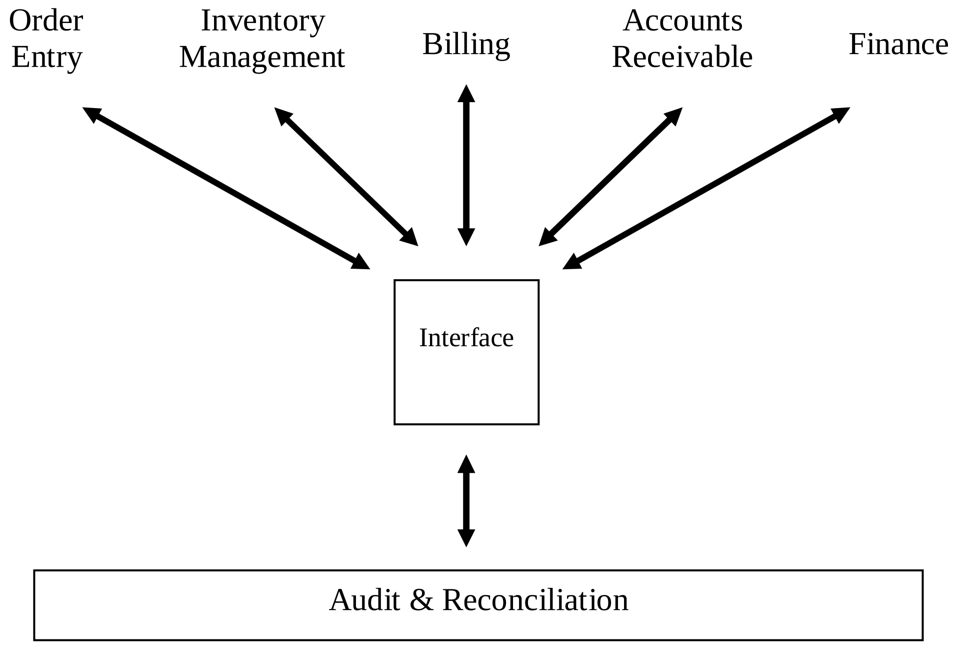

Figure 2.1 SAP architecture [11].

2.5.ERP Implementation Projects

2.5.1. Implementation of ERP

ERP when successfully implemented links all areas of a company including order management, manufacturing, human resources, financial systems, and distribution with external suppliers and customers into a tightly integrated system with shared data and visibility. Potential benefits include drastic declines in inventory, breakthrough reductions in working capital, abundant information about customer wants and needs, along with the ability to view and manage the extended enterprise of suppliers, alliances and customers as an integrated whole.

The term ERP stands for enterprise resource planning, however it is not good enough to just plan resources required running the enterprise, they need to be managed as well. An organization must assess itself, to see if it is ready for ERP. It must determine if it is ready for the competitive business environment of today and then strengthen its position for tomorrow's changes. Some of the companies that implement ERP systems do not realize the full benefits that the system offers because most organizations are not organized in the correct fashion to achieve the benefits. Many companies that attempt to implement ERP systems run into difficulty because the organization is not ready for integration and the various departments within it have their own agendas and objectives that conflict with each other.

While companies such as Cisco Systems, Eastman Kodak, and Textronix have reaped the expected benefits of ERP systems, many businesses are discovering that their ERP implementation is a nightmare. FoxMeyer Drug, a $5 billion pharmaceutical company, recently filed for bankruptcy [9].

Dell Computers spent tens of millions of dollars on an ERP system only to scrap it because the system was too rigid for their expanding global operations. ERP implementations involve, in truth, broad organizational transformation processes, with significant implications to the organization's management model, organization structure, management style and culture, and particularly, to people [9].

ERP software is very adaptable but not very malleable and companies that wish to use them correctly have to change their working practices to fit the software. The key factor of an ERP implementation is the way in which the software is configured. The most important issue to identify before an implementation is the 'core' of the business, which can be identified by the use of the business model.

One original motive for buying an ERP system was to automate business processes, but the modern view has shifted to the quick access of up-to-date and timely management information. The majority of difficulties experienced by ERP implementations have been the costly development of additional software to help 'bridge' or retrieve information from legacy systems. Before ERP management reports can be generated and distributed to managers, the data has to be created first which can be a costly and inefficient process. In an attempt to improve the timeliness and accuracy of management data, many software vendors are making end-users responsible for updating their own information rather than relying on information technology (IT) resources.

ERP software consists of a number of modules that link together to form a complete business solution; however the main difficulties experienced by ERP users have been in manipulating the data stored within the system. Software developers have begun to address the need for additional information tools. Some of these tools include the need for detailed and advanced planning and advanced scheduling and customer relationship management. Abdinnour-Helm et al. [13] discussed the pre-implementation attitudes and organizational readiness for implementing an ERP system. Huang and Palvia [14] analyze the ERP implementation issues in advanced and developing countries. Umble et al. [1] presents the empirical findings on implementation procedures and critical success factors for ERP. Van Stijn and Wensley [15] address some concerns, methods and directions for future research on organizational memory and the completeness of process modeling in ERP systems [9].

Most ERP software vendors supply their customers with an implementation program as part of an overall solution package. For example SAP provides some of its customers with accelerated SAP (ASAP). ASAP suggests the adoption of a 'big bang' implementation. This program opts for a quick implementation that is specifically designed for small and medium sized companies. 'Big bang' implementations offer lower costs and generally use only a few of the software's interfaces, however the risks are greatly increased, as less time is spent on development and assessing business needs.

2.5.2. Benefits &Cost of ERP Implementation

An ERP system can be thought of as a business-wide integration mechanism of all organizational information system (IS). This integration makes organizations able to take quick reaction to competitive pressures and market opportunities, be more flexible product configurations, achieve reduced inventory, and maintain tightened supply chain links.

ERP benefits can be classified into tangible and intangible. Tangible benefits refer to inventory reduction, reduction of personnel, increased productivity, improvements in order management, more rapid closing of financial cycles, reduction in IT and procurement costs, improvement of cash flow management, increase of revenue and profits, reduction in transportation and logistics costs, reduction in the need for system maintenance, and improvement in on time delivery performance. Intangibles refer to the increased visibility of corporate data, new or improved business processes, improved responsiveness to customers, unanticipated reduction in cost, tighter integration between systems, standardization of computing platforms, increased flexibility, global sharing of information, Y2K compliance, improved business performance, and improved visibility into supply chain management (SCM) process [4].

Despite these significant benefits that ERP systems can provide, they are very expensive even under ideal circumstances. ERP projects often represent the single largest investment in an information systems (IS) project in the histories of the companies and, in many cases, the largest single investment in any corporate wide project [16].

The cost of ERP software itself can range from hundreds of thousands of dollars to several million dollars. This cost can further be escalated when considering hiring consultants to help in the selection, configuration, and implementation of the system. According to an IT research firm, Gartner Group, companies may spend up to three times much money on consultants as they do on the ERP system itself [17]. Other costs may include the human resources needed to work full time on the implementation project. Additionally, an organization may need to install new hardware to run the ERP software, and a new database to store the ERP data. Furthermore, integrating the ERP system with other types of applications is usually a necessity. It is also important that end-user training and change management costs are considered in the equation [4]. Standish group is reporting that, according to resent 200 ERP cases, the average purchase price for a single ERP application is $1.3 million, with the cost to implement averaging at $6.4 million [18].

2.5.3. Success of ERP Implementation Projects

A successful project is one that delivers expected results. These traditionally include a budget, a schedule, and a scope- “triple constraints” of project management. Any project that meets these measures is, by this definition, a success. In fact, many project managers are regarded as successful if they can hit two of the three [19].

An ERP implementation is considered to be a success if it achieves a substantial proportion of its potential benefits. These benefits might include personnel reductions, a decrease in the cost of information technology, better inventory control, and an improvement in order and cash management. An alternate definition of implementation success is that the system achieves the level of return on investment (ROI) identified in the project approval phase. Thus, an ERP implementation should be evaluated based on cost of ownership versus quantifiable benefits, taking into account the time required to implement the system [1].

Recent studies show that many of ERP projects have ‘failed’, in the combination of budget and/or schedule overruns and/or for not meeting users’ requirements. The well known and now widely quoted Chaos Report by Standish Group [18] declared that software projects are in chaos. Table 2.1 provides a summarized report card on project outcomes based on the Report.

Table 2.1 Project resolution by type [20].

Project outcome	Resolution	%
Type 1	Successful	16.2%
Type 2	“Challenged”	52.7%
Type 3	“Impaired”	31.1%

Type 1 projects are those completed on time and within budget, with all required functions and features initially specified. The ‘‘challenged’’ projects, though completed and operational, suffered budget overruns and/or program slips, and offered fewer functions and features than originally specified. The ‘‘impaired’’ projects are those cancelled or abandoned at some point during the development cycle. It is anticipated that many of the IS projects would continue to be ‘challenged’ or ‘impaired’. The truly ‘successful’ stories from the outset will be relative rare. The problem of systems impairment is more serious when projects are terminated or abandoned because of potential damages to organizations [20].

The top three reasons for the failure of IT-related projects, as cited by IT managers surveyed by Information Week, were poor planning or poor management (cited by 77%), change in business goals during the project (75%), and lack of business management support (73%). As a result, most IT-related projects fall far short of their potential payback, and 26% are canceled before completion. Moreover, in many of the completed projects, the technology is deployed in a vacuum and users resist it [1].

Langenwalter [21] claims that the percentage of ERP implementations that can be classified as ‘‘failures’’ ranges from 40% to 60% or higher. Ptak [22] defines failure as an implementation that does not achieve the ROI identified in the project approval phase and finds that failure rates are in the range of 60–90%. Also, King and Burgess [7], is reporting that three quarters of ERP projects were judged as unsuccessful by the implementing firms.

According to these results it can be said that, ERP projects represent a major investment but the failure rates of these projects are very high and ERP implementation projects are fraught with risk. With proper focus, the risk of an ERP implementation can be mitigated. However, to do this, risks must be identified and managed.

As organizations invest substantial resources and effort on software development, controlling the risks associated with software projects becomes crucial [23]. Hence, understanding the nature of the various software risks and their relationship with project performance has become increasingly important since the risk management strategy and plan depends on it.

Developing an efficient and suitable risk management strategy depends on understanding two basic components; probability of occurrence and impact on project performance. The probability of occurrence of each software risk is different and its degree of impact on project cost, schedule and quality is also different. Hence, these two software risk components must be taken into consideration to develop a good software risk management strategy and plan. If not, the real benefits of the risk management activity may be lower than the resources invested [24].

3. RISK MANAGEMENT OF ERP PROJECTS

Every action taken in business entails some level of risk. While it is impossible to eliminate all risk from any business undertaking, least of all from one so radical as process change and large-scale business software implementation, it is possible to manage risk in a way that allows a business to pursue its legitimate opportunities without endangering its survival.

SAP projects, by their nature, are fraught with risk. An SAP project is not just a software implementation project; rather it is a major change initiative. With proper focus, the risks of an SAP implementation can be mitigated. However, to do this, the risk must be identified and managed.

Risk is any factor that can affect the ability of the project to deliver results that are on time and on budget, and that meet expectations [11].

3.1.Benefits of Project Risk Management

Projects, by their nature, are unique and many of the more interesting ones are complex. They frequently take place over an extended period of time and demand the engagement of a wide range of resources, including people, finance, facilities, materials and intellectual property. In most circumstances, projects have defined objectives or an end-state that provides those involved in the project with a clear vision and specification of their goal.

The purpose of project risk management is to minimize the risks of not achieving the objectives of the project and the stakeholders with an interest in it, and to identify and take advantage of opportunities. In particular, risk management assists project managers in setting priorities, allocating resources and implementing actions and processes that reduce the risk of the project not achieving its objectives.

Risk management facilitates better business and project outcomes. It does this by providing insight, knowledge and confidence for better decision making. In particular, it supports better decisions about planning and design processes to prevent or avoid risks and to capture and exploit the opportunities, better contingency planning for dealing with risks and their impacts, better allocation of resources to risks and alignment of project budgets to risks, and better decisions about the best allocation of risk amongst the parties involved in a project activity. Together, these lead to increased certainty and a reduction in overall risk exposure.

Of these benefits, improved outcomes from the capture of opportunities and the reduction in risk exposure provide the main justifications for undertaking risk management. At the management level, better insight is a critical aspect, leading to the better decisions. Risk management also provides a framework that avoids sudden surprises and justifies prudent risk reduction and mitigation measures.

The benefits of risk management are not confined to large or risky projects. The process may be formalized in these circumstances, but it is applicable for all scales of project and procurement activity. It can be applied at all stages in the project cycle, from the earliest assessments of strategy to the supply, operation, maintenance and disposal of individual items, facilities or assets. It has many applications, ranging from the evaluation of alternative activities for budgets and business plans to the management of cost overruns and delays in projects and programs.

Risk management will also provide benefits in better accountability and justification of decisions, by providing a consistent and robust process that supports decision-making [25].

3.2.Risk Management Processes

A risk is a potential problem, a situation that, if it materializes, will adversely affect the project. Risks that materialize are no longer risks, they are problems.

All projects have risks, and all risks ultimately handled. Some disappear, some develop into problems that demand attention, and a few escalate into crises that destroy projects and careers. The goal of risk management is to ensure that risks never fall into the third category.

Risk management processes are consisting of four groups: identifying, analyzing, controlling and mitigating, and avoiding [19]. Figure 3.1 shows the risk management processes.

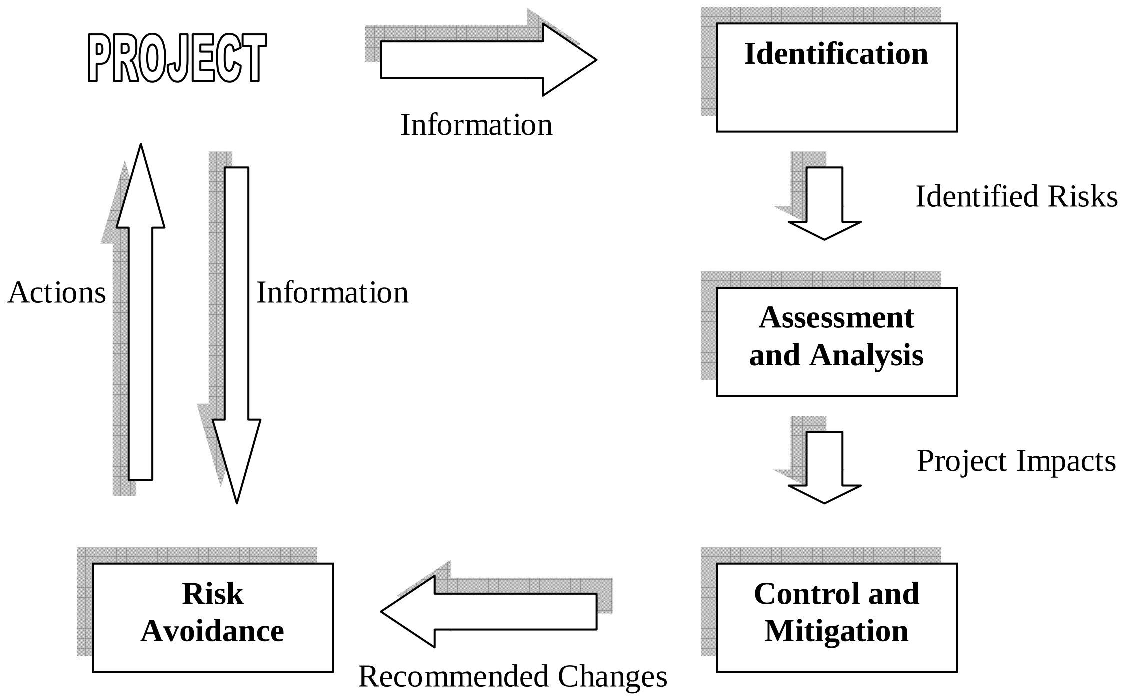

Figure 3.1 Risk management processes [11].

3.2.1. Risk Identification

Risk identification determines what might happen that could affect the objectives of the project, and how those things might happen.

The risk identification process must be comprehensive, as risks that have not been identified can not be assessed, and their emergence at a later time may threaten the success of the project and cause unpleasant surprises. The process should be structured using the key elements to examine risk systematically, in each area of the project to be addressed.

A number of techniques can be used for risk identification, but brainstorming is a preferred method because of its flexibility and capability, when appropriately structured, of generating a wide and diverse range of risks.

Information used in the risk identification process may include historical data, theoretical analysis, empirical data and analysis, informed opinions of the project team and other experts, and the concerns of stakeholders.

The output is a comprehensive list of possible risks to the successful outcome of the project, usually in the form of the risk register, with management responsibilities allocated to them [11].

3.2.2. Risk Assessment and Analysis

Assessing and analyzing risks means determining their potential impact on the project, as well as their likelihood of happening. The impact on the project can be in terms of missed milestones, the need for rework, the need for re-implementation, and the level of acceptance the project will have after it is completed [11].

Risk assessment is the overall process of risk analysis and risk evaluation. Its purpose is to develop agreed priorities for the identified risks.

