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R&D Project Performance Evaluation With Multiple and Interdependent Criteria

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Zeynep Tohumcu, Esra Karasakal

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R&D PROJECT PERFORMANCE EVALUATION WITH MULTIPLE AND INTERDEPENDENT CRITERIA

A THESIS SUBMITTED TO
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BY

ZEYNEP TOHUMCU

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FOR
THE DEGREE OF MASTER OF SCIENCE
IN
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Approval of the Graduate School of Natural and Applied Sciences.

____

Prof. Dr. Canan Özgen
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

____

Prof. Dr. Çağlar Güven
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

____

Assist. Prof. Esra Karasakal
Supervisor

Examining Committee Members

Prof. Dr. Murat Köksalan	(METU, IE)	____________________
Assist. Prof. Esra Karasakal	(METU, IE)	____________________
Prof. Dr. Meral Azizoğlu	(METU, IE)	____________________
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Önder Okyay (M.S.)	(TÜBİTAK-SAGE)	____________________

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Name, Last name : Zeynep Tohumcu

Signature :

ABSTRACT

R&D PROJECT PERFORMANCE EVALUATION WITH MULTIPLE AND INTERDEPENDENT CRITERIA

Tohumcu, Zeynep
M.S., Department of Industrial Engineering
Supervisor : Assist. Prof. Esra Karasakal

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In this study, an Analytic Network Process (ANP) and Data Envelopment Analysis (DEA) based approach was developed in order to measure the performance of customer-based Research and Development projects being executed in TÜBİTAK-SAGE, Defense Research and Development Institute, under the Scientific and Technological Research Council of Turkey.

In order to evaluate project performance, many criteria, containing various sub-criteria were determined. In order to handle the interdependencies among the criteria and the sub-criteria, ANP was used. The ANP model generated in this study is a hybrid model consisting of both a hierarchy and a network. The pairwise comparison matrices that were built up for defining the importance and influences of the criteria/sub-criteria in the ANP model were formed as interval judgments from a group decision making process, based on data obtained from a questionnaire conducted among the experts in the Institute. From the interval pairwise comparison matrices, weight intervals for the sub-criteria were determined and these bounds were used as assurance region constraints in a super-efficiency DEA model, through which the project ranking was obtained. Taking into consideration that there may occur some missing values in some projects for some of the sub-criteria, the super-efficiency DEA model was extended to handle missing data.

The model was applied to a real case study on performance evaluation of the ongoing customer-based projects in the Institute. For comparison purposes, the case study was also solved by two other approaches.

Keywords: Project Performance Evaluation, Multiple Criteria Decision Making, Group Decision Making, Analytic Network Process, Data Envelopment Analysis

ÖZ

AR-GE PROJELERİNİN PERFORMANSININ DEĞERLENDİRİLMESİ İÇİN BAĞIMLI KRİTERLER İLE ÇOK KRİTERLİ KARAR VERME YAKLAŞIMI

Tohumcu, Zeynep
Yüksek Lisans, Endüstri Mühendisliği Bölümü
Tez Yöneticisi : Yrd. Doç. Dr. Esra Karasakal

Haziran 2007, 222 Sayfa

Bu çalışmada, Savunma Sanayii Araştırma ve Geliştirme Enstitüsü, TÜBİTAK-SAGE'de sözleşmeli olarak yürütülen Ar-Ge projelerinin performanslarının değerlendirmesi için Analitik Ağ Süreci (AAS) ve Veri Zarflama Analizi (VZA) tabanlı bir yaklaşım geliştirilmiştir.

Performans değerlendirmede kullanılmak üzere belirlenen kriter/alt-kriterler birbirlerine bağımlı olup, bu bağımlılıklar hiyerarşik ve ağ şeması yapılarının özelliklerini taşıyan hibrid bir AAS modeli geliştirilerek ele alınmıştır. AAS modelinde, kriter/alt-kriterlerin önem ve etkilerini belirlemekte kullanılan ikili karşılaştırma matrisleri, Enstitü içerisinde bir anket yapılarak, grup karar verme yaklaşımı ile, aralıklı yargılar şeklinde oluşturulmuştur. Bu aralıklı yargılardan alt-kriter ağırlıkları için birer aralık elde edilmiş, ve bu aralıklar projeleri sıralamak için kullanılacak olan süper verimli ("*super efficient*") VZA modeline kısıt olarak eklenmiştir. Oluşturulan VZA modeli, eksik verileri de ele alabilecek şekilde geliştirilmiştir.

Enstitüde yürütülmekte olan sözleşmeli projelerin performansları bu model ile değerlendirilerek, model gerçek bir uygulamada kullanılmıştır. Karşılaştırma amacıyla, bu uygulama farklı iki yaklaşım ile de çözülmüştür.

Anahtar Kelimeler: Projelerde Performans Değerlendirme, Çok Kriterli Karar Verme, Grup Karar Verme, Analitik Ağ Süreci, Veri Zarflama Analizi

To My Precious Mother

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
COTS	Commercially-off-the-Shelf
CDR	Critical Design Review
DEA	Data Envelopment Analysis
DM	Decision Maker
DMU	Decision Making Unit
DoD	Department of Defense
LP	Linear Program/ Linear Programming
MCDM	Multiple Criteria Decision Making
MIL-HDBK	Military Handbook
MIL-STD	Military Standard
TPM	Technical Performance Measurement
PDR	Preliminary Design Review
R&D	Research and Development
SDR	System Design Review
SRR	System Requirements Review
TÜBİTAK SAGE	The Scientific & Technological Research Council of Turkey Defense Industry Research and Development Institute
WBS	Work Breakdown Structure
MAH	Maximise Agreement Heuristic

LIST OF PARAMETERS

ACWP	Actual Cost of Work Performed
APWC	Actual percentage of work completed at time t
ART	Average Response Time to Customer Change Requests
ARTR	Average Response Time to Additional Customer Requests
AS	The Satisfaction of the Customer Regarding the Deliverables
BCWP	Budgeted Cost of Work Performed
BCWS	Budgeted Cost of Work Scheduled
BEXP	Total budget allocated to overseas procurements with export license until time t
BOMCC	Total cost of COTS items in the BOM
BOMCCM	Total cost of common items in the BOM
BOMCI	Total cost of items in the BOM
BOMI	Total number of items in the BOM
BOMU	The number of unique items in the BOM
BOP	Total budget allocated to overseas procurements until time t
BOPP	Budget planned to be allocated to overseas procurements
BT	Total budget allocated to trainings until time t
CDIS	Paraphrased Dissatisfaction of the Customer in Administrative and Technical Subjects throughout the Project
CIU	Common Item Usage among Projects
CIU_{max}	Highest possible value for the ratio of the total cost of common items in the BOM to the total cost of all the items in the BOM
COTSU	Commercially-off-the-Shelf Item Usage
$COTSU_{max}$	Highest possible value for the ratio of the total cost of COTS items in the BOM to the total cost of all the items in the BOM
DC_{cr}	Realized duration for concluding a customer change request cr (in calendar days)

DD	Average Delay in the Delivery Dates of Documents or Prototypes Specified in the Contract in Liability of the Institute
DD_{max}	Upper limit for the average delay in the delivery of documents or prototypes specified in the contract in liability of the Institute
DR_r	Time limit (in calendar days) given by the customer for a customer request r
DCR_r	Realized duration (in calendar days) for concluding a customer request r
DTD_d	The delay in the delivery of a deliverable d specified in the contract (in calendar days)
EC_{cr}	Expected duration for concluding the customer change request cr (in calendar days)
$ENGC_{max}$	Upper limit for the average number of class I engineering changes made per configuration item for a given evaluation period
ENGC	Maturity of the Design (Average number of class I engineering changes made per configuration item in a given evaluation period)
EXPD	Export License Dependence
GR_s	Evaluation grade of a subcontractor s
IA	Total number of items accepted that are supplied by subcontractors until time t
IS	Total number of items that are supplied by subcontractors until time t
l	Length of the period that project's performance evaluation is made (in months)
MPA	Actual manpower (in man month)
MPD	Deviation in Manpower
MPP	Planned manpower (in man month)
MsC	Milestone Completion
MsC_{max}	Upper limit for the average delay in the completion times of the milestones
MsD_m	The delay in the completion time of a milestone m (in calendar days)

NCC	Total number of complaints received from the customer in a given phase
NCC_{max}	Upper limit for the total number of complaints received from the customer for a given phase
NCI	Total number of configuration items
NCIR	Total number of configuration items reviewed in a given technical review
NCSC	Total number of non-conformities corrected on time that were identified in the subcontractor reviews until time t
NCSI	Total number of non-conformities identified in the subcontractor reviews until time t
ND	Total number of deliverables that should have been submitted to the customer until time t
NDA	Total number of deliverables accepted at the first inspection without any change request until time t
NDC	Total number of customer change requests received until time t
NEC	Total number of class I engineering changes made in a given evaluation period
NMs	Number of milestones that should have been completed until time t
NNC	Total number of ongoing non-conformities in a given evaluation period
NNC_{max}	Upper limit for the total number of non-conformities for a given evaluation period
NNCQ	Number of Non-Conformities
NNCR	Total number of non-conformities identified in a given technical review
NNCS	Average number of non-conformities per subcontractor identified in subcontractor quality audits
$NNCS_{max}$	Upper limit for the average number of non-conformities per subcontractor

$NNCS_{sq}$	Number of non-conformities identified in the qth quality audit of subcontractor s
NR	Total number of additional requests submitted by the customer until time t
NS	Total number of subcontractors that have been worked with from the beginning of the project until time t
NT	Total number of TPM parameters in a given evaluation period
NTW	Number of TPM parameters whose demonstrated values are worse than the planned values in a given evaluation period
OPR	Overseas Procurement Rate
OPRD	Deviation in Overseas Procurement Rate
OT	Total number of overtime (in hours) in a given evaluation period
OTR	Overtime Rate
PCD	Number of critical personnel departed from the project in a given evaluation period
PCI	Number of critical personnel included to the project in a given evaluation period
PCT	Total number of critical personnel working in the project at the end of a given evaluation period
PED	Deviation in Project Expenditure
PP	Total amount of payments made to the Institute personnel from a given project's income until time t
PPCD	Deviation in Project Personnel Cost
PPCA	Actual Project Personnel cost until time t
PPCP	Planned Project Personnel cost until time t
PPWC	Planned percentage of work that should have been completed at time t
PR	Total revenue of a project up to time t
PT	Total number of personnel working in the project in a given evaluation period
QS	Quality of the Subcontractors