- Risk analysis is the systematic use of available information to determine how often specified events may occur and the magnitude of their consequences.
- Risk evaluation is the process of comparing the estimated risk against given risk criteria to determine the significance of the risk.

The assessment process:

- determines the consequences of each risk, should it arise;
- assesses the likelihood of those consequences occurring;
- converts the consequence and likelihood ratings to an initial priority for the risk; and
- develops agreed risk priorities and inherent risk levels.

The agreed priorities are used to determine where the greatest effort should be focused in treating identified risks. They facilitate structured action planning and resource allocation.

This stage of the risk management process generates a prioritized list of risks and a detailed understanding of their impacts upon the success of the project should they occur. The consequence and likelihood ratings and the agreed risk priorities are all recorded in the risk register [25].

3.2.3. Risk Control and Mitigation

Risk can be controlled through a number of different strategies and actions. It is important to think through a clear, coherent strategy for risk control before undertaking any of the specific actions. Risk control must be constantly monitored. A good way to start is to step back when each project milestone is reached and assess the effectiveness of risk control actions taken during the time it took to reach the milestone. Revisit identifying and assessing the risks that may dominate the next milestone phase, and determine if the current risk control strategy and actions will serve well during the next phase, or a new strategy should be developed and new actions outlined [11].

3.2.4. Risk Avoidance

It is possible to avoid some risks. This is mostly done by being brutally realistic about the nature and amount of resources it will take to successfully complete a project. It is important that executives and key users define their expectations for the project up front and for the functionality of the system when it is installed. Then, the project leader must be completely honest in telling those executives and key users what kind of costs and time commitment are necessary to undertake the project [11].

3.3.Risk in Implementing ERP Projects

A simple definition of "risk" is a problem that has not yet happened but which could cause some loss or threaten the success of your project if it did.

Another definition of "risk" is any uncertainty in a project plan that you can potentially control, or at least track. This means that there are many risks in a project. The trick is to identify the most critical risks and control them. Overcoming a risk creates opportunity. Risk is integral to the business and the project planning process; therefore risk should not be thought as something different or separate from management [26].

A number of research studies have investigated the issue of the relative importance of various risks in software development projects and have attempted to classify them in various ways. Much has been written about the causes of IS project failures. Poor technical methods are only one of the causes and this cause is relatively minor in comparison to larger issues such as failures in communications and ineffective leadership [16].

Many studies have proven that proper management of software risks affects the success of software development projects. Software risks are multifaceted and thus difficult to measure even though several studies have already been conducted since 1990's.

Tchokogué et al. [27] used a case study approach to evince the lessons learned from a successful implementation of an ERP system. They pointed out some strategic, tactic and operational considerations inherent in an ERP implementation that are prerequisites to effective organizational transformation required by a system implementation such as SAP/R3. In his study Yeo [20] represented a wide range of possible factors that may impact information systems success. Sumner [16] identified the risk factors in implementing traditional management information system (MIS) projects, described the risk factors associated with enterprise-wide/ERP projects and identified the risk factors in ERP projects which are unique to these projects. Yusuf et al. [9] examined key dimensions of implementation of ERP systems within a large manufacturing organization and identified core issues to confront in successful implementation of enterprise information systems. Umble et al. [1] defined 9 critical factors for successful ERP implementation: clear understanding of strategic goals, commitment by top management, excellent project management, organizational change management, a great implementation team, data accuracy, extensive education and training, focused performance measures, multi-site issues. This study also identified software selection steps and implementation procedures critical to a successful implementation. Han and Huang [24] conducted an empirical study based on 115 software projects on analyzing the probability of occurrence and impact of the six dimensions: user, requirement, project complexity, planning &control, team, organizational environment which comprising 27 software risks on project performance. Al-Mashari et al. [4] presented a novel taxonomy of the critical success factors in ERP. In light of Lyytien and Hirschheim's [28] definition of failure, successes of IT project were classified in four groups: correspondence success, process success, interaction success, and expectation success. Zhang et al. [29] developed an ERP implementation success framework by adapting the Ives et al. information systems (ISs) research model and DeLone and McLean's IS success model to identify both 12 critical success factors which were further classified into four categories: organizational environment, user environment, system environment, ERP vendor environment and 4 success measures: user satisfaction, individual impact, organizational impact, intended business performance improvement. In their research Somers and Nelson [30] asked US executives to rank the ERP critical success factors and they produced the following top 10 factors: top management support, project team competence, interdepartmental cooperation, clear goals &objectives, project management, interdepartmental communication, management of expectations, project champion, vendor support, careful package selection. Tüysüz and Kahraman [31] identified 6 main-environment &ownership, relationship management, project management, resources &planning, personnel &staffing, technology- and 28 sub risk factors for evaluation of the riskiness of an IT project and they proposed a fuzzy evaluation methodology for determination of project risk level. Norris et al. [11] defined SAP project's risk factors in 6 categories: executive risks, project management risks, technical risks, organizational risks, decision making risks, functional risks.

3.4. Fuzzy Sets and Risk Measurement Methodology

A number of research studies have investigated the issue of risk measurement. There are many qualitative and quantitative risk measurement methods in the literature. Due to the nature of risk benefiting from the fuzzy logic in risk evaluation is more reliable.

Fuzzy numbers are used for risk evaluation in various ways in the literature.

Kuchta [32] puts forward a fuzzy way of measuring the criticality of project activities and of the whole project. The criticality measure serves as a measure of risk and helps in making the decision whether to accept or to reject the project. In this approach, the decision makers expresses what he/she understands by "very critical," "a little critical," and so forth in the form of a fuzzy number. According to this approach, the criticality of the project (CritPr) is obtained by Equation 3.1:

$$\mathrm{CritPr}=\sum_{i=1}^{N} w_{ai}.\mathrm{Crit}_i \tag{3.1}$$

Where $w_i = (i=1,2,...,N)$ are weights such that $\sum_{i=1}^{N} w_{ai} = 1$. N is the number of project activities and $Crit_i$ is the criticality of the project activity i.

Lee et al. [33] present a new and flexible algorithm to evaluate the rate of aggregative risk in fuzzy circumstances by fuzzy sets theory during any phase of the software development life cycle. In this algorithm, each individual risk item is ranked using two fuzzy sets with triangular membership functions, grade of risk and grade of importance. Then the rate of each individual risk item is evaluated by multiplication by the centroid method. According to this algorithm, the final rate of aggregative risk (New_RIK) in software development is obtained by Equation 3.2:

$$New\_RIK = \frac{\sum_{h=1}^{n} GW_2(h)*R2(h)}{\sum_{h=1}^{n} GW_2(h)} = \sum_{h=1}^{n} GW_2(h)*R2(h) \tag{3.2}$$

3.4.1. Fuzzy Set Theory

The fuzzy set theory is a mathematical theory designed to model the vagueness or imprecision of human cognitive processes that was pioneered by Zadeh [34]. This theory is basically a theory of classes with unsharp boundaries. What is important to recognize is that any crisp theory can be fuzzified by generalizing the concept of a set within that theory to the concept of a fuzzy set. Fuzzy set theory and fuzzy logic have been applied in a great variety of applications, which are reviewed by several authors. Fuzzy set theory is an important branch of Operations Research, providing tools to quantify imprecise verbal statements and to classify outcomes of decision-analytical experiments.

Fuzzy set theory has been criticized for being probability theory in disguise; it is easy to understand now that the two theories are concerned with two distinct phenomena: with observations that can be classified in vaguely described (imprecise) categories only, and with experiments such that the outcomes can be classified into well-defined (crisp) categories. In essence, fuzzy set theory is concerned with our probability to categorize things and to label the categories via natural language [35].

The key idea of fuzzy set theory is that an element has a degree of membership in a fuzzy set. The membership function represents the grade of membership of an element in a set. The membership values of an element vary between 1 and 0. Elements can belong to a set in a certain degree and elements can also belong to multiple set. Fuzzy set allows the partial membership of elements. Transition between membership and non-membership is gradually. Membership function maps the variation of value of linguistic variables into different linguistic classes. The adaptation of membership function for a given linguistic variable under a given situation is done in three ways [36]:

(a) Experts previous knowledge about the linguistic variable;
(b) Using simple geometric forms having slopes (triangular, trapezoidal or *s*-functions) as per the nature of the variable; and
(c) By trial and error learning process.

3.4.2. Fuzzy Sets and Triangular Fuzzy Numbers

To deal with vagueness of human thought, Zadeh [34] first introduced the fuzzy set theory, which was oriented to the rationality of uncertainty due to imprecision or vagueness. A major contribution of fuzzy set theory is its capability of representing vague data. The theory also allows mathematical operators and programming to apply to the fuzzy domain.

A fuzzy set is a class of objects with a continuum of grades of member -ship. Such a set is characterized by a membership (characteristic) function, which assigns to each object a grade of member ship ranging between 0 and 1. In this set the general terms such as “large”, “medium”, and “small” each will be used to capture a range of numerical values. A tilde “ ~ ” will be placed above a symbol if the symbol represents a fuzzy set.

A fuzzy number is a special fuzzy set, such that $\mu = \{(x, \mu_{\tilde{M}}(x), x \in R)\}$ where the value of x lies on the real line R_1 i.e. $-\infty < x < \infty$ and $\mu_{\tilde{M}}(x)$ is a continuous mapping from $R1$ to the close interval [0, 1]. If l, m and u, respectively, denote the smallest possible value, the most promising value and the largest possible value that describe a fuzzy event then the triangular fuzzy number (TFN) can be denoted as a triplet (l, m, u) where, $l \le m \le u$. When $l = m = u$, it is a non-fuzzy number by convention. The membership function can be defined as:

$$\mu_{\tilde{M}}(x) = \begin{cases} (x-l)/(m-l), & l \le x \le m \\ (u-x)/(u-m), & m \le x \le u \\ 0, & \text{otherwise} \end{cases} \tag{3.3}$$

A TFN is shown in Figure 3.2.

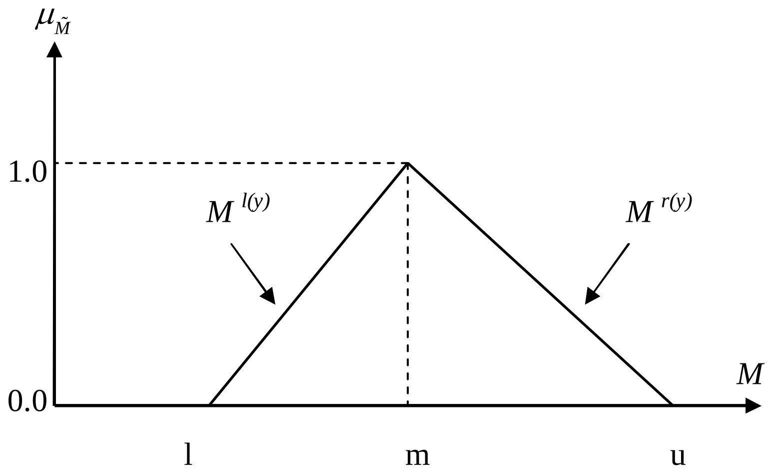

Figure 3.2 A triangular fuzzy number.

A fuzzy number can be given by its corresponding left and right representation of each degree of membership:

$$M = \left(M^{l(y)}, M^{r(y)} \right) = \left(l + (m-l)y, u + (m-u)y \right), y \in [0,1] \tag{3.4}$$

l(y) and *r(y)* denote the left side and the right side representation of a fuzzy number, respectively.

Consider two triangular fuzzy numbers M_1 and M_2, $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$. The operational laws of triangular fuzzy numbers are as follows [37]:

1. $(l_1, m_1, u_1) \oplus (l_2, m_2, u_2)$

$$= (l_1 + l_2,\ m_1 + m_2,\ u_1 + u_2). \tag{3.5}$$

2. $(l_1, m_1, u_1) \odot (l_2, m_2, u_2)$

$$\cong (l_1 l_2,\ m_1 m_2,\ u_1 u_2). \tag{3.6}$$

3. $(\lambda, \lambda, \lambda) \odot (l_1, m_1, u_1)$

$$\cong (\lambda l_1, \lambda m_1, \lambda u_1),\ \ \lambda \rangle 0,\ \lambda \in R. \tag{3.7}$$

4. $(l_1, m_1, u_1)^{-1} \cong (1/u_1, 1/m_1, 1/l_1)$ (3.8)

3.4.3. Multi-Attribute Evaluation Under Fuzziness: Fuzzy AHP

There are many fuzzy AHP methods proposed by various authors. These methods are systematic approaches to the alternative selection and justification problem by using the concepts of fuzzy set theory and hierarchical structure analysis. Decision makers usually find that it is more certain to give interval judgments than fixed value judgments. This is because usually he/she is unable to be explicit about his/her preferences due to the fuzzy nature of the comparison process.

The first studies of fuzzy AHP is presented by Van Laarhoven and Pedrycz [38] which compared fuzzy ratios described by triangular membership functions. Buckley [39] determines fuzzy priorities of comparison ratios whose membership functions are trapezoidal. Chang [37] introduces a new approach for handling fuzzy AHP, with the use of triangular fuzzy numbers for pair wise comparison scale of fuzzy AHP, and the use of the extent analysis method for the synthetic extent values of the pair wise comparisons.

In their research, Tüysüz and Kahraman [31] reviewed numbers of fuzzy AHP approaches.

Table 3.1 gives a comparison of the fuzzy AHP methods in the literature that have important differences in their theoretical structures. The comparison includes the advantages and disadvantages of each method.

Kahraman et al. [40-41], Buyukozkan et al. [42], Chan and Kumar [43], and Ayağ and Özdemir [36] used Chang's [37] fuzzy AHP for various decision-making problems in their researches.

Because of the advantages of Chang's [37] extent analysis on fuzzy AHP are relatively superior to the others due to the reasons mentioned in Table 3.1, this method will be used in project risk evaluation. In the literature, there is only one publication dealing with project risk evaluation using fuzzy AHP. Tüysüz and Kahraman proposed FAHP for risk evaluation of an information technology (IT) project. Mustafa and Al-Bahar [44] introduced the primary work of using AHP in project risk evaluation. They apply AHP in assessing the riskiness of a construction project.

Table 3.1 The comparison of different fuzzy AHP methods [42].

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

3.4.4. Extended Fuzzy AHP

In fuzzy extended AHP which was proposed by Chang [37] the steps of Saaty's [46] crisp AHP can be followed. We can summarize the basic steps of this AHP as follows:

Step 1: State the problem.
Step 2: Determine the objectives of the problem.
Step 3: Identify the criteria that influence the decision.
Step 4: Structure the problem in a hierarchy of different levels constituting goal, criteria, sub-criteria and alternatives.

The simplest form used to structure a decision problem is a hierarchy consisting of three levels: the goal of the decision at the top level, followed by a second level consisting of the criteria by which the alternatives located in the third level, will be evaluated (see Fig.3.3). Hierarchical decomposition of complex systems appears to be a basic device used by the human mind to cope with diversity. One organizes the factors affecting the decision in gradual steps from the general, in the upper levels of hierarchy, to the particular, in the lower levels. The purpose of the structure is to make it possible to judge the importance of the elements in a given level with respect to some of all of the elements in the adjacent level above [45].

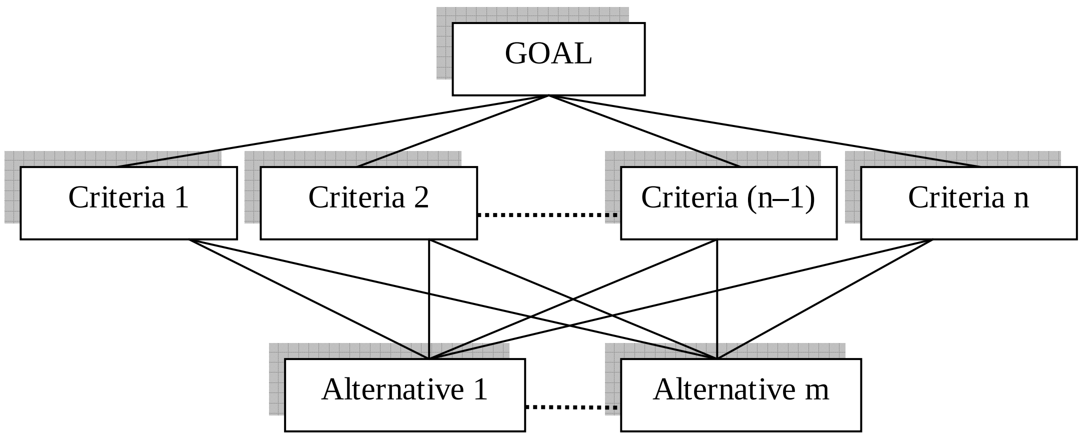

Figure 3.3 A three level hierarchy.

Step 5: Compare each element in the corresponding level and calibrate them on the numerical scale. This requires n (n-1)/2 comparisons, where n is the number of elements with the considerations that diagonal elements are equal or (1, 1, 1) in fuzzy AHP and the other elements will simply be the reciprocals of the earlier comparisons.