RH	Risk Handling
RS_p	Sum of the risk scores in evaluation period p
RS_{p+1}	Sum of the risk scores in evaluation period p+1
SAS	Acceptance Satisfaction of the Supplied Items
SD	Schedule Deviation
SIU	Standard Item Usage
SIU_{min}	Lowest possible value for the ratio of the number of unique items in the BOM to the total number of items in the BOM
SIU_{max}	Highest possible value for the ratio of the number of unique items in the BOM to the total number of items in the BOM
SP	Supplementary Payment to the Institute Personnel
SQR	Subcontractor Quality Audit Results
SRR	Subcontractor Review Results
t	Time that the project's performance evaluation is made
TNC_{max}	Upper limit for the average number of non-conformities per configuration item reviewed for a given evaluation period
TECHPERF	Technical Performance Measures
TECHREW	Technical Review Results (Average number of non-conformities identified per configuration item in a given technical review)
TESTPERF	Test Performance
TOR	Turnover Rate
TRAIN	Contribution to the Self-Development of the Institute Personnel (Amount of trainings)
TS	Number of successful verification tests performed until time t
TT	Total number of verification tests performed until time t

Subscripts:

cr	Customer change request
d	Deliverable

p	Evaluation period
q	Quality audit
r	Customer request
s	Subcontractor

CHAPTER 1

INTRODUCTION

1.1 Objective and the Content of the Study

Efficient project management is the major factor to achieve success in projects. Especially today, project management techniques are considered to be extremely valuable, and being enforced in various projects. Generally, a group of projects are being executed in most of the organizations; overall management of all the projects in a coordinated way becomes more challenging in such an environment. The complexity, high uncertainty and risky nature of the Research and Development (R&D) projects make them even harder to manage and require additional effort. In order to perform management of the projects in an effective way in an organization, the performance of the ongoing projects should be monitored regularly.

In this study, a method was developed in order to measure the performance of customer-based Research and Development projects being executed in the Defense Research and Development Institute, TÜBİTAK-SAGE. The proposed model provides a ranking of the projects with respect to their performance.

To evaluate the performance of the customer-based projects in the Institute, many criteria, including various sub-criteria were determined. It was observed that there are interdependencies among these criteria and the sub-criteria; and in order to handle the interdependencies, Analytic Network Process (ANP) was used in determining the priorities of the sub-criteria. The ANP model generated in this study is a hybrid model consisting of both a hierarchy and a network.

The importance and influences of the criteria/sub-criteria in the ANP model were defined by constructing pairwise comparison matrices as interval judgments from a group decision making process, based on data obtained from a questionnaire conducted among the experts in the Institute. From the interval pairwise comparison matrices, sub-criteria weights were also determined as intervals.

In order to rank the projects with respect to their performances, Data Envelopment Analysis (DEA) was decided to be used since it provides a fair evaluation by highlighting the predominant sides of the projects and allowing each project to appear in the best possible light.

The weight intervals obtained from the interval pairwise comparison matrices were used as assurance region constraints in a super-efficiency DEA model. It was observed that there may occur some missing values in some projects for some of the sub-criteria, therefore the super-efficiency DEA model was extended to handle missing data. Two different approaches were used to handle the missing values, one resulting in a complete ranking of projects and the other resulting in partial ranking.

The model was applied to a real case study on performance evaluation of the ongoing customer-based projects in the Institute. Afterwards, the case study was also solved by two other approaches for comparison purposes.

1.2 Problem Definition - The Current System in the Institute and the Necessity for a Project Performance Evaluation System

TÜBİTAK-SAGE, a subsidiary of the Scientific and Technological Research Council of Turkey, is a governmental R&D institute specialized in the field of defense industry. The defense projects executed in the Institute covers R&D activities for development of systems composed of hardware, software, or both, from conceptual design to prototype production and testing. There are also some test and evaluation and reverse engineering projects, and projects that include feasibility studies. Furthermore, in the near future, projects including the serial production of the developed systems in the Institute are going to be initiated.

Owing to the spreading approach of "Procurement based on R&D" among Turkish Armed Forces, the number of projects, and thus the number of employees increased considerably in the last decade. The increase in the number of employees in the Institute is represented graphically in Figure 1. As it can be seen from the figure, the number of personnel has increased approximately by a factor of 3 since 1996. By the year 2007, there are around 325 employees in the Institute, 195 of which are researchers.

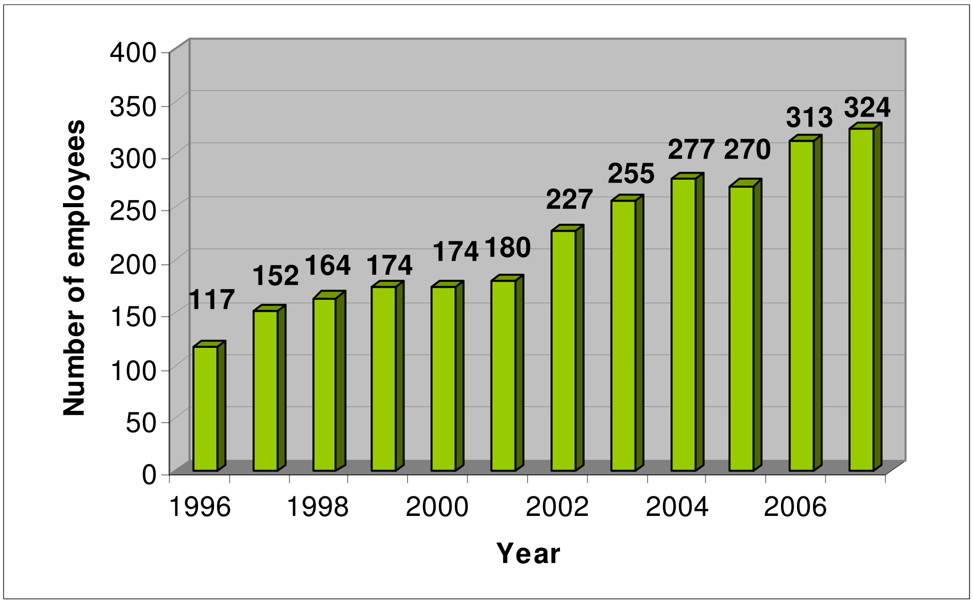

Figure 1 Increase in the Number of Employees at TÜBİTAK-SAGE

Two kinds of projects are being executed in the Institute: customer-based projects and in-house projects. The majority of the projects are customer-based projects, which are funded by the customers such as Turkish Armed Forces, Ministry of National Defense or other companies in the defense industry. Some of these customer-based projects are also being funded by TUBİTAK. The remaining projects are in-house projects funded by the Institute itself. In-house projects are devised and carried out both to increase the technological level in some key areas and to develop some critical components. These two type of projects are kept distinct from each other and rated separately. Customer-based projects are given higher priority with respect to in-house projects. These projects also cover systems or R&D activities greater in magnitude, and majority of the Institute resources (budget and workforce) is allocated preferentially to them. The average number of ongoing customer-based projects in the Institute has increased from 13 to 21 in the last seven years. In Figure 2, the alteration in the number of customer-based projects is represented graphically. It should be mentioned that, the reason of the decrease in the number of projects in years 2003 and 2004 is the termination of many small scale projects. Furthermore, by the end of year 2001, two major projects were initiated and since most of the resources of the Institute were allocated to these projects, no other small scale project was initiated during the following years. These two projects are in termination phase nowadays.

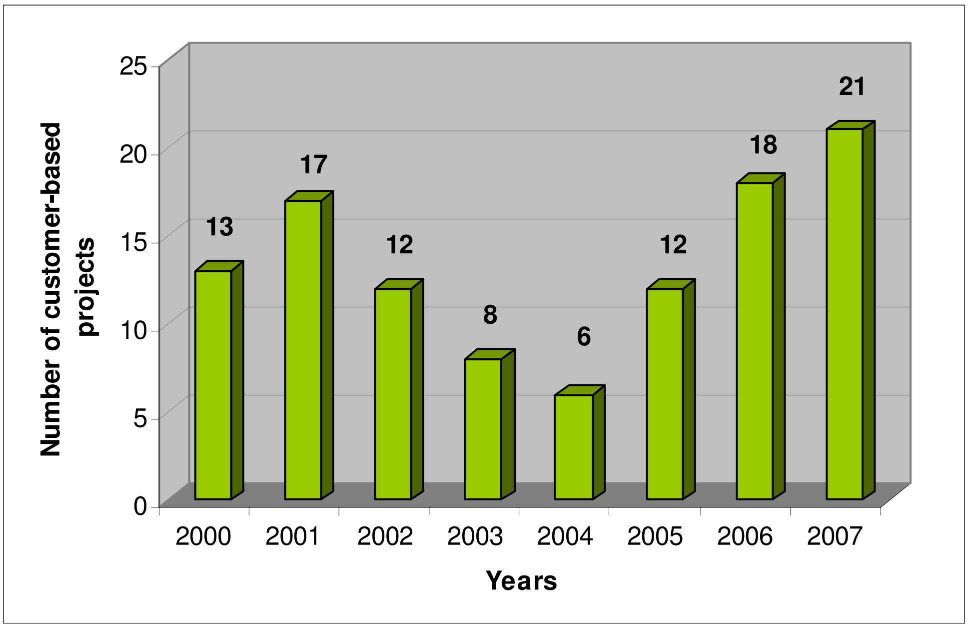

Figure 2 Number of Customer-Based Projects at TÜBİTAK-SAGE

Another key point is the appreciable increase in the complexity and importance of these projects besides the increase in the project number. As it can be seen from Figure 3, there has been a considerable increase in the total contractual budget of the ongoing projects since year 2000, which symbolizes the complexity and the magnitude of the projects. The graph given in Figure 3 is scaled based on year 2000. It can be observed that, by the year 2007, the total contractual budget of the ongoing customer-based projects has increased up to approximately 200 times of the total contractual budget of the customer-based projects in year 2000.