If strong importance of element i over element j hold, then the pair wise comparison scale can be represented by the fuzzy number $a_{ij}=(l,m,u)$ and its reciprocal will be $a_{ij}^{-1}=(1/u,1/m,1/l)$. A 3x3 pair wise comparison matrix can be represented as follows:

$$\begin{pmatrix} a_{11}=(1,1,1) & a_{12}=(l_{12},m_{12},u_{12}) & a_{13}=(l_{13},m_{13},u_{13}) \\ a_{21}=(1/u_{12},1/m_{12},1/l_{12}) & a_{22}=(1,1,1) & a_{23}=(l_{23},m_{23},u_{23}) \\ a_{31}=(1/u_{13},1/m_{13},1/l_{13}) & a_{32}=(1/u_{23},1/m_{23},1/l_{23}) & a_{33}=(1,1,1) \end{pmatrix}$$

Step 6: Perform calculations to check consistency. The consistency in fuzzy AHP is another important subject that needs to be examined. In literature there are a few methods for checking consistency.

- The AHP methodology of Saaty [46] provides a consistency index to measure any inconsistency within the judgments in each comparison matrix as well as for the entire hierarchy. The index can be used to indicate whether or not the targets can be arranged in an appropriate order of ranking and how consistent are the pair wise comparison matrices. In fuzzy AHP for consistency checking, the defuzzification method of triangular fuzzy numbers was employed to convert the fuzzy comparison matrices into crisp matrices, which thereafter are used for the investigation of the consistency similarly in crisp AHP.

  A triangular fuzzy number, represented as $M=(l,m,u)$, can be defuzzified to a crisp number as follows [47]:

$$M_{crisp}=(4m+l+u)/6 \tag{3.9}$$

The consistency index, CI, and the consistency ratio, CR, for a comparison matrix can be computed with the use of following equations:

$$CI=\frac{(\lambda_{max}-n)}{(n-1)} \tag{3.10}$$

$$CR=\frac{CI}{RI(n)} \tag{3.11}$$

Where λ_{max} is the largest eigen value of the comparison matrix, n is the dimension of the matrix, and RI (n) is a random index, that depends on n, as shown in Table 3.2.

If the CI value is found to be sufficiently small, the decision-maker's judgment may be consistent enough to give useful weighting estimates for various decision making criteria. If CI/RI $\leq$ 0.10, the degree of consistency is satisfactory. If CI/RI > 0.10, there are inconsistencies. In this case, the AHP may not yield meaningful results unless one re-examines the judgments and changes them as necessary to reduce the inconsistency below 0.10 [45].

λ_{max} can be calculated by the following steps [48]:

Assume that A is the defuzzified pair wise comparison matrix for m objectives.

$$A=\begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix}$$

Divide each entry in column j of A by the sum of the entries in column j. New matrix is Aw, in which the sum of the entries in each column will be 1. This operation is normalization.

$$Aw = \begin{bmatrix} \frac{a_{11}}{\sum a_{i1}} & \frac{a_{12}}{\sum a_{i2}} & \cdots & \frac{a_{1n}}{\sum a_{in}} \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ \frac{a_{n1}}{\sum a_{i1}} & \frac{a_{n2}}{\sum a_{i2}} & \cdots & \frac{a_{nn}}{\sum a_{in}} \end{bmatrix} \tag{3.12}$$

Compute c_i as the average of the entries in row i of Aw to yield the column vector C. Where c_i represents the relative degree of importance of the ith objective.

$$C = \begin{bmatrix} c_1 \\ c_2 \\ \cdots \\ c_n \end{bmatrix} = \begin{bmatrix} \frac{\frac{a_{11}}{\sum a_{i1}}}{n} + \frac{\frac{a_{12}}{\sum a_{i2}}}{n} + \ldots + \frac{\frac{a_{1n}}{\sum a_{in}}}{n} \\ \cdots\cdots\cdots\cdots\cdots\cdots \\ \cdots\cdots\cdots\cdots\cdots\cdots \\ \frac{\frac{a_{n1}}{\sum a_{i1}}}{n} + \frac{\frac{a_{n2}}{\sum a_{i2}}}{n} + \ldots + \frac{\frac{a_{nn}}{\sum a_{in}}}{n} \end{bmatrix} \tag{3.13}$$

Compute A.C.

$$A.C = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \times \begin{bmatrix} c_1 \\ \cdots \\ c_n \end{bmatrix} = \begin{bmatrix} x_1 \\ \cdots \\ x_n \end{bmatrix} \tag{3.14}$$

Calculate λmax.(maximum eigen value of the comparison matrix) by using the A.C and C matrices.

$$\lambda_{\max} = \frac{1}{n} \sum_{i=1}^{n} \frac{\text{ith entry in A.C}}{\text{ith entry in C}} = \frac{1}{n} \sum_{i=1}^{n} \frac{x_i}{c_i} \tag{3.15}$$

Table 3.2 Average random consistency index (RI) [45].

N	1	2	3	4	5	6	7	8	9	10
Random Consistency Index(R.I)	0	0	.52	.89	1.11	1.25	1.35	1.40	1.45	1.49

- Buckley [39] gives the following definition of consistency in terms of fuzzy numbers:

  A fuzzy positive reciprocal comparison matrix $\overline{R} = \left[\overline{r}_{ij}\right]$ is consistent if and only if the following indifference relationships hold:

  $$\overline{r}_{ik} \odot \overline{r}_{kj} \approx \overline{r}_{ij}, \quad \mathrm{i,j,k} \in 1,...,\mathrm{n}, \tag{3.16}$$

  where $\odot$ is a fuzzy multiplication symbol. Relationship (3.16) means that the fuzzy indifference relationship has a maximum membership value of 1.

- Leung and Cao [49] extended Buckley's approach. Fuzzy relationships are transformed into equivalent auxiliary crisp relationships in the forms of feasible region of relative weights.

  A fuzzy comparison matrix is defined to be consistent within tolerance deviation δ, if the α-level cut feasible region S'_α is not empty.

  $$S'_\alpha = \left\{ w : (1-\delta) L_{ij\alpha} \le \frac{w_i}{w_j} \le (1+\delta) U_{ij\alpha}, \quad i \ne j = 1,...,n, w_j \ge 0, \sum_{j=1,...,n} w_j = 1 \right\} \tag{3.17}$$

  where w_i and w_j are the weights of the ith and jth elements, respectively. Here δ represents deviations from the upper bound $U_{ij\alpha}$ and the lower bound $L_{ij\alpha}$.

A practical way to test the fuzzy comparison consistency within tolerance deviation δ is to solve the following auxiliary linear program:

$$
\begin{aligned}
&\min\beta=\beta_1+\beta_2\\
&\text{s.t.}\ln\left(1\text{-}\delta\right)L_{ij1}\le \ln(w_i)\text{-}\ln(w_j)+\beta_{1ij}\text{-}\beta_{2ij}\le \ln(1+\delta)U_{ij1}, \qquad i\ne j,1,...,n\\
&\beta_1\ge\beta_{1ij},\ \beta_2\ge\beta_{2ij},\ \beta_{1ij},\ \beta_{2ij}\ge 0
\end{aligned}
\tag{3.18}
$$

where $\ln(w_i)$, β_{1ij}, β_{2ij}, β_1, β_2 are decision variables.

If $\beta=0$, the fuzzy comparison matrix is consistent within tolerance deviation δ. If $\beta>0$, this means that there are no feasible weights, that the fuzzy comparison matrix is not consistent within δ. In this case, the decision maker would make the judgments again.

Step 7: Compute the value of fuzzy synthetic extent.

Let X={x_1, x_2, ..., x_n} be an object set, and U={u_1,u_2,..., u_m} be a goal set. According to the method of Chang's extent analysis, each object is taken and extent analysis for each goal, g_i, is performed, respectively. Therefore, m extent analysis values for each object can be obtained, with the following signs Chang [37]:

$$M_{g_i}^1, M_{g_i}^2, ..., M_{g_i}^m, \quad i=1,2,...,n \tag{3.19}$$

where all the $M_{g_i}^j$ $(j=1,2,...,m)$ are triangular fuzzy numbers (TFNs).

The value of fuzzy synthetic extent with respect to the i th object is defined as

$$S_i=\sum_{j=1}^{m}M_{g_i}^j\otimes\left[\sum_{i=1}^{n}\sum_{j=1}^{m}M_{g_i}^j\right]^{-1} \tag{3.20}$$

Step 8: Calculate the priority vectors of the fuzzy AHP.

Step 8.1: The degree of possibility of $M_1 \geq M_2$ is defined as

$$V\left(M_1 \geq M_2\right) = \sup_{x \geq y}\left[\min\left(\mu_{M_1}(x), \mu_{M_2}(y)\right)\right] \tag{3.21}$$

When a pair (x,y) exists such that $x \geq y$ and $\mu_{M_1}(x) = \mu_{M_2}(y) = 1$, then we have $V\left(M_1 \geq M_2\right) = 1$. Since M_1 and M_2 are convex fuzzy numbers;

$$\begin{aligned} &V\left(M_1 \geq M_2\right) = 1 \quad \text{iff } m_1 \geq m_2, \\ &V\left(M_2 \geq M_1\right) = \operatorname{hgt}\left(M_1 \cap M_2\right) = \mu_{M_1}(d), \end{aligned} \tag{3.22}$$

where d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_2} (see Figure 3.4).

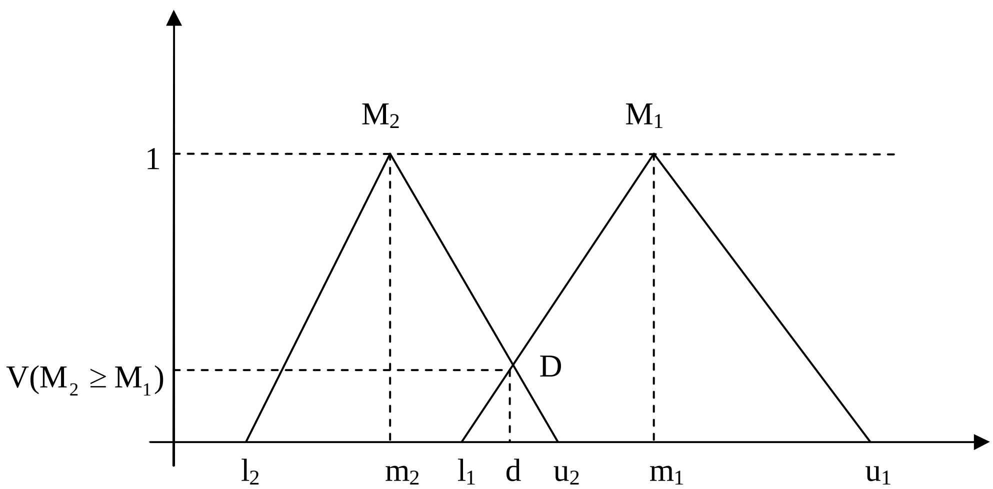

Figure 3.4 The intersection between M_1 and M_2.

When $M_1 = (l_1,m_1,u_1)$ and $M_2 = (l_2,m_2,u_2)$, the ordinate of D is given by:

$$V\left(M_2 \geq M_1\right)=hgt\left(M_1 \cap M_2\right)$$

$$=\begin{cases} 1, & \text{if } m_2 \geq m_1 \\ 0, & \text{if } l_1 \geq u_2 \\ \dfrac{\left(l_1\text{-}u_2\right)}{\left[\left(m_2\text{-}u_2\right)\text{-}\left(m_1\text{-}l_1\right)\right]}, & \text{otherwise} \end{cases} \tag{3.23}$$

To compare M_1 and M_2, we need both the values of $V\left(M_1 \geq M_2\right)$ and $V\left(M_2 \geq M_1\right)$.

Step 8.2: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $M_i\left(i=1,2,...,k\right)$ can be defined by

$$V(M \geq M_1,M_2,...,M_k) = V\left[\left(M \geq M_1\right) \text{and} \left(M \geq M_2\right) \text{and...and} (M \geq M_k)\right]$$
$$= \min V(M \geq M_i), \quad i=1,2,...,k . \tag{3.24}$$

Assume that;

$$d'\left(A_i\right)=\min V\left(S_i \geq S_k\right), \tag{3.25}$$

For $k=1,2,...,n$; $k \neq i$. Then the weight vector is given by

$$W'=(d'(A_1),d'(A_2),...,d'(A_n))^T \tag{3.26}$$

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

Step 8.3: Via normalization, the normalized weight vectors are

$$W=(d(A_1),d(A_2),...,d(A_n))^T \tag{3.27}$$

where W is a non fuzzy number.

4. APPLICATION

4.1.Application Company

The implementer company is a global automotive corporation working in partnership with all the major vehicle manufacturers to design and develop an innovative range of products.

The business type of the company is import and sale of electrical wire harnesses and components for motor cars through a number of sales offices in Europe. The main products of the company are connectors and Electrical/Electronical Distribution Systems (EEDS).

With affiliate companies across 38 countries and a workforce of almost more than 150,000 employees the company is an international organization confident in all its markets. In Turkey there are 3 affiliate companies and two of them are located in Bursa.

As mentioned in the previous sections, today, one of the major sources of competitive advantage has been the ability to speed up the supply chain process. This demand led to a significant development in ERP systems. Instead of developing IT system in-house, more and more companies are turning to off-the-shelf ERP solutions to plan their IT resources more effectively and manage their legacy systems.

In this research the implementer company which is in Mudanya-Bursa has decided to implement SAP/R3 software package as an ERP solution to their existing system for optimizing their supply chain process and enforce its competency in the market. The company aims to integrate all its business units and standardize the flow of management by using SAP/R3 as an ERP solution.

Except the cutting area in all production units, logistic department, planning department, industrial engineering department, company warehouses, CSC warehouse, human resources department will integrated by using SAP. In cutting area cutting area optimizer "CAO" software will be used. Figure 4.1 shows a simple usage layout of SAP and CAO.

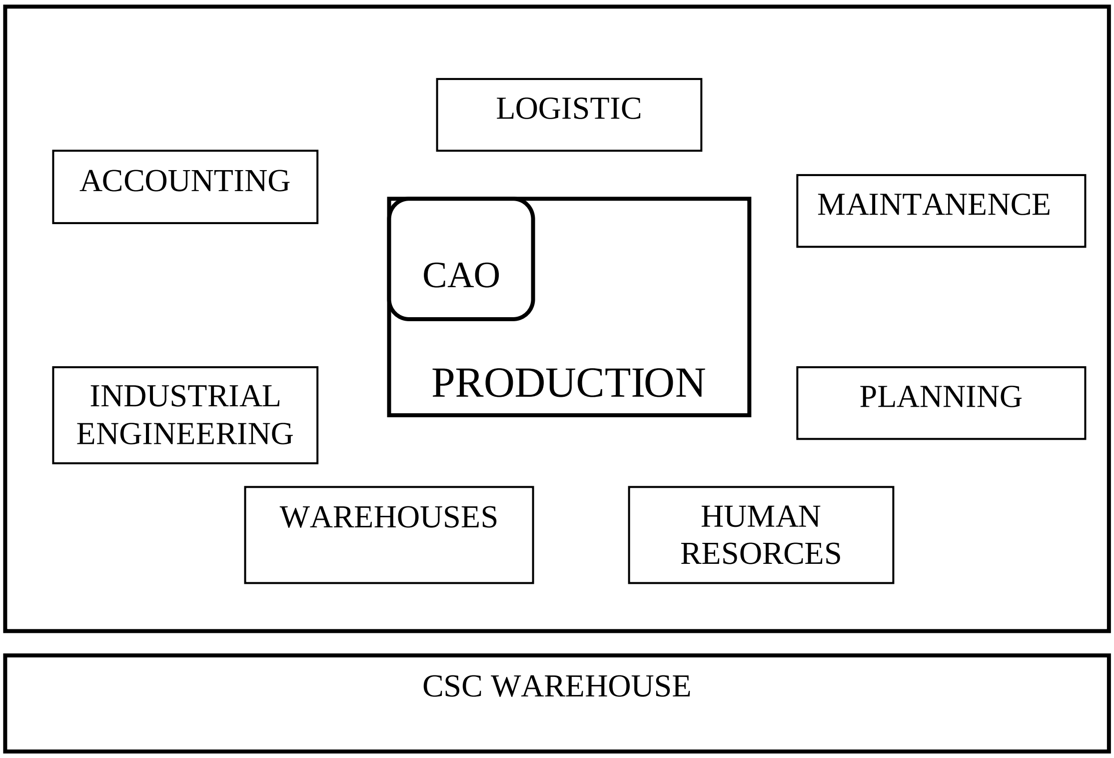

Figure 4.1 A Simple usage layout of SAP and CAO.

4.2.Application of FEAHP in Risk Evaluation of an ERP Project

Risks are multidimensional; so they should be evaluated with respect to more than one criterion to get more reliable results. The Analytic Hierarchy Process (AHP) is one of the most widely used multiple criteria decision-making tools. The AHP can effectively handle both qualitative and quantitative data.

Risk is essentially uncertainty and includes imprecise and vague data. AHP uses crisp data and does not take uncertainty into account. Fuzzy set theory is a mathematical theory designed to model the vagueness or impression of human judgment. It is especially powerful when there is an unavailability of precise or complete information. Fuzzy set theory can be a valid supporting tool to overcome the handicaps of AHP in fuzzy environment.