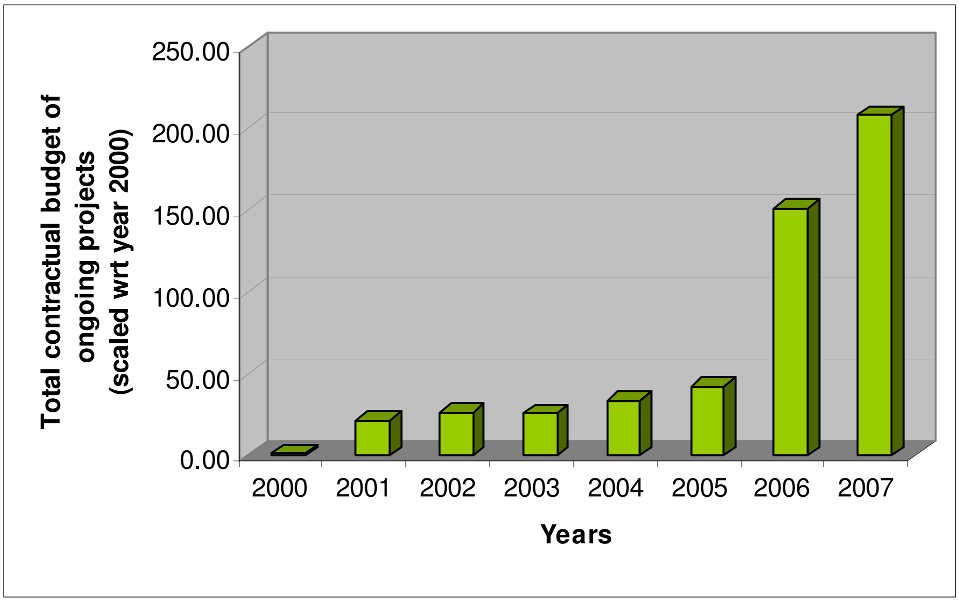

Figure 3 The Increase in Total Contractual Budget of Ongoing Projects at TÜBİTAK-SAGE

The Institute applies project management techniques in each project and performs activities on planning, monitoring and evaluating the status of the projects regularly. In the current project monitoring process, the projects are being monitored under time and budget constraints. However, the noticeable increase in the number of projects, the complexity of projects and the number of personnel result in a more complicated environment, in which a more sophisticated monitoring process, based on some other criteria in addition to the time and budget constraints, is required.

The ongoing projects in the Institute use common resources (both for man-power, facilities and money) and in the presence of limited resources, the effective management of resource allocations to those projects is vital. Careful attention is required in funding priorities and wise decisions should be made by the top level management of the Institute. The performance of the projects should be evaluated and actions such as comparing the projects based on their performances; analyzing the ranking and identifying the projects at the uppermost and at the lowermost positions; for the projects at the lowermost positions, searching the reasons for the projects to be at the end; and taking necessary precautions if there exist problems, should be performed.

It becomes a necessity for TÜBİTAK-SAGE to improve the approach of project monitoring and evaluation approach by developing a more sophisticated project performance evaluation system in order to perform the aforementioned actions and manage R&D projects more effectively and efficiently.

The Institute desires to achieve the answers of the following questions:

What is the relative ranking of the projects with respect to their performance? (Which projects are at the uppermost positions, which projects are at the lowermost positions in the ranking?)
What are the weak and the strong points of the projects?

The performance evaluation system should provide the answers to the above questions. It should be applicable to all type of projects defined above, and it should cover all the aspects of project performance by considering various criteria related to performance of R&D projects.

The nature of the problem, as explained above, reveals the requirement to apply a multiple criteria decision making approach in this study.

1.3 Organization of the Thesis

This chapter includes the general information about the Institute, the projects and development activities in the Institute and the need for an evolved project performance evaluation system.

The following chapter, namely the Literature Review chapter, reviews the previous studies on project performance evaluation criteria and the applications on ANP, interval judgments and DEA are reviewed.

In Chapter 3, the ANP and DEA methodologies that the proposed model is based on are briefly explained.

In Chapter 4, the system development process applied in the R&D projects executed in the Institute is summarized. The criteria and sub-criteria determined for measuring the performance of the projects in the Institute, the metrics used for measuring the sub-criteria and the scaling used in the metrics are explained. The interdependency relations among the criteria and the sub-criteria are also presented.

The proposed model is introduced in Chapter 5. The implementation of the model is explained in Chapter 6 with the results obtained from the ANP model and a case study implementation of the DEA model. The case study is also solved by two other approaches for comparison purposes. The discussion on the results obtained from the case study and the overall comparison of the implemented approaches are provided in this chapter.

Finally, in Chapter 7, the discussions and conclusions on the study are provided and directions for future research areas are discussed.

CHAPTER 2

LITERATURE REVIEW

2.1 R&D Project Performance Evaluation

A comprehensive literature survey on R&D project performance evaluation criteria was performed, however very few studies were encountered. A great percent of the studies found during literature survey were about performance evaluation of R&D firms or R&D department of firms instead of performance evaluation of R&D projects. Generally, criteria such as number of patents, number of technical publications or citations to technical publications, amount of resources allocated to R&D, amount of investment made to R&D were found in the literature which are not applicable for evaluating the performance of the projects being executed at the Institute.

The criteria that are found during literature survey and their applicability to the project performance evaluation system in the Institute are summarized in Table 1. The explanations of the criteria and discussions on their applicability are provided in detail in the following pages.

Table 1 Criteria Used in the Literature

	Criterion	Source	Applicability
1	Category bias	Pillai et al. (2002)	Not considered
2	Benefits to the developing organization	Lipovetsky et al. (1997), Pillai et al. (2002)	Inapplicable
3	Benefits to the research area of the project and benefits at the national level	Lipovetsky et al. (1997)	Inapplicable

Table 1 Continued - Criteria Used in the Literature

	Criterion	Source	Applicability
4	Customer satisfaction (Benefits to the customer)	Brown and Gobeli (1992), Chiesa et al. (1996), Hauser and Zettelmeyer (1997), Lipovetsky et al. (1997), Tipping et al. (1995)	Similar criterion is defined
5	Project's probability of success	Davis et al. (2001)	Inapplicable
6	Risk	Pillai et al. (2002)	Similar criterion is defined
7	Bottlenecks	Nagpaul and Bhatnagat (1985)	Inapplicable
8	Decision effectiveness	Pillai et al. (2002)	Inapplicable
9	Appreciation by the project personnel	DeCotiis and Dyer (1977), Tipping et al. (1995), Westerveld (2003)	Similar criterion is defined
10	Organization performance	Chiesa et al. (1996)	Similar criteria are defined
11	Economic metrics	Kostoff (1995)	Inapplicable
12	R&D effectiveness index	Brown and Gobeli (1992), Werner and Souder (1997)	Inapplicable
13	Goal clarity	Tipping et al. (1995)	Not considered
14	Percent of project milestones achieved	Kerssens-van Drongelen and Cook (1997), Tipping et al. (1995)	Similar criterion is defined
15	Percentage milestone slippage/ Percent of project milestones exceeded	Brown and Gobeli (1992), Haque and Moore (2004)	
16	Timeliness (fast feedback)	Brown and Gobeli (1992) Loch and Tapper (2002)	
17	Technical performance (technical success)	Brown and Gobeli (1992), DeCotiis and Dyer (1977), Hauser and Zettelmeyer (1997), Kondo (1998), Kerssens-van Drongelen and Cook (1997), Lee et al. (1996), Lipovetsky et al. (1997)	Similar criterion is defined
18	Stability of the design	DeCotiis and Dyer (1977), Ojanen and Vuola (2003)	Similar criterion is defined
19	Technical progress	Chiesa and Masella (1996)	Considered by some other criteria
20	Feasibility of the projects	Kerssens-van Drongelen and Bilderbeek (1999)	Inapplicable

The Criteria Used in the Previous Studies

1. Category bias

This criterion is related to the priority given to the projects by the organization. Certain projects may be more important than other projects and hence needs more attention. This requires that a relationship to be formed in such a way that certain projects need to be performed better to give the same level of performance index.

This criterion is decided not to be considered as a performance evaluation criterion for the projects in the Institute. Likewise the explanation above, certain projects are given more importance with respect to other projects and need more attention; however this difference is not desired to be reflected to the ranking of the projects with respect to their performance. After the realization of the project ranking, the necessary actions will be performed by the top management of the Institute, considering the relative importance of the projects.

2. Benefits to the developing organization

This criterion is related to the tangible or intangible benefits of the project to the developing organization. Benefits both in the short run and in the long run should be considered. Factors such as project desirability, expected utility, development time and cost, development of a new technological capability as a result of the project, improvement of the reputation of the organization as a result of the project can be considered within the context of this criterion.

This criterion is inapplicable to the performance evaluation system constructed for the projects executed in the Institute. This criterion can be used as a project selection criterion, rather than a project performance evaluation criterion.

3. Benefits to the research area of the project and benefits at the national level

Factors such as development of a new technological capability as a result of the project, contribution to critical fields as a result of the project, contribution to other projects as a result of the project can be considered within the context of this criterion.

This criterion is inapplicable to the performance evaluation system constructed for the projects executed in the Institute. It can be used as a project selection criterion, rather than a project performance evaluation criterion

4. Customer satisfaction (Benefits to the customer)

The customer should be involved in the performance measurement process. This criterion is related to the reputation of the developing organization for the customer. The design meeting customer needs can be considered within the context of this criterion.

A criterion related to customer satisfaction is also used in the performance evaluation system constructed in this study; however the factors considered within the context of this criterion are different than the factor explained above. In this study, within the context of customer satisfaction, generally the satisfaction of the customer regarding the administrative subjects is evaluated. The satisfaction of the customer regarding the technical subjects such as “the design meeting customer needs” is not considered within this criterion, but it is evaluated by the definition of some other criteria related to technical performance measurement and test performance.

5. Project’s probability of success

The technical and commercial probability of success should be taken into account when this criterion is considered.

This criterion is inapplicable to the performance evaluation system constructed in this study. Achievement of technical success is an obligation for all of the customer-based projects executed in the Institute. The commercial success is an inappropriate criterion since the projects are initiated depending on contract awards for systems demanded by Turkish Armed Forces. This criterion can be used as a project selection criterion, rather than a project performance evaluation criterion.

6. Risk

The risks in the project should be identified and monitored. The project performance is inversely related with this criterion (project performance decreases as risk increases).

A criterion related to risk management is also defined in the performance evaluation system constructed in this study.