Because of risk's multidimensional and imprecise nature, in this research FEAHP method is proposed in order to determine the risk level of an SAP implementation project.

4.2.1. Identification of Main Risk Criteria and Sub Risk Criteria

In this section, for the identification phase of the study, risk criteria were composed from early studies and experiences of SAP consultants. According to these researches risk is classified in 6 main groups:

1. **Executive Risks:**

- **Goals & Plan "GP" Risk:** When the project goals are not met, the information system is considered as a failure. It is certain that goals and strategic plan should be specified clearly in advance and that their achievements should be accurately measured. If project goals and strategic plan are not well defined in the earliest steps of the project in other words lack of clear goals and strategic plan will affect the success of the project.

- **Business Environment "BE" Risk:** Unstable business environment criterion includes a climate of change in the business and organizational environment that creates instability in the project.

- **Ownership "O" Risk:** This criterion includes oversight by executives and visibility of their commitment. Successful implementations require strong leadership qualifications, experience, commitment, and participation by top management. Experience in implementing large scale integrated packages, including MRP systems, provides a better understanding of the challenges associated with commercial, off-the shelf software implementation. In previous researches many authors concluded that commitment from the top management was one of the most important critical success factors for implementation.

2. **Organizational Risk:**

- **Cooperation "CO" Risk:** Lack of cooperation between departments, failure to mix internal and external personnel are some of sub risk criterions which can be classified under cooperation risk criteria. Cooperation and communication are very important criterions for successful implementation. Here it is important to integrate external and internal personnel for the success of the project. Using a mix of consultants and internal staff to work on a project team enables internal staff members to "grow" the necessary technical skills for ERP systems design and implementation.

- **Staffing "S" Risk:** If the implementer company has not got enough skilled personnel to conduct the implementation project and the success of the implementation project depends on only a few key people then the risk level of the project will increase. Many of the organizations found it difficult to recruit and retain good ERP specialists because the market rates for these people are high. Management must understand and appreciate the criticality of high-tech worker turnover, recruitment and retention issues.

- **Expertise "E" Risk:** Information technology (IT) expertise of the firm is a very important factor which affects the project success. If there is no adequate IT expertise of the firm they should brought in the consultants they needed in order to overcome technical and procedural challenges in design and implementation. At this point it is important to obtain consultants who are specialists in specific application modules.

- **Organization's Culture "OC" Risk:** Lack fit of organizational culture and SAP culture is one important cause of project implementation failures. For a more successful implementation the dimensions of organizational culture should be identified to find their relationships with the implementation of ERP systems. ERP implementation projects will be more successful in a result oriented, employee oriented, professional, open and tight control system organizations.

3. **Project Management Risks:**

- **Scoping & planning "SP" Risk:** Important deadlines, milestones, phases of the project, and requirements should be identified at the beginning of the project. A clear plan will help the organization avoid the "scope creep" which can strain the ERP budget, project progress, and complicate the implementation. Lack of clear project scope and objectives, unrealistic deadlines, project size, weak definitions of requirements, and extent of changes in the project can be classified in this risk group.

- **Resource "R" Risk:** Lack of use of resources, inappropriate resources certainly increases the riskiness of the project. At the earliest stages of the project resource analysis should be made and if there is no appropriate resource exist external support and preventive actions should be taken.

- **Project Implementation Team "PIT" Risk:** Inexperienced team members, poor team relationships, inappropriate balance of technical &business skills of team members, lack of team members' commitment, and lack of an effective leader can be listed as the major sub risk factors of "project implementation team" risk criteria. Successful implementations require impressive project teams so this criterion is one of the major success factors of an ERP implementation project.

- **Change Management "CM" Risk:** The change management strategy mobilized the troops by decentralizing change sessions within the business units, where information can circulate directly between individuals and where modifications in roles and structures are addressed and taken into account at the lowest level. If people are not properly prepared for the imminent changes, then resistance and chaos will be predictable consequences of the changes created by the implementation. Some of the sub risk factors of this group can be classified as: lack of clear change strategy, conflicts between users/departments about the change management, resistance for the change management, lack of an effective change champion and misunderstanding changes in requirements correctly. Change management risks are probably the major risks in an ERP implementation project. Because ERP projects are not only a software implementation project but also a primarily technological challenge which affect whole organization.

- **Training "T" Risk:** Training/education is probably the most widely recognized critical success factors. ERP implementation requires a critical mass of knowledge to enable people to solve problems within the framework of the system. If the employees do not understand how a system works, they will invent their own processes using those parts of the system they are able to manipulate. The full benefits of ERP cannot be realized until end users are using the new system properly. To make end user training successful, the training should start early, preferably well before the implementation begins and qualified consultants should be used. Executives often dramatically underestimate the level of education and training necessary to implement an ERP system as well as the associated costs. Top management must be fully committed to spend adequate money on education and end user training and incorporate it as part of the ERP budget.

  Lack of top management commitment to training, poor use of qualified consultants, insufficient training & reskilling (inadequate knowledge transfer), lack of appropriate plan for end-user training &education are sub risk factors which can be evaluated under the training risk criteria.

4. Technical Risks "TR":

- **Technical Expertise "TE" Risk:** Lack of appropriate technical personnel who can support the implementation process and getting inadequate assistance of SAP consultants will cause technical risks.

- **Software Complexity "SC" Risk:** The technological complexity and technical difficulty of the project can be stated as the sub risk criterions of software complexity risk factor. ERP software packages are not new technologies they have been using since 1990's. But the necessity of customization and technical complexity of their modules make them risky.

- **Database Inaptitude "DI" Risk:** Lack of an integrated technology strategy for supporting implementation causes further risks and bottlenecks in project success. The different 'technology' environments within one organization created delays in establishing consistency and coordination in the platforms, database management systems and operating system environments. Technology bottlenecks can occur when designers try to implement bridges between ERP modules and legacy applications. In our implementer company in cutting areas another software program called Cutting Area Optimizer (CAO) will be used. Integrating these two CAO and SAP software and using the same database is an important point which will create risk.

  Another important sub risk criteria for database inaptitude is manipulation errors of data from old system to new system. The new system requires the retrieval of old data from the legacy systems that has to be normalized, screened and stored in a sensible data format within the new systems data repository. While translating the old data to new system some manipulation errors will occur this situation causes errors in reporting systems.

- **Hardware "H" Risk:** Failure to meet hardware specifications and the affection risks of procedures when there exist a breakdown in the hardware are some sub risk factors for hardware risk criteria.

- **Adaptation Delays "AD":** As the ERP solution package "SAP" has been chosen by the implementer company. Certain SAP modules are customized for the company by the SAP consultants. Shortfalls in these externally furnished components and adaptation delays of SAP modules adaptation will increase the risk level of the implementation project.

5. **Decision Making Risks:**

- **Slow Decision Making "SDM" Risk:** Long decision cycles and inability to make crucial decisions are critical risk factors which will increase the riskiness of the implementation project.

- **Poor Decision Making "PDM" Risk:** Lack of effective decision making processes and inadequate use of effective decision making techniques can take place in this group of risk criteria.

6. **Functional Risks "FR":**

- **End-Users "EU":** Data accuracy is absolutely required for an ERP system to function properly. Because of the integrated nature of ERP, if someone enters the wrong data, the mistake can have a negative domino effect throughout the entire enterprise. Therefore, educating users on the importance of data accuracy and correct data entry procedures should be a top priority in an ERP implementation.

  ERP systems also require that everyone in the organization must work within the system, not around it. Employees must be convinced that the company is committed to using the new system, will totally changeover to the new system, and will not allow continued use of the old system. If the organization continues to run parallel systems, some employees will continue using the old systems and can generate resistance to using the new system, largely because people are ill-prepared for using it effectively. Not entering accurate and complete data to the system on time and resistance to using new system can take place in the end-user risk criteria group.

- **Process &System Integrity "PSI" Risk:** Modifying the purchased software or re-engineering existing business processes are two different solutions of process and system integrity problem. One of the principal reasons why ERP and other large technologically sophisticated systems fail is that organizations simply underestimate the extent to which they have to change and reengineering the existing business processes in order to accommodate their purchase. Either SAP customization or business process reengineering (BPR) processes includes risk so Process &system integrity criteria can be defined as an important success factor.

4.2.2. Construction of AHP Structure

In this study a four leveled hierarchy is proposed in order to classify the risk factors. The objective, which takes place at the top level, is to evaluate the riskiness of an SAP/R3 implementation project. The second level consists of 6 main risk factors. The third level consists of 21 sub-risk factors. And finally 3 risk levels high, medium and low located in the fourth level as alternatives. Figure 4.2 shows the AHP structure.

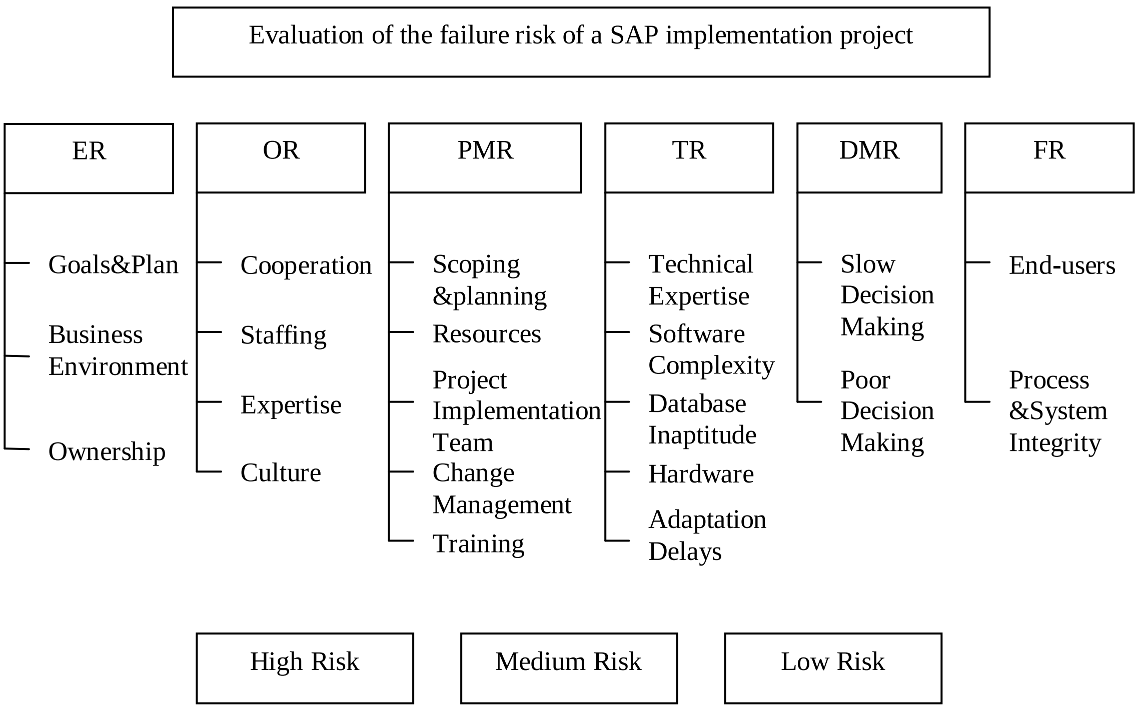

Figure 4.2 Four leveled AHP structure.

In conventional AHP/FAHP the alternatives have certain bounds, but when the risk levels are categorized as alternatives the bound of the each level should be identified clearly.

4.2.3. Risk Level Identification

The significance of a risk can be expressed as a combination of its consequences or impacts on project objectives, and the likelihood of those consequences arising. For clear and accurate identification of risk levels "likelihood" and "consequence" ratings were used. Table 4.1 shows a matrix defining the significance of various combinations of likelihood and consequence scales.

Table 4.1 Likelihood and consequence scales.

	Consequences				
Likelihood	*Insignificant*	*Minor*	*Moderate*	*Major*	*Catastrophic*
Almost certain	Medium	Medium	High	High	High
Likely	Low	Medium	Medium	High	High
Possible	Low	Medium	Medium	Medium	High
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Medium	Medium

As mentioned in the previous sections, recent studies show that many of ERP projects have 'failed', in the combination of budget and/or schedule overruns. According to these findings top management suggested to rate the consequences in terms of cost and schedule factor.

Table 4.2 - 4.3 shows the consequence descriptions of cost and schedule factors. As the consequence descriptions, also likelihood rating descriptions were made by top management. Table 4.4 shows the likelihood ratings.

Table 4.2 Consequence ratings of cost factor.

Rating	Cost Factor
Insignificant	Budget estimates not exceeded, some transfer of money.
Minor	Project cost estimates exceeded budget by 1-5%.
Moderate	Project cost estimates exceeded budget by 5-15%.
Major	Project cost estimates exceeded budget by 15-30%.
Catastrophic	Project cost estimates exceeded budget by more than 30%.

Table 4.3 Consequence ratings of schedule factor

Rating	Schedule Factor
Insignificant	Negligible impact, slight schedule change compensated by slack time.
Minor	Minor slip in project schedule, less than 10 days.
Moderate	Small slip in project schedule, from 10 to 30 days.
Major	Project schedule slip from 1 to 2 months.
Catastrophic	Large project schedule slip, key milestones not achieved.

Table 4.4 Likelihood ratings.

Rating	Likelihood descriptions
Almost certain	Very high possibility of occurrence. Probability over 0.8.
Likely	High possibility of occurrence. Probability 0.5-0.8.
Possible	Possible. Probability 0.1-0.5.
Unlikely	Low possibility of occurrence (not impossible). Probability 0.02-0.1.
Rare	Very low possibility of occurrence. Probability less than 0.02.

4.2.4. Construction of Matrices and Risk Evaluation

In FEAHP, after developing the hierarchy the second step is comparative judgment. SAP consultants and IT experts of the firm are made their comparisons by using the triangular fuzzy scale which is given in Table 4.5.

In order to take the imprecision of human qualitative assessments into consideration defined fuzzy numbers are used. Sample questionnaire forms to receive the experts' assessments are given in Appendix A.

Table 4.5 Triangular fuzzy conversion scale.

Linguistic scale	Fuzzy scale	Fuzzy reciprocal scale
Equally important	(1, 1, 1)	(1, 1, 1)
Moderately more important	(2/3, 1, 3/2)	(2/3, 1, 3/2)
Strongly more important	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very strongly more important	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)
Absolutely more important	(7/2, 4, 9/2)	(2/9, 1/4, 2/7)

The elements on the second level/main risk criteria are arranged into a matrix and the judgments about the relative importance of the elements are made by the experts. As mentioned in the previous sections the pair wise comparison will be performed in terms of which of the elements will dominate the other. Comparisons are made by linguistic judgments. These judgments will then be expressed as triangular fuzzy numbers. The pair wise comparison matrix for main risk criteria is shown in Table 4.6. The values of the matrix are the mean values of the decision makers' preferences. Detailed fuzzy evaluation matrices of each expert are given in Appendix B.

Table 4.6 The fuzzy evaluation matrix of criteria with respect to the goal.

	ER	OR	PMR	TR	DMR	FR
ER	(1,1,1)	(0.94,1.33,1.83)	(0.49,0.67,0.94)	(0.85,1.17,1.55)	(1.55,2.00,2.50)	(1.55,2.00,2.50)
OR	(0.57,0.83,1.22)	(1,1,1)	(0.77,1.00,1.27)	(0.77,1.00,1.27)	(0.94,1.33,1.83)	(0.85,1.17,1.55)
PMR	(1.22,1.67,2.17)	(1.13,1.50,1.89)	(1,1,1)	(1.22,1.67,2.17)	(1.22,1.67,2.17)	(1.50,2.00,2.50)
TR	(0.85,1.17,1.55)	(1.13,1.50,1.89)	(0.49,0.67,0.94)	(1,1,1)	(1.22,1.67,2.17)	(0.94,1.33,1.83)
DMR	(0.45,0.61,0.85)	(0.57,0.83,1.22)	(0.49,0.67,0.94)	(0.49,0.67,0.94)	(1,1,1)	(0.94,1.33,1.83)
FR	(0.45,0.61,0.85)	(0.85,1.17,1.55)	(0.40,0.50,0.66)	(0.57,0.83,1.22)	(0.57,0.83,1.22)	(1,1,1)

Before performing the calculations consistency of the pair wise comparison matrices were examined. First triangular fuzzy numbers were converted to crisp numbers by using Equation (3.9). Then by using Equations (3.10) and (3.11), consistency ratio CR is calculated. It is found that the degree of consistency is satisfactory for all of the comparison matrices.