7. Bottlenecks

Bottlenecks in the project should be identified. The project performance is inversely related with this criterion.

This criterion is not considered as a project performance evaluation criterion in this study. It is inevitable to encounter bottlenecks during the execution of the projects because of the high uncertainty and risky nature of the R&D projects and it is also obligatory to handle these bottlenecks in all of the customer-based projects executed in the Institute.

8. Decision effectiveness

This criterion is related to the capability of the management of the developing organization to take the right decisions at the right time. Factors such as leadership, goal clarity, technical and managerial review systems and innovative management practices can be considered within the context of this criterion.

This criterion is not considered as a project performance evaluation criterion in this study, since it is related to the approach of the top management in the Institute. This criterion can be used in evaluation of the performance of the Institute, rather than being used as a project performance evaluation criterion.

9. Appreciation by the project personnel

The extent to which project personnel feel they have the support and freedom they need to be successful in the project, the extent to which the project provides those involved an interesting, challenging, and professionally developing experience can be considered within the context of this criterion.

A similar criterion, related to satisfaction of the project personnel, is also defined in the performance evaluation system constructed in this study; however the factors considered within the context of this criterion are rather different.

10. Organization performance

Factors such as, effective use of appropriate systems and tools, effective usage of materials/components, effective usage of facilities, effective usage of human resources (skills of the personnel and effective use with respect to their skills); effective usage of financial resources, documentation can be considered within the context of this criterion.

The factors related to effective usage of the resources are also considered in defining the project performance evaluation criteria in this study.

11. Economic metrics

Metrics such as Return on Investment, Rate of Return, and Net Present Value can be used. It should be noted that economic approaches have limited value when applied to R&D projects, because of the uncertain nature of the data.

As it is also mentioned in the literature as above, such economic metrics are inapplicable to the R&D projects executed in the Institute. Therefore, this criterion is not considered as a project performance evaluation criterion in this study.

12. R&D effectiveness index

This is an index, defined by the following formula.

$$\left(\frac{\text{Revenue}}{\text{Total R \& D Costs}}\right)$$

Likewise the economic metrics defined above, this criterion is inapplicable to the R&D projects executed in the Institute and it is not considered as a project performance evaluation criterion in this study.

13. Goal clarity

This criterion signifies if the project performance objectives are clearly identified and understood by all participants on the project team.

This is an intangible criterion, for which, it is difficult to perform an objective evaluation. Therefore, it is not considered as a project performance evaluation criterion in this study.

14. -15. "Percent of project milestones achieved" and "Percentage milestone slippage/ Percent of project milestones exceeded"

Completion of the milestones in the time predicted is a measure of effective planning and management. Using one of these two criteria, number 14 or 15, is adequate. These criteria can be used conjugate of each other.

A criterion related to completion of the milestones is also defined in the performance evaluation system constructed in this study.

16. Timeliness (fast feedback)

Factors such as timeliness in meeting project milestones and timeliness in meeting design completions can be considered within the context of this criterion.

This is a similar criterion with the two criteria defined above (number 14 and 15). As it is mentioned above, a criterion related to completion of the milestones is also defined in the performance evaluation system constructed in this study.

17. Technical performance (technical success)

This criterion is related to the degree of design goal attainment and refers to the contract that was signed with the customer. Factors such as meeting the functional specifications, meeting the technical specifications (percentage of technical specifications met or exceeded), the results of the technical reviews and the status of technical performance measures can be considered within the context of this criterion.

A criterion related to technical performance, and similar factors mentioned above within the context of this criterion are also defined in the performance evaluation system constructed in this study.

18. Stability of the design

This criterion describes the extent to which technical specifications and process designs are planned and stated in advance of various project phases and the extent to which they are modified during the project. Number of design changes in the projects can be considered within the context of this criterion. The following formula can also be used for this criterion.

$$\left(\frac{\text{Number of Design Changes in the Project}}{\text{Total Cost of the Project}}\right)\times 100$$

A criterion related to stability of the design is also defined, with a factor similar to number of design changes, in the performance evaluation system constructed in this study.

19. Technical progress

Factors such as the ratio of technical progress to costs and the ratio of technical progress to time can be considered within the context of this criterion.

This criterion is not considered as a project performance evaluation criterion in this study, since technical progress is considered by some other factors defined within the context of technical performance criterion.

20. Feasibility of the projects

During monitoring, the feasibility of the projects should be checked. If a given project is not feasible anymore, it should be directly terminated.

This criterion is not considered as a project performance evaluation criterion in this study, since the feasibility study is performed before the initiation of the projects and completion of the customer-based projects is obligatory unless the occurrence of force majeure or termination is demanded by the customer. This criterion can be used as a project selection criterion, rather than a project performance evaluation criterion.

2.2 Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) is a widely used method for solving complicated problems with multiple criteria decision making environments. AHP was proposed by Saaty in 1980 (Saaty, 1980) and has been used in a wide range since then. The basic idea of the approach is to construct a hierarchy by breaking down a problem into its smaller components and then make pairwise comparisons to develop priorities in each hierarchy. The problem is modeled as a linear hierarchy, with a goal at the top level, then criteria, sub-criteria, and finally alternatives in the lowest level. After the hierarchy is constructed, the elements at each level of the hierarchy are compared to each other, using some or all of the elements on the next higher level as criteria of the lower level elements. The set of all judgments are made by pairwise comparisons by using the nine-point scale of Saaty (Saaty, 1991).