By using the consistent fuzzy comparison matrix which is given in Table 4.6 the value of fuzzy synthetic extent with respect to the overall goal is calculated by using Equation (3.20). Calculations are made by Microsoft Excel. Fuzzy synthetic values are obtained as follows:

$$S_{ER} = (6.38, 8.17, 10.32) \otimes (0.02, 0.02, 0.03)$$
$$= (0.12, 0.20, 0.32)$$

$$S_{OR} = (4.90, 6.33, 8.14) \otimes (0.02, 0.02, 0.03)$$
$$= (0.09, 0.15, 0.25)$$

$$S_{PMR} = (7.29, 9.51, 11.90) \otimes (0.02, 0.02, 0.03)$$
$$= (0.14, 0.23, 0.37)$$

$$S_{TR} = (5.63, 7.34, 9.38) \otimes (0.02, 0.02, 0.03)$$
$$= (0.11, 0.18, 0.29)$$

$$S_{DMR} = (3.94, 5.11, 6.78) \otimes (0.02, 0.02, 0.03)$$
$$= (0.07, 0.12, 0.21)$$

$$S_{FR} = (3.84, 4.94, 6.50) \otimes (0.02, 0.02, 0.03)$$
$$= (0.07, 0.12, 0.20)$$

And by using these synthetic values degree of possibility values are obtained from Equation (3.23).

$V(S_{ER} \geq S_{OR}) = 1$, $V(S_{ER} \geq S_{PMR}) = 0.85$, $V(S_{ER} \geq S_{TR}) = 1$,

$V(S_{ER} \geq S_{DMR}) = 1$, $V(S_{ER} \geq S_{FR}) = 1$,

$V(S_{OR} \geq S_{ER})= 0.75,$ $V(S_{OR} \geq S_{PMR})= 0.60,$ $V(S_{OR} \geq S_{TR})= 0.86,$
$V(S_{OR} \geq S_{DMR})= 1,$ $V(S_{OR} \geq S_{FR})= 1,$

$V(S_{PMR} \geq S_{ER})= 1,$ $V(S_{PMR} \geq S_{OR})= 1,$ $V(S_{PMR} \geq S_{TR})= 1,$
$V(S_{PMR} \geq S_{DMR})= 1,$ $V(S_{PMR} \geq S_{FR})= 1,$

$V(S_{TR} \geq S_{ER})= 0.90,$ $V(S_{TR} \geq S_{OR})= 1,$ $V(S_{TR} \geq S_{PMR})= 0.75,$
$V(S_{TR} \geq S_{DMR})= 1,$ $V(S_{TR} \geq S_{FR})= 1,$

$V(S_{DMR} \geq S_{ER})= 0.55,$ $V(S_{DMR} \geq S_{OR})= 0.80,$ $V(S_{DMR} \geq S_{PMR})= 0.41,$
$V(S_{DMR} \geq S_{TR})= 0.66,$ $V(S_{DMR} \geq S_{FR})= 1,$

$V(S_{FR} \geq S_{ER})= 0.52,$ $V(S_{FR} \geq S_{OR})= 0.77,$ $V(S_{FR} \geq S_{PMR})= 0.37,$
$V(S_{FR} \geq S_{TR})= 0.63,$ $V(S_{FR} \geq S_{DMR})= 0.97,$

By applying Equation 3.25, d' values are obtained:

$$d'(ER) = V(S_{ER} \geq S_{OR}, S_{PMR}, S_{TR}, S_{DMR}, S_{FR})$$
$$= \min(1,\ 0.85,\ 1,\ 1,\ 1) = 0.85$$

$$d'(OR) = V(S_{OR} \geq S_{ER}, S_{PMR}, S_{TR}, S_{DMR}, S_{FR})$$
$$= \min(0.75,\ 0.60,\ 0.86,\ 1,\ 1) = 0.60$$

$$d'(PMR) = V(S_{PMR} \geq S_{ER}, S_{OR}, S_{TR}, S_{DMR}, S_{FR})$$
$$= \min(1,\ 1,\ 1,\ 1,\ 1) = 1$$

$$d'(TR) = V(S_{TR} \geq S_{ER}, S_{OR}, S_{PMR}, S_{DMR}, S_{FR})$$
$$= \min(0.90,\ 1,\ 0.75,\ 1,\ 1) = 0.75$$

$$d'(DMR) = V(S_{DMR} \geq S_{ER}, S_{OR}, S_{PMR}, S_{TR}, S_{FR})$$
$$= \min(0.55, 0.80, 0.41, 0.66, 1) = 0.41$$

$$d'(FR) = V(S_{FR} \geq S_{ER}, S_{OR}, S_{PMR}, S_{TR}, S_{DMR})$$
$$= \min(0.52, 0.77, 0.37, 0.63, 0.97) = 0.37$$

Therefore, according to Equation (3.26) the weight vector is given by the minimum d' values of each risk criterion:

$$W' = (0.85, 0.60, 1, 0.75, 0,41, 0.37)^T$$

Via normalization the normalized weight vector with respect to goal W_G is obtained as:

$$W_G = (0.21, 0.15, 0.26, 0.19, 0.10, 0.09)^T.$$

Figure 4.3 exhibits the weighting values for main risk criteria.

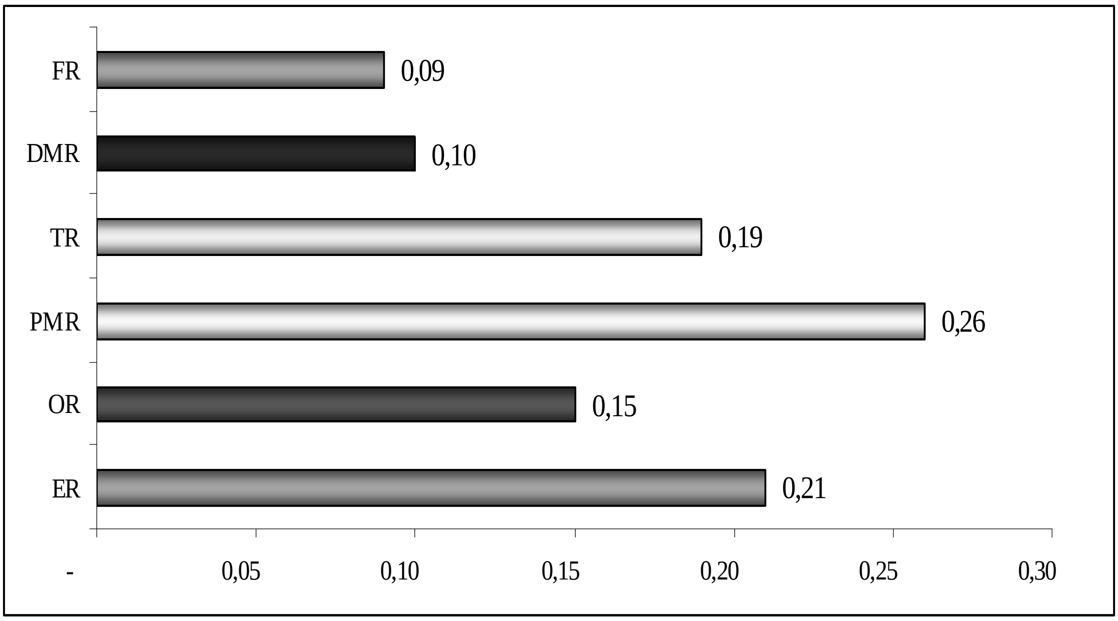

Figure 4.3 Weighting values of main risk criteria.

After the pair wise comparisons and evaluation of weight vector with respect to the goal the same steps are repeated in order to find the weight vectors of each sub-risk criterion. Thus six comparison matrices are composed and weight vectors are evaluated as shown in Table 4.7 - 4.12.

Table 4.7 Evaluation of the sub-risk criterion with respect to executive risks.

	GP	BE	O	W_{ER}
GP	(1,1,1)	(1.5, 2.00, 2.50)	(0.94, 1.33, 1.83)	0.52
BE	(0.40, 0.50, 0.66)	(1,1,1)	(0.49, 0.67, 0.94)	0.08
O	(0.57, 0.83, 1.22)	(1.22, 1.67, 2.17)	(1,1,1)	0.40

Table 4.8 Evaluation of the sub-risk criterion with respect to organizational risks.

	CO	S	E	OC	W_{OR}
CO	(1,1,1)	(1.83, 2.33, 2.83)	(1.22, 1.67, 2.17)	(1.22, 1.67, 2.17)	0.46
S	(0.36, 0.44, 0.57)	(1,1,1)	(0.49, 0.67, 0.94)	(0.66, 1.00, 1.50)	0.09
E	(0.49, 0.67, 0.94)	(1.22, 1.67, 2.17)	(1,1,1)	(1.22, 1.67, 2.17)	0.32
OC	(0.49, 0.67, 0.94)	(0.66, 1.00, 1.50)	(0.49, 0.67, 0.94)	(1,1,1)	0.13

Table 4.9 Evaluation of the sub-risk criterion with respect to project management risks.

	SP	R	PIT	CM	T	W_{PMR}
SP	(1,1,1)	(1.22,1.67,2.17)	(1.22,1.67,2.17)	(0.66,1.00,1.50)	(0.94,1.33,1.83)	0.26
R	(0.49,0.67,0.94)	(1,1,1)	(0.94,1.33,1.83)	(0.40,0.50,0.66)	(0.57,0.83,1.22)	0.14
PIT	(0.49,0.67,0.94)	(0.57,0.83,1.22)	(1,1,1)	(0.49,0.67,0.94)	(0.94,1.33,1.83)	0.15
CM	(0.66,1.00,1.50)	(1.50,2.00,2.50)	(1.22,1.67,2.17)	(1,1,1)	(1.27,1.67,2.17)	0.28
T	(0.57,0.83,1.22)	(0.94,1.33,1.83)	(0.57,0.83,1.22)	(0.54,0.78,1.13)	(1,1,1)	0.17

Table 4.10 Evaluation of the sub-risk criterion with respect to technical risks.

	TE	SC	DI	H	AD	W_{TR}
TE	(1,1,1)	(1.22,1.67,2.17)	(0.94,1.33,1.83)	(0.94,1.33,1.83)	(0.94,1.33,1.83)	0.25
SC	(0.49,0.67,0.94)	(1,1,1)	(0.49,0.67,0.94)	(0.57,0.83,1.22)	(0.54,0.78,1.13)	0.12
DI	(0.57,0.83,1.22)	(1.22,1.67,2.17)	(1,1,1)	(1.83,2.33,2.83)	(0.94,1.33,1.83)	0.27
H	(0.57,0.83,1.22)	(0.94,1.33,1.83)	(0.36,0.44,0.57)	(1,1,1)	(0.57,0.83,1.22)	0.15
AD	(0.57,0.83,1.22)	(1.27,1.67,2.17)	(0.57,0.83,1.22)	(0.94,1.33,1.83)	(1,1,1)	0.21

Table 4.11 Evaluation of the sub-risk criterion with respect to decision making risks.

	SDM	PDM	W_{DMR}
SDM	(1,1,1)	(0.82, 1.11, 1.47)	0.42
PDM	(1.19, 1.50, 1.89)	(1,1,1)	0.58

Table 4.12 Evaluation of the sub-risk criterion with respect to functional risks.

	EU	PSI	W_{FR}
EU	(1,1,1)	(0.77, 1.00, 1.27)	0.38
PSI	(1.13, 1.50, 1.89)	(1,1,1)	0.62

In this section, as the first step of the evaluations, firstly the relative weights of the main risk criterion with respect to the goal and then relative weights of the sub-risk criterion with respect to the related main risk criteria are evaluated.

Finally, the experts assessed the risk level of sub-risk criterion by again making pair wise comparisons between high risk (HR), medium risk (MR), and low risk (LR) and performed similar calculations. Table 4.13 gives the summary of combinations of priority weights of sub-risk criterion.

The weights of risk levels with respect to the each main risk criteria are given by adding the weights per risk level multiplied by weights of the corresponding sub-risk criteria.

Finally the weights of each risk level can be calculated by weights per risk level multiplied by weights of the corresponding main criteria. Table 4.14 shows the weights of risk levels with respect to the each main risk criteria and overall score of each risk level.

Table 4.13 Summary of combinations of priority weights.

Sub-risk criterion of executive risks						
	GP	BE	O			Risk level's weight
Weight	0.52	0.08	0.40			
Risk levels						
High Risk	0.74	0.57	0.60			0.67
Medium Risk	0.26	0.43	0.40			0.33
Low Risk	0.00	0.00	0.00			0.00
Sub-risk criterion of organizational risks						
	CO	S	E	OC		
Weight	0.46	0.09	0.32	0.13		Risk level's weight
Risk levels						
High Risk	0.40	0.60	0.37	0.32		0.40
Medium Risk	0.33	0.29	0.45	0.45		0.38
Low Risk	0.27	0.11	0.18	0.23		0.22
Sub-risk criterion of project management risks						
	SP	R	PIT	CM	T	
Weight	0.26	0.14	0.15	0.28	0.17	Risk level's weight
Risk levels						
High Risk	0.40	0.18	0.42	0.61	0.76	0.49
Medium Risk	0.52	0.37	0.52	0.36	0.24	0.41
Low Risk	0.08	0.45	0.06	0.03	0.00	0.10
Sub-risk criterion of project technical risks						
	TE	SC	DI	H	AD	
Weight	0.25	0.12	0.27	0.15	0.21	Risk level's weight
Risk levels						
High Risk	0.18	0.36	0.57	0.41	0.40	0.39
Medium Risk	0.69	0.61	0.43	0.46	0.30	0.49
Low Risk	0.13	0.03	0.00	0.13	0.30	0.12
Sub-risk criterion of project decision making risks						
	SDM	PDM				
Weight	0.42	0.58				Risk level's weight
Risk levels						
High Risk	0.68	0.59				0.63
Medium Risk	0.32	0.41				0.37
Low Risk	0.00	0.00				0.00
Sub-risk criterion of project functional risks						
	EU	PSI				
Weight	0.38	0.62				Risk level's weight
Risk levels						
High Risk	0.54	0.28				0.38
Medium Risk	0.46	0.58				0.53
Low Risk	0.00	0.14				0.09

Table 4.14 Weights of risk levels and overall score.

	Main risk criterion of the goal						
	ER	OR	PMR	TR	DMR	FR	
Weight	0.21	0.15	0.26	0.19	0.10	0.09	Risk level's weight
Risk levels							
High Risk	0.67	0.40	0.49	0.39	0.63	0.38	0.50
Medium Risk	0.33	0.38	0.41	0.49	0.37	0.53	0.41
Low Risk	0.00	0.22	0.10	0.12	0.00	0.09	0.09

4.2.5. Research Results

By using fuzzy extended AHP, firstly, the relative importance of main risk criteria with respect to the goal and the relative importance of sub-risk criteria with respect to the related main risk criteria were calculated. As shown in Figure 4.3 project management risks "PMR" carries the highest priority of 26% and it is followed by with 21% executive risks "ER", 19% technical risks "TR", 15% organizational risks "OR", 10% decision making risks "DMR" and 9% functional risks "FR".

Goals and plan risks "GP" is identified as the most important attribute under the criterion of executive risks. Under the organizational risks criterion cooperation risks "CO" carries higher priority weights. Change management risks "CM" is the most important attribute under the project management risks criterion. For technical risks criterion database inaptitude "DI", for decision making criterion poor decision making "PDM" and for functional risks criterion process and system integrity "PSI" sub attributes carries the highest priority weights.

After the evaluation of priority weights of risk levels with respect to the each sub-risk criterion, Figure 4.4 and Figure 4.5 are obtained as a summary.

In Figure 4.4 it can be seen that training "T", goals and plan "G&P" and slow decision making "SDM" sub-risk factors are the most risky attributes of this project. Preventive actions for reducing risk should be taken starting from these attributes.

Similarly Figure 4.4, Figure 4.5 shows the priority weights of main risk criteria's risk levels. According to these results executive risks "ER" includes the highest risk when it is compared with the other risk factors.

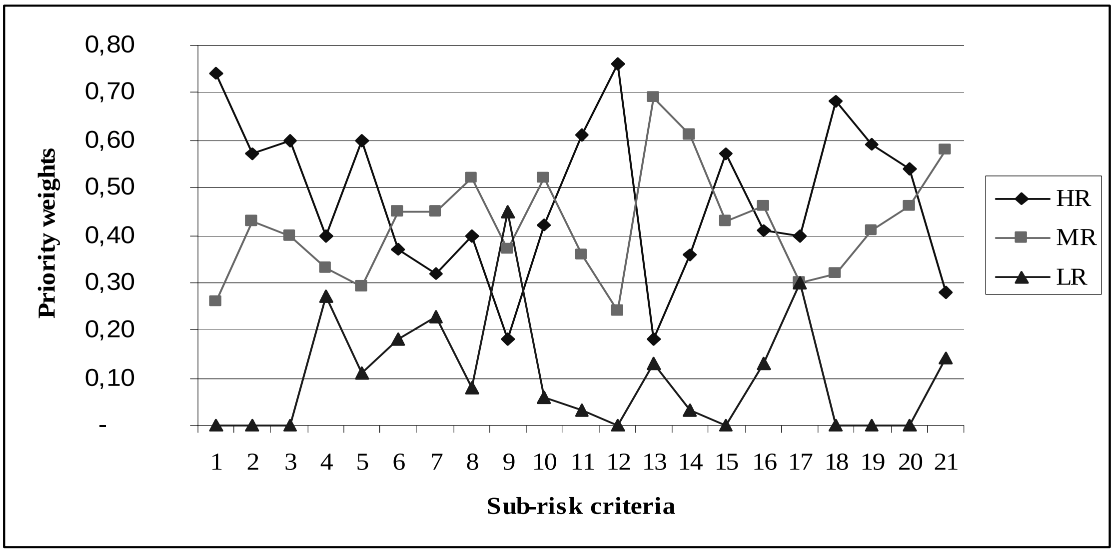

Figure 4.4 Priority weights of each risk level with respect to the sub-risk factors.

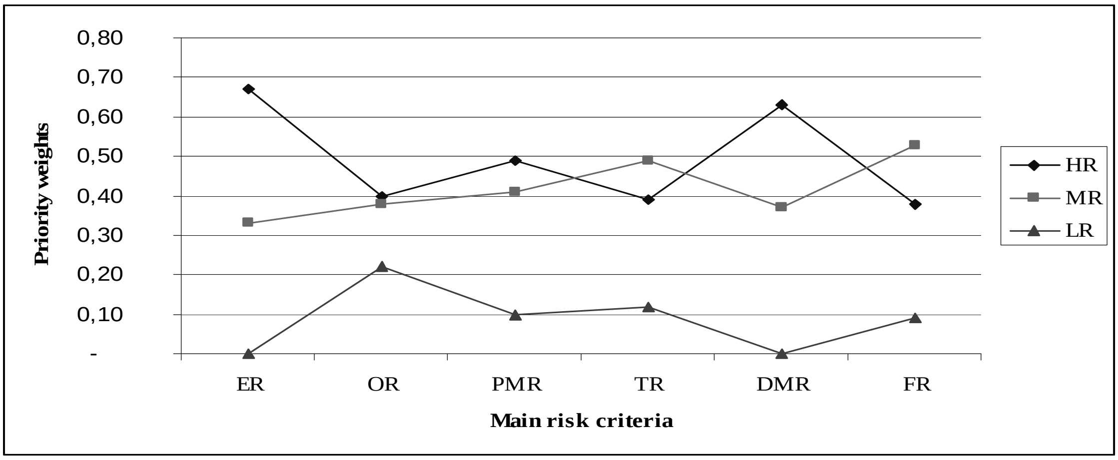

Figure 4.5 Priority weights of each risk level with respect to the risk factors.

After the calculations which were recommended in the previous sections the final risk levels are obtained. Figure 4.6 represents the riskiness of the implementation project. With 50% high, 41% medium and 9% low risk this project is a risky project.

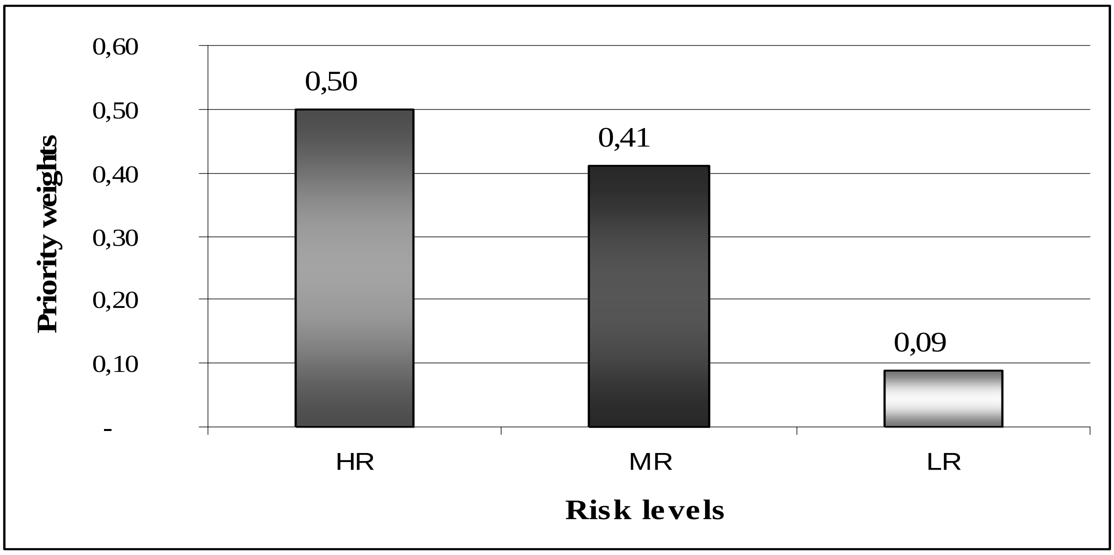

Figure 4.6 Final priority weights of risk levels.

5. CONCLUSION

In this research Fuzzy Extended Analytic Hierarchy Process approach has been presented to evaluate the riskiness of an ERP implementation project. In the approach triangular fuzzy numbers were used. The aim of this study is to identify the risk factors and furthermore evaluate the failure risk of an SAP/R3 implementation project.

Risk evaluation process is very important for ERP implementation projects. Because, recent studies show that more than three quarters of enterprise resource planning (ERP) projects were judged as unsuccessful by the implementing firms. According to these results we can say that ERP implementation projects are risky projects. Thus, the risk evaluation is critically important for the success of these kinds of projects.

Project risk evaluation should be performed by using one of the multi-attribute evaluation methods. Because of the multidimensional nature of risks benefiting from the multi-attribute evaluation methods is more reliable. And also risk is essentially uncertainty and includes imprecise and vague data. This requires a method that allows the use of decision makers' vague judgments in the pair wise comparison of attributes. The fuzzy AHP method meets this requirement. There are many fuzzy AHP methods developed in the literature. In this study, Chang's [37] extent analysis method on fuzzy AHP is selected and applied to the risk evaluation of an ERP implementation project.

The FEAHP model discussed in this paper is proved to be simple, less time taking and having less computational expense as compared to other existing decision making systems. The use of FEAHP does not involve cumbersome mathematical operation and so making it of general use for solving practical multi attribute decision making problems. The FEAHP has the ability to capture the vagueness of human thinking style and effectively solve multi-attribute decision making problems.

The result of the study shows that the risk level of the SAP/R3 implementation project is very high. To reduce the level of risk by benefiting from the risk criteria priority weights, some preventive actions can be taken. Thus, relative importance of risks can enable the project managers to develop a better risk management strategy.

In this study FAHP method is selected and applied instead of conventional crisp AHP the evaluations can also be made by using AHP. The AHP is one of the most widely used multi-criteria decision making tool but application of AHP in risk evaluation will have some shortcomings.

The AHP does not take into account the uncertainty. It is mainly used in nearly crisp decision applications. But risk is uncertainty, so it is not useful using AHP in risk evaluation. The results obtained from AHP will not be accurate as the results obtained from FAHP.

Furthermore, it is also recognized that human assessment on qualitative attributes is always subjective and thus imprecise. Therefore, conventional AHP seems inadequate to capture decision-maker’s requirements explicitly. In order to model this kind of uncertainty in human preference, fuzzy sets could be incorporated with the pair wise comparison as an extension of AHP. The fuzzy AHP approach allows a more accurate description of the decision making process.

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APPENDICES

APPENDIX A: QUESTIONNAIRE

Read the following questions and put check marks on the pair wise comparison matrices. If an attribute on the left is more important than the one matching on the right, put your check mark to the left of the importance "*Equally*" under the importance level you prefer. If an attribute on the left is less important than the one matching on the right, put your check mark to the right of the importance *"Equally"* under the importance level you prefer.

QUESTIONS

With respect to the overall goal "evaluation of the failure risk of a SAP project"

1. How important is executive risk when it is compared with organizational risk?
2. How important is executive risk when it is compared with project management risk?
3. How important is executive risk when it is compared with technical risk?
4. How important is executive risk when it is compared with decision making risk?
5. How important is executive risk when it is compared with functional risk?
6. How important is organizational risk when it is compared with project management risk?
7. How important is organizational risk when it is compared with technical risk?
8. How important is organizational risk when it is compared with decision making risk?
9. How important is organizational risk when it is compared with functional risk?
10. How important is project management risk when it is compared with technical risk?
11. How important is project management risk when it is compared with decision making risk?
12. How important is project management risk when it is compared with functional risk?

13. How important is technical risk when it is compared with decision making risk?
14. How important is technical risk when it is compared with functional risk?
15. How important is decision making risk when it is compared with functional risk?

Table AI. Questionnaire forms used to facilitate comparisons of main and sub-risk factors.

Importance of one main attribute over another											
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
1	ER										OR
2	ER										PMR
3	ER										TR
4	ER										DMR
5	ER										FR
6	OR										PMR
7	OR										TR
8	OR										DMR
9	OR										FR
10	PMR										TR
11	PMR										DMR
12	PMR										FR
13	TR										DMR
14	TR										FR
15	DMR										FR

With respect to the main attribute ‘executive risks(ER)’

16. How important is goals &plan when it is compared with business environment?
17. How important is goals &plan when it is compared with ownership?
18. How important is business environment when it is compared with ownership?

Table AI. Continued.

Importance of one sub-risk factor over another											
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
16	GP										BE
17	GP										O
18	BE										O

With respect to the main attribute 'organizational risks (OR)'

19. How important is cooperation when it is compared with staffing?
20. How important is cooperation when it is compared with expertise?
21. How important is cooperation when it is compared with culture?
22. How important is staffing when it is compared with expertise?
23. How important is staffing when it is compared with culture?
24. How important is expertise when it is compared with culture?

Table AI. Continued.

		Importance of one sub-risk factor over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
19	CO										S
20	CO										E
21	CO										C
22	S										E
23	S										C
24	E										C

With respect to the main attribute 'project management risks (PMR)'

25. How important is scoping &planning when it is compared with resources?
26. How important is scoping &planning when it is compared with project implementation team?
27. How important is scoping &planning when it is compared with change management?
28. How important is scoping &planning when it is compared with training?
29. How important is resources when it is compared with project implementation team?
30. How important is resources when it is compared with change management?
31. How important is resources when it is compared with training?
32. How important is project implementation team when it is compared with change management?
33. How important is project implementation team when it is compared with training?
34. How important is change management when it is compared with training?

Table AI. Continued.

Questions	Attributes	Importance of one sub-risk factor over another: Extremely	Very strongly	Strongly	Moderately	Equally	Moderately	Strongly	Very strongly	Extremely	Attributes
25	SP										R
26	SP										PIT
27	SP										CM
28	SP										T
29	R										PIT
30	R										CM
31	R										T
32	PIT										CM
33	PIT										T
34	CM										T

With respect to the main attribute ‘technical risks (TR)’

35. How important is technical expertise when it is compared with software complexity?
36. How important is technical expertise when it is compared with database inaptitude?
37. How important is technical expertise when it is compared with hardware?
38. How important is technical expertise when it is compared with adaptation delays?
39. How important is software complexity when it is compared with database inaptitude?
40. How important is software complexity when it is compared with hardware?
41. How important is software complexity when it is compared with adaptation delays?
42. How important is database inaptitude when it is compared with hardware?
43. How important is database inaptitude when it is compared with adaptation delays?
44. How important is hardware when it is compared with adaptation delays?

Table AI. Continued.

		Importance of one sub-risk factor over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
35	TE										SC
36	TE										DI
37	TE										H
38	TE										AD
39	SC										DI
40	SC										H
41	SC										AD
42	DI										H
43	DI										AD
44	H										AD

With respect to the main attribute ‘decision making risks (DMR)’

45. How important is slow decision making when it is compared with poor decision making?

Table AI. Continued.

		Importance of one sub-risk factor over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
45	SDM										PDM

With respect to the main attribute ‘functional risks (FR)’

46. How important is end-users when it is compared with process &system integrity?

Table AI. Continued.

		Importance of one sub-risk factor over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
46	EU										PSI

With respect to the sub-attribute 'Goals &Plan (GP)'

47. What degree do you assign when high risk is compared with medium risk?
48. What degree do you assign when high risk is compared with low risk?
49. What degree do you assign when medium risk is compared with low risk?

Table AII. Questionnaire forms used to facilitate comparisons of risk degrees.

		Importance of one risk level over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
47	HR										MR
48	HR										LR
49	MR										LR

With respect to the sub-attribute 'Business Environment (BE)'

50. What degree do you assign when high risk is compared with medium risk?
51. What degree do you assign when high risk is compared with low risk?
52. What degree do you assign when medium risk is compared with low risk?

Table AII. Continued.

		Importance of one risk level over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
50	HR										MR
51	HR										LR
52	MR										LR

With respect to the sub-attribute 'Ownership (O)'

53. What degree do you assign when high risk is compared with medium risk?
54. What degree do you assign when high risk is compared with low risk?
55. What degree do you assign when medium risk is compared with low risk?

Table AII. Continued.

		Importance of one risk level over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
53	HR										MR
54	HR										LR
55	MR										LR

With respect to the sub-attribute ‘Cooperation (CO)’

56. What degree do you assign when high risk is compared with medium risk?
57. What degree do you assign when high risk is compared with low risk?
58. What degree do you assign when medium risk is compared with low risk?

Table AII. Continued.

		Importance of one risk level over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
56	HR										MR
57	HR										LR
58	MR										LR

With respect to the sub-attribute ‘Staffing (S)’

59. What degree do you assign when high risk is compared with medium risk?
60. What degree do you assign when high risk is compared with low risk?
61. What degree do you assign when medium risk is compared with low risk?

Table AII. Continued.

		Importance of one risk level over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
59	HR										MR
60	HR										LR
61	MR										LR

With respect to the sub-attribute ‘Expertise (E)’

62. What degree do you assign when high risk is compared with medium risk?
63. What degree do you assign when high risk is compared with low risk?
64. What degree do you assign when medium risk is compared with low risk?

Table AII. Continued.

		Importance of one risk level over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
62	HR										MR
63	HR										LR
64	MR										LR

With respect to the sub-attribute ‘Culture (C)’

65. What degree do you assign when high risk is compared with medium risk?
66. What degree do you assign when high risk is compared with low risk?
67. What degree do you assign when medium risk is compared with low risk?

Table AII. Continued.

		Importance of one risk level over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
65	HR										MR
66	HR										LR
67	MR										LR

With respect to the sub-attribute ‘Scoping &Planning (SP)’

68. What degree do you assign when high risk is compared with medium risk?
69. What degree do you assign when high risk is compared with low risk?
70. What degree do you assign when medium risk is compared with low risk?

Table AII. Continued.

		Importance of one risk level over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
68	HR										MR
69	HR										LR
70	MR										LR

With respect to the sub-attribute 'Resources (R)'

71. What degree do you assign when high risk is compared with medium risk?
72. What degree do you assign when high risk is compared with low risk?
73. What degree do you assign when medium risk is compared with low risk?

Table AII. Continued.

		Importance of one risk level over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
71	HR										MR
72	HR										LR
73	MR										LR

With respect to the sub-attribute 'Project Implementation Team (PIT)'

74. What degree do you assign when high risk is compared with medium risk?
75. What degree do you assign when high risk is compared with low risk?
76. What degree do you assign when medium risk is compared with low risk?

Table AII. Continued.

		Importance of one risk level over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
74	HR										MR
75	HR										LR
76	MR										LR

With respect to the sub-attribute 'Change Management (CM)'

77. What degree do you assign when high risk is compared with medium risk?
78. What degree do you assign when high risk is compared with low risk?
79. What degree do you assign when medium risk is compared with low risk?

Table AII. Continued.

		Importance of one risk level over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
77	HR										MR
78	HR										LR
79	MR										LR

With respect to the sub-attribute 'Training (T)'

80. What degree do you assign when high risk is compared with medium risk?
81. What degree do you assign when high risk is compared with low risk?
82. What degree do you assign when medium risk is compared with low risk?

Table AII. Continued.

		Importance of one risk level over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
80	HR										MR
81	HR										LR
82	MR										LR

With respect to the sub-attribute 'Technical Expertise (TE)'

83. What degree do you assign when high risk is compared with medium risk?
84. What degree do you assign when high risk is compared with low risk?
85. What degree do you assign when medium risk is compared with low risk?

Table AII. Continued.

		Importance of one risk level over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
83	HR										MR
84	HR										LR
85	MR										LR

With respect to the sub-attribute 'Software Complexity (SC)'

86. What degree do you assign when high risk is compared with medium risk?
87. What degree do you assign when high risk is compared with low risk?
88. What degree do you assign when medium risk is compared with low risk?

Table AII. Continued.

		Importance of one risk level over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
86	HR										MR
87	HR										LR
88	MR										LR

With respect to the sub-attribute 'Database Inaptitude (DI)'

89. What degree do you assign when high risk is compared with medium risk?
90. What degree do you assign when high risk is compared with low risk?
91. What degree do you assign when medium risk is compared with low risk?

Table AII. Continued.

		Importance of one risk level over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
89	HR										MR
90	HR										LR
91	MR										LR

With respect to the sub-attribute 'Hardware (H)'

92. What degree do you assign when high risk is compared with medium risk?
93. What degree do you assign when high risk is compared with low risk?
94. What degree do you assign when medium risk is compared with low risk?

Table AII. Continued.

		Importance of one risk level over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
92	HR										MR
93	HR										LR
94	MR										LR

With respect to the sub-attribute 'Adaptation Delays (AD)'

95. What degree do you assign when high risk is compared with medium risk?
96. What degree do you assign when high risk is compared with low risk?
97. What degree do you assign when medium risk is compared with low risk?

Table AII. Continued.

		Importance of one risk level over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
95	HR										MR
96	HR										LR
97	MR										LR

With respect to the sub-attribute 'Slow Decision Making (SDM)'

98. What degree do you assign when high risk is compared with medium risk?
99. What degree do you assign when high risk is compared with low risk?
100. What degree do you assign when medium risk is compared with low risk?

Table AII. Continued.

Importance of one risk level over another											
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
98	HR										MR
99	HR										LR
100	MR										LR

With respect to the sub-attribute 'Poor Decision Making (PDM)'

101. What degree do you assign when high risk is compared with medium risk?
102. What degree do you assign when high risk is compared with low risk?
103. What degree do you assign when medium risk is compared with low risk?

Table AII. Continued.

Importance of one risk level over another											
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
101	HR										MR
102	HR										LR
103	MR										LR

With respect to the sub-attribute 'End-Users (EU)'

104. What degree do you assign when high risk is compared with medium risk?
105. What degree do you assign when high risk is compared with low risk?
106. What degree do you assign when medium risk is compared with low risk?

Table AII. Continued.

Importance of one risk level over another											
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
104	HR										MR
105	HR										LR
106	MR										LR

With respect to the sub-attribute 'Process & System Integrity (PSI)'

107. What degree do you assign when high risk is compared with medium risk?

108. What degree do you assign when high risk is compared with low risk?

109. What degree do you assign when medium risk is compared with low risk?

Table AII. Continued.

		Importance of one risk level over another									
Questions	**Attributes**	**Extremely**	**Very strongly**	**Strongly**	**Moderately**	**Equally**	**Moderately**	**Strongly**	**Very strongly**	**Extremely**	**Attributes**
107	HR										MR
108	HR										LR
109	MR										LR

APPENDIX B

Expert evaluations.

Table B.1 Pair wise comparisons of main risk criterion.

	ER			OR			PMR			TR			DMR			FR		
ER	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50	0,40	0,50	0,66	0,40	0,50	0,66	0,66	1,00	1,50	0,66	1,00	1,50
				0,66	1,00	1,50	0,40	0,50	0,66	0,66	1,00	1,50	1,50	2,00	2,50	1,50	2,00	2,50
				0,66	1,00	1,50	0,66	1,00	1,50	1,50	2,00	2,50	2,50	3,00	3,50	2,50	3,00	3,50
				0,94	1,33	1,83	0,49	0,67	0,94	0,85	1,17	1,55	1,55	2,00	2,50	1,55	2,00	2,50
OR	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**	0,40	0,50	0,66	0,40	0,50	0,66	0,66	1,00	1,50	0,40	0,50	0,66
	0,66	1,00	1,50				0,40	0,50	0,66	0,40	0,50	0,66	0,66	1,00	1,50	0,66	1,00	1,50
	0,66	1,00	1,50				1,50	2,00	2,50	1,50	2,00	2,50	1,50	2,00	2,50	1,50	2,00	2,50
	0,57	0,83	1,22	1,00	1,00	1,00	0,77	1,00	1,27	0,77	1,00	1,27	0,94	1,33	1,83	0,85	1,17	1,55
PMR	1,50	2,00	2,50	1,50	2,00	2,50	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50	0,66	1,00	1,50	1,50	2,00	2,50
	1,50	2,00	2,50	1,50	2,00	2,50				1,50	2,00	2,50	1,50	2,00	2,50	1,50	2,00	2,50
	0,66	1,00	1,50	0,40	0,50	0,66				1,50	2,00	2,50	1,50	2,00	2,50	1,50	2,00	2,50
	1,22	1,67	2,17	1,13	1,50	1,89	1,00	1,00	1,00	1,22	1,67	2,17	1,22	1,67	2,17	1,50	2,00	2,50
TR	1,50	2,00	2,50	1,50	2,00	2,50	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50	1,50	2,00	2,50
	0,66	1,00	1,50	1,50	2,00	2,50	0,40	0,50	0,66				1,50	2,00	2,50	0,66	1,00	1,50
	0,40	0,50	0,66	0,40	0,50	0,66	0,40	0,50	0,66				0,66	1,00	1,50	0,66	1,00	1,50
	0,85	1,17	1,55	1,13	1,50	1,89	0,49	0,67	0,94	1,00	1,00	1,00	1,22	1,67	2,17	0,94	1,33	1,83
DMR	0,66	1,00	1,50	0,66	1,00	1,50	0,66	1,00	1,50	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50
	0,40	0,50	0,66	0,66	1,00	1,50	0,40	0,50	0,66	0,40	0,50	0,66				1,50	2,00	2,50
	0,29	0,33	0,40	0,40	0,50	0,66	0,40	0,50	0,66	0,66	1,00	1,50				0,66	1,00	1,50
	0,45	0,61	0,85	0,57	0,83	1,22	0,49	0,67	0,94	0,49	0,67	0,94	1,00	1,00	1,00	0,94	1,33	1,83
FR	0,66	1,00	1,50	1,50	2,00	2,50	0,40	0,50	0,66	0,40	0,50	0,66	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**
	0,40	0,50	0,66	0,66	1,00	1,50	0,40	0,50	0,66	0,66	1,00	1,50	0,40	0,50	0,66			
	0,29	0,33	0,40	0,40	0,50	0,66	0,40	0,50	0,66	0,66	1,00	1,50	0,66	1,00	1,50			
	0,45	0,61	0,85	0,85	1,17	1,55	0,40	0,50	0,66	0,57	0,83	1,22	0,57	0,83	1,22	1,00	1,00	1,00
CR : 0.099																		

Table B.2 Pair wise comparisons of executive risks' sub-risk criteria.

	GP			BE			O		
GP	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50	0,66	1,00	1,50
				1,50	2,00	2,50	0,66	1,00	1,50
				1,50	2,00	2,50	1,50	2,00	2,50
	1,00	1,00	1,00	1,50	2,00	2,50	0,94	1,33	1,83
BE	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50
	0,40	0,50	0,66				0,40	0,50	0,66
	0,40	0,50	0,66				0,40	0,50	0,66
	0,40	0,50	0,66	1,00	1,00	1,00	0,49	0,67	0,94
O	0,66	1,00	1,50	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**
	0,66	1,00	1,50	1,50	2,00	2,50			
	0,40	0,50	0,66	1,50	2,00	2,50			
	0,57	0,83	1,22	1,22	1,67	2,17	1,00	1,00	1,00
CR : 0.089									

Table B.3 Pair wise comparisons of organizational risks' sub-risk criteria.

	CO			S			E			OC		
CO	**1,00**	**1,00**	**1,00**	2,50	3,00	3,50	0,66	1,00	1,50	1,50	2,00	2,50
				1,50	2,00	2,50	1,50	2,00	2,50	0,66	1,00	1,50
				1,50	2,00	2,50	1,50	2,00	2,50	1,50	2,00	2,50
	1,00	1,00	1,00	1,83	2,33	2,83	1,22	1,67	2,17	1,22	1,67	2,17
S	0,29	0,33	0,40	**1,00**	**1,00**	**1,00**	0,40	0,50	0,66	0,66	1,00	1,50
	0,40	0,50	0,66				0,66	1,00	1,50	0,66	1,00	1,50
	0,40	0,50	0,66				0,40	0,50	0,66	0,66	1,00	1,50
	0,36	0,44	0,57	1,00	1,00	1,00	0,49	0,67	0,94	0,66	1,00	1,50
E	0,66	1,00	1,50	1,50	2,00	2,50	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50
	0,40	0,50	0,66	0,66	1,00	1,50				0,66	1,00	1,50
	0,40	0,50	0,66	1,50	2,00	2,50				1,50	2,00	2,50
	0,49	0,67	0,94	1,22	1,67	2,17	1,00	1,00	1,00	1,22	1,67	2,17
OC	0,40	0,50	0,66	0,66	1,00	1,50	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**
	0,66	1,00	1,50	0,66	1,00	1,50	0,66	1,00	1,50			
	0,40	0,50	0,66	0,66	1,00	1,50	0,40	0,50	0,66			
	0,49	0,67	0,94	0,66	1,00	1,50	0,49	0,67	0,94	1,00	1,00	1,00
CR : 0.076												

Table B.4 Pair wise comparisons of project management risks' sub-risk criteria.

	SP			R			PIT			CM			T		
SP	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50	1,50	2,00	2,50	0,66	1,00	1,50	0,66	1,00	1,50
				1,50	2,00	2,50	1,50	2,00	2,50	0,66	1,00	1,50	0,66	1,00	1,50
				1,50	2,00	2,50	0,66	1,00	1,50	0,66	1,00	1,50	1,50	2,00	2,50
	1,00	1,00	1,00	1,22	1,67	2,17	1,22	1,67	2,17	0,66	1,00	1,50	0,94	1,33	1,83
R	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50	0,40	0,50	0,66	0,40	0,50	0,66
	0,40	0,50	0,66				0,66	1,00	1,50	0,40	0,50	0,66	0,66	1,00	1,50
	0,40	0,50	0,66				0,66	1,00	1,50	0,40	0,50	0,66	0,66	1,00	1,50
	0,49	0,67	0,94	1,00	1,00	1,00	0,94	1,33	1,83	0,40	0,50	0,66	0,57	0,83	1,22
PIT	0,40	0,50	0,66	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**	0,40	0,50	0,66	1,50	2,00	2,50
	0,40	0,50	0,66	0,66	1,00	1,50				0,40	0,50	0,66	0,66	1,00	1,50
	0,66	1,00	1,50	0,66	1,00	1,50				0,66	1,00	1,50	0,66	1,00	1,50
	0,49	0,67	0,94	0,57	0,83	1,22	1,00	1,00	1,00	0,49	0,67	0,94	0,94	1,33	1,83
CM	0,66	1,00	1,50	1,50	2,00	2,50	1,50	2,00	2,50	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50
	0,66	1,00	1,50	1,50	2,00	2,50	1,50	2,00	2,50				0,66	1,00	1,50
	0,66	1,00	1,50	1,50	2,00	2,50	0,66	1,00	1,50				2,50	3,00	3,50
	0,66	1,00	1,50	1,50	2,00	2,50	1,22	1,67	2,17	1,00	1,00	1,00	1,27	1,67	2,17
T	0,66	1,00	1,50	1,50	2,00	2,50	0,40	0,50	0,66	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**
	0,66	1,00	1,50	0,66	1,00	1,50	0,66	1,00	1,50	0,66	1,00	1,50			
	0,40	0,50	0,66	0,66	1,00	1,50	0,66	1,00	1,50	0,29	0,33	0,40			
	0,57	0,83	1,22	0,94	1,33	1,83	0,57	0,83	1,22	0,54	0,78	1,13	1,00	1,00	1,00
CR : 0.064															

Table B.5 Pair wise comparisons of technical risks' sub-risk criteria.

	TE			SC			DI			H			AD		
TE	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50	1,50	2,00	2,50	1,50	2,00	2,50	0,66	1,00	1,50
				1,50	2,00	2,50	0,66	1,00	1,50	0,66	1,00	1,50	0,66	1,00	1,50
				0,66	1,00	1,50	0,66	1,00	1,50	0,66	1,00	1,50	1,50	2,00	2,50
	1,00	1,00	1,00	1,22	1,67	2,17	0,94	1,33	1,83	0,94	1,33	1,83	0,94	1,33	1,83
SC	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**	0,40	0,50	0,66	0,66	1,00	1,50	0,29	0,33	0,40
	0,40	0,50	0,66				0,66	1,00	1,50	0,40	0,50	0,66	0,66	1,00	1,50
	0,66	1,00	1,50				0,40	0,50	0,66	0,66	1,00	1,50	0,66	1,00	1,50
	0,49	0,67	0,94	1,00	1,00	1,00	0,49	0,67	0,94	0,57	0,83	1,22	0,54	0,78	1,13
DI	0,40	0,50	0,66	1,50	2,00	2,50	**1,00**	**1,00**	**1,00**	2,50	3,00	3,50	0,66	1,00	1,50
	0,66	1,00	1,50	0,66	1,00	1,50				1,50	2,00	2,50	0,66	1,00	1,50
	0,66	1,00	1,50	1,50	2,00	2,50				1,50	2,00	2,50	1,50	2,00	2,50
	0,57	0,83	1,22	1,22	1,67	2,17	1,00	1,00	1,00	1,83	2,33	2,83	0,94	1,33	1,83

H	0,40	0,50	0,66	0,66	1,00	1,50	0,29	0,33	0,40	**1,00**	**1,00**	**1,00**	0,40	0,50	0,66
	0,66	1,00	1,50	1,50	2,00	2,50	0,40	0,50	0,66				0,66	1,00	1,50
	0,66	1,00	1,50	0,66	1,00	1,50	0,40	0,50	0,66				0,66	1,00	1,50
	0,57	0,83	1,22	0,94	1,33	1,83	0,36	0,44	0,57	1,00	1,00	1,00	0,57	0,83	1,22
AD	0,66	1,00	1,50	2,50	3,00	3,50	0,66	1,00	1,50	1,50	2,00	2,50	**1,00**	**1,00**	**1,00**
	0,66	1,00	1,50	0,66	1,00	1,50	0,66	1,00	1,50	0,66	1,00	1,50			
	0,40	0,50	0,66	0,66	1,00	1,50	0,40	0,50	0,66	0,66	1,00	1,50			
	0,57	0,83	1,22	1,27	1,67	2,17	0,57	0,83	1,22	0,94	1,33	1,83	1,00	1,00	1,00
CR : 0.082															

Table B.6 Pair wise comparisons of decision making risks' sub-risk criteria.

	SDM			**PDM**		
SDM	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50
				0,29	0,33	0,40
				1,50	2,00	2,50
	1,00	1,00	1,00	0,82	1,11	1,47
PDM	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**
	2,50	3,00	3,50			
	0,40	0,50	0,66			
	1,19	1,50	1,89	1,00	1,00	1,00

Table B.7 Pair wise comparisons of functional risks' sub-risk criteria.

	EU			**PSI**		
EU	**1,00**	**1,00**	**1,00**	0,40	0,50	0,66
				0,40	0,50	0,66
				1,50	2,00	2,50
	1,00	1,00	1,00	0,77	1,00	1,27
PSI	1,50	2,00	2,50	**1,00**	**1,00**	**1,00**
	1,50	2,00	2,50			
	0,40	0,50	0,66			
	1,13	1,50	1,89	1,00	1,00	1,00

Table B.8 Pair wise comparison of risk levels with respect to the sub-risk criterion of executive risk.

risk level pair wise comparisons of goals &plan (GP)									
		HR			**MR**			**LR**	
HR	**1,00**	**1,00**	**1,00**	2,50	3,00	3,50	3,50	4,00	4,50
				1,50	2,00	2,50	2,50	3,00	3,50
				0,66	1,00	1,50	3,50	4,00	4,50
	1,00	1,00	1,00	1,55	2,00	2,50	3,17	3,67	4,17
MR	0,29	0,33	0,40	**1,00**	**1,00**	**1,00**	2,50	3,00	3,50
	0,40	0,50	0,66				2,50	3,00	3,50
	0,66	1,00	1,50				2,50	3,00	3,50
	0,45	0,61	0,85	1,00	1,00	1,00	2,50	3,00	3,50
LR	0,22	0,25	0,29	0,29	0,33	0,40	**1,00**	**1,00**	**1,00**
	0,29	0,33	0,40	0,29	0,33	0,40			
	0,22	0,25	0,29	0,29	0,33	0,40			
	0,24	0,28	0,33	0,29	0,33	0,40	1,00	1,00	1,00
CR : 0.096									

risk level pair wise comparisons of business environment (BE)									
		HR			**MR**			**LR**	
HR	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50	2,50	3,00	3,50
				0,66	1,00	1,50	1,50	2,00	2,50
				0,66	1,00	1,50	2,50	3,00	3,50
	1,00	1,00	1,00	0,94	1,33	1,83	2,17	2,67	3,17
MR	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50
	0,66	1,00	1,50				1,50	2,00	2,50
	0,66	1,00	1,50				2,50	3,00	3,50
	0,57	0,83	1,22	1,00	1,00	1,00	1,83	2,33	2,83
LR	0,29	0,33	0,40	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**
	0,40	0,50	0,66	0,40	0,50	0,66			
	0,29	0,33	0,40	0,29	0,33	0,40			
	0,33	0,39	0,49	0,36	0,44	0,57	1,00	1,00	1,00
CR : 0.075									

risk level pair wise comparisons of ownership (O)									
		HR			**MR**			**LR**	
HR	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50	1,50	2,00	2,50
				0,66	1,00	1,50	1,50	2,00	2,50
				1,50	2,00	2,50	2,50	3,00	3,50
	1,00	1,00	1,00	0,94	1,33	1,83	1,83	2,33	2,83
MR	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50
	0,66	1,00	1,50				1,50	2,00	2,50
	0,40	0,50	0,66				1,50	2,00	2,50
	0,57	0,83	1,22	1,00	1,00	1,00	1,22	1,67	2,17

LR	0,40	0,50	0,66	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**
	0,40	0,50	0,66	0,40	0,50	0,66			
	0,29	0,33	0,40	0,40	0,50	0,66			
	0,36	0,44	0,57	0,49	0,67	0,94	1,00	1,00	1,00
CR : 0.07									

Table B.9 Pair wise comparison of risk levels with respect to the sub-risk criterion of organizational risk.

risk level pair wise comparisons of cooperation (CO)									
		HR			**MR**			**LR**	
HR	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50	1,50	2,00	2,50
				0,66	1,00	1,50	1,50	2,00	2,50
				0,66	1,00	1,50	0,66	1,00	1,50
	1,00	1,00	1,00	0,66	1,00	1,50	1,22	1,67	2,17
MR	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50
	0,66	1,00	1,50				0,66	1,00	1,50
	0,66	1,00	1,50				0,66	1,00	1,50
	0,66	1,00	1,50	1,00	1,00	1,00	0,66	1,00	1,50
LR	0,40	0,50	0,66	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**
	0,40	0,50	0,66	0,66	1,00	1,50			
	0,66	1,00	1,50	0,66	1,00	1,50			
	0,49	0,67	0,94	0,66	1,00	1,50	1,00	1,00	1,00
CR : 0.099									
risk level pair wise comparisons of staffing (S)									
		HR			**MR**			**LR**	
HR	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50	1,50	2,00	2,50
				1,50	2,00	2,50	1,50	2,00	2,50
				0,66	1,00	1,50	1,50	2,00	2,50
	1,00	1,00	1,00	1,22	1,67	2,17	1,50	2,00	2,50
MR	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50
	0,40	0,50	0,66				1,50	2,00	2,50
	0,66	1,00	1,50				0,66	1,00	1,50
	0,49	0,67	0,94	1,00	1,00	1,00	0,94	1,33	1,83
LR	0,40	0,50	0,66	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**
	0,40	0,50	0,66	0,40	0,50	0,66			
	0,40	0,50	0,66	0,66	1,00	1,50			
	0,40	0,50	0,66	0,57	0,83	1,22	1,00	1,00	1,00
CR : 0.091									
risk level pair wise comparisons of expertise (E)									
		HR			**MR**			**LR**	
HR	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50	0,66	1,00	1,50
				0,66	1,00	1,50	1,50	2,00	2,50
				0,66	1,00	1,50	0,66	1,00	1,50
	1,00	1,00	1,00	0,66	1,00	1,50	0,94	1,33	1,83

MR	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50
	0,66	1,00	1,50				1,50	2,00	2,50
	0,66	1,00	1,50				1,50	2,00	2,50
	0,66	1,00	1,50	1,00	1,00	1,00	1,50	2,00	2,50
LR	0,66	1,00	1,50	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**
	0,40	0,50	0,66	0,40	0,50	0,66			
	0,66	1,00	1,50	0,40	0,50	0,66			
	0,57	0,83	1,22	0,40	0,50	0,66	1,00	1,00	1,00
CR : 0.084									

risk level pair wise comparisons of organization's culture (OC)

		HR			**MR**			**LR**	
HR	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50	0,66	1,00	1,50
				0,66	1,00	1,50	0,66	1,00	1,50
				0,66	1,00	1,50	0,66	1,00	1,50
	1,00	1,00	1,00	0,66	1,00	1,50	0,66	1,00	1,50
MR	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50
	0,66	1,00	1,50				1,50	2,00	2,50
	0,66	1,00	1,50				1,50	2,00	2,50
	0,66	1,00	1,50	1,00	1,00	1,00	1,50	2,00	2,50
LR	0,66	1,00	1,50	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**
	0,66	1,00	1,50	0,40	0,50	0,66			
	0,66	1,00	1,50	0,40	0,50	0,66			
	0,66	1,00	1,50	0,40	0,50	0,66	1,00	1,00	1,00
CR : 0.086									

Table B.10 Pair wise comparison of risk levels with respect to the sub-risk criterion of project management risk.

risk level pair wise comparisons of scoping &planning (SP)

	HR			**MR**			**LR**		
HR	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50	1,50	2,00	2,50
				0,66	1,00	1,50	1,50	2,00	2,50
				0,40	0,50	0,66	0,66	1,00	1,50
	1,00	1,00	1,00	0,57	0,83	1,22	1,22	1,67	2,17
MR	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50
	0,66	1,00	1,50				1,50	2,00	2,50
	1,50	2,00	2,50				1,50	2,00	2,50
	0,94	1,33	1,83	1,00	1,00	1,00	1,50	2,00	2,50
LR	0,40	0,50	0,66	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**
	0,40	0,50	0,66	0,40	0,50	0,66			
	0,66	1,00	1,50	0,40	0,50	0,66			
	0,49	0,67	0,94	0,40	0,50	0,66	1,00	1,00	1,00
CR : 0.091									

risk level pair wise comparisons of resources (R)

	HR			MR			LR		
HR	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50	0,40	0,50	0,66
				0,66	1,00	1,50	0,40	0,50	0,66
				0,40	0,50	0,66	0,40	0,50	0,66
	1,00	1,00	1,00	0,57	0,83	1,22	0,40	0,50	0,66
MR	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50
	0,66	1,00	1,50				0,66	1,00	1,50
	1,50	2,00	2,50				0,66	1,00	1,50
	0,94	1,33	1,83	1,00	1,00	1,00	0,66	1,00	1,50
LR	1,50	2,00	2,50	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**
	1,50	2,00	2,50	0,66	1,00	1,50			
	1,50	2,00	2,50	0,66	1,00	1,50			
	1,50	2,00	2,50	0,66	1,00	1,50	1,00	1,00	1,00

CR : 0.084

risk level pair wise comparisons of project implementation team (PIT)

	HR			MR			LR		
HR	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50	1,50	2,00	2,50
				0,66	1,00	1,50	1,50	2,00	2,50
				0,66	1,00	1,50	0,66	1,00	1,50
	1,00	1,00	1,00	0,66	1,00	1,50	1,22	1,67	2,17
MR	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**	2,50	3,00	3,50
	0,66	1,00	1,50				1,50	2,00	2,50
	0,66	1,00	1,50				1,50	2,00	2,50
	0,66	1,00	1,50	1,00	1,00	1,00	1,83	2,33	2,83
LR	0,40	0,50	0,66	0,29	0,33	0,40	**1,00**	**1,00**	**1,00**
	0,40	0,50	0,66	0,40	0,50	0,66			
	0,66	1,00	1,50	0,40	0,50	0,66			
	0,49	0,67	0,94	0,36	0,44	0,57	1,00	1,00	1,00

CR : 0.09

risk level pair wise comparisons of change management (CM)

	HR			MR			LR		
HR	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50	1,50	2,00	2,50
				1,50	2,00	2,50	1,50	2,00	2,50
				1,50	2,00	2,50	1,50	2,00	2,50
	1,00	1,00	1,00	1,22	1,67	2,17	1,50	2,00	2,50
MR	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50
	0,40	0,50	0,66				1,50	2,00	2,50
	0,40	0,50	0,66				0,66	1,00	1,50
	0,49	0,67	0,94	1,00	1,00	1,00	1,22	1,67	2,17
LR	0,40	0,50	0,66	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**
	0,40	0,50	0,66	0,40	0,50	0,66			
	0,40	0,50	0,66	0,66	1,00	1,50			
	0,40	0,50	0,66	0,49	0,67	0,94	1,00	1,00	1,00

CR : 0.098

risk level pair wise comparisons of training (T)

	HR			MR			LR		
HR	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50	2,50	3,00	3,50
				1,50	2,00	2,50	1,50	2,00	2,50
				1,50	2,00	2,50	1,50	2,00	2,50
	1,00	1,00	1,00	1,50	2,00	2,50	1,83	2,33	2,83

MR	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50
	0,40	0,50	0,66				1,50	2,00	2,50
	0,40	0,50	0,66				0,66	1,00	1,50
	0,40	0,50	0,66	1,00	1,00	1,00	1,22	1,67	2,17
LR	0,29	0,33	0,40	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**
	0,40	0,50	0,66	0,40	0,50	0,66			
	0,40	0,50	0,66	0,66	1,00	1,50			
	0,36	0,44	0,57	0,49	0,67	0,94	1,00	1,00	1,00
CR : 0.073									

Table B.11 Pair wise comparison of risk levels with respect to the sub-risk criterion of technical risk.

risk level pair wise comparisons of technical expertise (TE)									
		HR			**MR**			**LR**	
HR	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50	0,66	1,00	1,50
				0,40	0,50	0,66	0,66	1,00	1,50
				0,29	0,33	0,40	0,66	1,00	1,50
	1,00	1,00	1,00	0,45	0,61	0,85	0,66	1,00	1,50
MR	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50
	1,50	2,00	2,50				1,50	2,00	2,50
	2,50	3,00	3,50				1,50	2,00	2,50
	1,55	2,00	2,50	1,00	1,00	1,00	1,50	2,00	2,50
LR	0,66	1,00	1,50	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**
	0,66	1,00	1,50	0,40	0,50	0,66			
	0,66	1,00	1,50	0,40	0,50	0,66			
	0,66	1,00	1,50	0,40	0,50	0,66	1,00	1,00	1,00
CR : 0.091									

risk level pair wise comparisons of software complexity (SC)									
		HR			**MR**			**LR**	
HR	**1,00**	**1,00**	**1,00**	0,40	0,50	0,66	1,50	2,00	2,50
				0,66	1,00	1,50	1,50	2,00	2,50
				0,40	0,50	0,66	0,66	1,00	1,50
	1,00	1,00	1,00	0,49	0,67	0,94	1,22	1,67	2,17
MR	1,50	2,00	2,50	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50
	0,66	1,00	1,50				1,50	2,00	2,50
	1,50	2,00	2,50				1,50	2,00	2,50
	1,22	1,67	2,17	1,00	1,00	1,00	1,50	2,00	2,50
LR	0,40	0,50	0,66	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**
	0,40	0,50	0,66	0,40	0,50	0,66			
	0,66	1,00	1,50	0,40	0,50	0,66			
	0,49	0,67	0,94	0,40	0,50	0,66	1,00	1,00	1,00
CR : 0.098									

risk level pair wise comparisons of database inaptitude (DI)

	HR			MR			LR		
HR	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50	2,50	3,00	3,50
				0,66	1,00	1,50	1,50	2,00	2,50
				0,66	1,00	1,50	1,50	2,00	2,50
	1,00	1,00	1,00	0,94	1,33	1,83	1,83	2,33	2,83
MR	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50
	0,66	1,00	1,50				1,50	2,00	2,50
	0,66	1,00	1,50				1,50	2,00	2,50
	0,57	0,83	1,22	1,00	1,00	1,00	1,50	2,00	2,50
LR	0,29	0,33	0,40	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**
	0,40	0,50	0,66	0,40	0,50	0,66			
	0,40	0,50	0,66	0,40	0,50	0,66			
	0,36	0,44	0,57	0,40	0,50	0,66	1,00	1,00	1,00

CR : 0.061

risk level pair wise comparisons of hardware (H)

	HR			MR			LR		
HR	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50	1,50	2,00	2,50
				0,66	1,00	1,50	1,50	2,00	2,50
				0,66	1,00	1,50	0,66	1,00	1,50
	1,00	1,00	1,00	0,66	1,00	1,50	1,22	1,67	2,17
MR	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50
	0,66	1,00	1,50				1,50	2,00	2,50
	0,66	1,00	1,50				1,50	2,00	2,50
	0,66	1,00	1,50	1,00	1,00	1,00	1,50	2,00	2,50
LR	0,40	0,50	0,66	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**
	0,40	0,50	0,66	0,40	0,50	0,66			
	0,66	1,00	1,50	0,40	0,50	0,66			
	0,49	0,67	0,94	0,40	0,50	0,66	1,00	1,00	1,00

CR : 0.073

risk level pair wise comparisons of adaptation delays (AD)

	HR			MR			LR		
HR	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50	1,50	2,00	2,50
				0,66	1,00	1,50	0,66	1,00	1,50
				0,66	1,00	1,50	0,66	1,00	1,50
	1,00	1,00	1,00	0,94	1,33	1,83	0,94	1,33	1,83
MR	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50
	0,66	1,00	1,50				0,66	1,00	1,50
	0,66	1,00	1,50				0,66	1,00	1,50
	0,57	0,83	1,22	1,00	1,00	1,00	0,66	1,00	1,50

LR	0,40	0,50	0,66	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**
	0,66	1,00	1,50	0,66	1,00	1,50			
	0,66	1,00	1,50	0,66	1,00	1,50			
	0,57	0,83	1,22	0,66	1,00	1,50	1,00	1,00	1,00
CR : 0.099									

Table B.12 Pair wise comparison of risk levels with respect to the sub-risk criterion of decision making risk.

risk level pair wise comparisons of slow decision making (SDM)									
		HR			**MR**			**LR**	
HR	**1,00**	**1,00**	**1,00**	2,50	3,00	3,50	3,50	4,00	4,50
				1,50	2,00	2,50	2,50	3,00	3,50
				0,66	1,00	1,50	2,50	3,00	3,50
	1,00	1,00	1,00	1,55	2,00	2,50	2,83	3,33	3,83
MR	0,29	0,33	0,40	**1,00**	**1,00**	**1,00**	2,50	3,00	3,50
	0,40	0,50	0,66				2,50	3,00	3,50
	0,66	1,00	1,50				2,50	3,00	3,50
	0,45	0,61	0,85	1,00	1,00	1,00	2,50	3,00	3,50
LR	0,22	0,25	0,29	0,29	0,33	0,40	**1,00**	**1,00**	**1,00**
	0,29	0,33	0,40	0,29	0,33	0,40			
	0,29	0,33	0,40	0,29	0,33	0,40			
	0,27	0,30	0,36	0,29	0,33	0,40	1,00	1,00	1,00
CR : 0.10									

risk level pair wise comparisons of poor decision making (PDM)									
		HR			**MR**			**LR**	
HR	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50	2,50	3,00	3,50
				1,50	2,00	2,50	2,50	3,00	3,50
				0,66	1,00	1,50	1,50	2,00	2,50
	1,00	1,00	1,00	1,22	1,67	2,17	2,17	2,67	3,17
MR	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50
	0,40	0,50	0,66				2,50	3,00	3,50
	0,66	1,00	1,50				2,50	3,00	3,50
	0,49	0,67	0,94	1,00	1,00	1,00	2,17	2,67	3,17
LR	0,29	0,33	0,40	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**
	0,29	0,33	0,40	0,29	0,33	0,40			
	0,40	0,50	0,66	0,29	0,33	0,40			
	0,33	0,39	0,49	0,33	0,39	0,49	1,00	1,00	1,00
CR : 0.10									

Table B.13 Pair wise comparison of risk levels with respect to the sub-risk criterion of functional risk.

risk level pair wise comparisons of end-users (EU)									
		HR			**MR**			**LR**	
HR	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50	2,50	3,00	3,50
				0,66	1,00	1,50	1,50	2,00	2,50
				0,66	1,00	1,50	1,50	2,00	2,50
	1,00	1,00	1,00	0,94	1,33	1,83	1,83	2,33	2,83
MR	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**	1,50	2,00	2,50
	0,66	1,00	1,50				1,50	2,00	2,50
	0,66	1,00	1,50				2,50	3,00	3,50
	0,57	0,83	1,22	1,00	1,00	1,00	1,83	2,33	2,83
LR	0,29	0,33	0,40	0,40	0,50	0,66	**1,00**	**1,00**	**1,00**
	0,40	0,50	0,66	0,40	0,50	0,66			
	0,40	0,50	0,66	0,29	0,33	0,40			
	0,36	0,44	0,57	0,36	0,44	0,57	1,00	1,00	1,00
CR : 0.074									
risk level pair wise comparisons of process &system integrity (PSI)									
		HR			**MR**			**LR**	
HR	**1,00**	**1,00**	**1,00**	0,66	1,00	1,50	1,50	2,00	2,50
				0,40	0,50	0,66	0,66	1,00	1,50
				0,40	0,50	0,66	0,66	1,00	1,50
	1,00	1,00	1,00	0,49	0,67	0,94	0,94	1,33	1,83
MR	0,66	1,00	1,50	**1,00**	**1,00**	**1,00**	2,50	3,00	3,50
	1,50	2,00	2,50				1,50	2,00	2,50
	1,50	2,00	2,50				1,50	2,00	2,50
	1,22	1,67	2,17	1,00	1,00	1,00	1,55	2,00	2,50
LR	0,40	0,50	0,66	0,29	0,33	0,40	**1,00**	**1,00**	**1,00**
	0,66	1,00	1,50	0,40	0,50	0,66			
	0,66	1,00	1,50	0,40	0,50	0,66			
	0,57	0,83	1,22	0,45	0,61	0,85	1,00	1,00	1,00
CR : 0.10									

BIOGRAPHICAL SKETCH

Ece Ünlüyıldız was born in 1982 in Bursa. She was graduated from Bursa Anatolian High School in 2000. She was graduated from Uludağ University Engineering and Architectural Faculty, Industrial Engineering Department as an industrial engineer in 2004. In 2004 she has been started her graduate program in Galatasaray University, Industrial Engineering Master of Science Program.