For each pairwise comparison matrix, the relative priorities of the elements are obtained by using the eigenvector method. Finally, the priorities across various levels of the hierarchy are aggregated and the priority of each alternative is obtained.

In AHP, the problem can be structured as a linear hierarchy and the basic assumption that, the elements in the hierarchy are independent from each other, is made. However, many decision problems cannot be structured hierarchically because they involve the interactions and dependencies in higher/lower level elements. (Lee and Kim, 2000; Kengpol and Tuominen, 2006; Shyur and Shih, 2006)

When the interdependencies among elements are neglected, an invalid result can be obtained in a complex decision environment.

2.3 Analytic Network Process (ANP)

Saaty (1996) introduced the approach Analytic Network Process (ANP) that is capable of handling the problems having dependence among alternatives or criteria. ANP is an extension of AHP, which can be used in presence of complex interdependent relationships among elements. Contrary to the unidirectional hierarchical and linear structure of the AHP, the ANP has a nonlinear structure and does not require a strict hierarchical structure. ANP is a network system, which involves feedback loops among clusters. The ANP handles the dependencies within a cluster of elements (inner dependence) or between different clusters (outer dependence). The interdependencies and feedback are incorporated through the construction of a supermatrix. The composite weights are obtained through the development of a supermatrix (Saaty, 1996).

The ANP allows for more complex interrelationships among the decision elements and provides a more accurate approach that reflects well the complex interactions in the real world situations (Saaty, 1996, 2003).

Since its introduction by Saaty (1996), the ANP method has been successfully used in various applications. The method has been increasingly used in numerous areas, especially in recent years.

Lee and Kim (2000, 2001) developed a methodology, that consists of a combination of analytic network process and zero-one goal programming model, for IS projects selection problems that have multiple criteria and interdependence property. The criteria weights obtained by ANP were then used in a zero-one goal programming model. The weights of the criteria were obtained by using the matrix manipulation based on Saaty and Takizawa (1986) instead of using the Supermatrix approach. Shyur and Shih (2006) proposed a hybrid model for the vendor selection process having multiple and interdependent criteria. First, the relative weights of criteria in vendor evaluation problem were obtained by ANP, and then the modified TOPSIS (technique for order performance by similarity to idea solution) approach was used for ranking the vendors in terms of their overall performances. Similarly, in Shyur (2006), the same hybrid approach was used in a COTS evaluation problem. In these papers, it is explained that, by using ANP only to obtain the criteria weights, but not in the entire evaluation process, the large number of pairwise comparisons was reduced. Kengpol and Tuominen (2006) used an integration of ANP, Delphi and Maximise Agreement Heuristic (MAH) methods in a group decision making problem for the evaluation of information technology for logistics firms. First, individual rankings of criteria were obtained by applying the ANP, then a consensus ranking were reached by utilizing Delphi and MAH methods. Meade and Presley (2002) used the ANP in selection of projects in a R&D environment. A generic ANP model were developed, which includes in its decision levels the actors involved in the decision, the stages of research, categories of metrics, and individual metrics. Cheng and Heng (2005) used the decision model of Meade and Presley (2002) to develop a R&D project selection method. Agarwal and Shankar (2002) developed an ANP based model to obtain the priorities for the performance dimensions of a supply chain. Piantanakulchai (2005) applied the ANP in Highway corridor selection problem. Bayazit and Karpak (2007) used an ANP based approach to identify the level of impact of different factors on total quality management implementation. Gencer and Gürpınar (in press) applied the ANP in supplier selection and implemented the proposed model in an electronic company. Cheng and Li (2007) used the ANP in the strategic partnering model which stands as an example for applications of ANP in process models. Lee and Wu (2007) applied the ANP in evaluation of knowledge management strategies for the companies. Jharkharia and Shankar (2007) applied the ANP in the selection of a logistic service provider. Topcu and Burnaz (2006) and Uysal et al. (2006) applied ANP in evaluation of retail locations and in evaluation of Turkish mobile communication operators where multiple decision makers exist. The geometric means of all paired-comparison judgments of different decision makers for each question were used as an input to the ANP model. Dağdeviren et al. (2005a) applied the ANP in the analysis of the overall workload level. Dağdeviren et al. (2005b) applied the ANP in a supplier selection problem. Erdoğmuş et al. (2005) proposed an ANP model for evaluating the high-tech alternatives for the renewal of a specific transaction processing system. In Erdoğmuş et al. (2006), evaluation of most suitable fuel that can be used for residential heating was made using ANP with group decision-making.

Some other applications of ANP are referred in Kengpol and Tuominen (2006), Topcu and Burnaz (2006), Uysal et al. (2006), Bayazit and Karpak (2007) and Gencer and Gürpınar (in press).

2.4 Interval Judgments

The estimation of the relative weights of criteria is an important task in multiple criteria decision making problems. Many methods for generating weights have been proposed in the literature. Pairwise comparison matrices are widely used to elicit decision maker's preferences in several weight generation methods such as the principal right eigenvector method (Saaty, 1980). Pairwise comparison matrices are the basic input of AHP/ANP applications. A conventional pairwise comparison matrix is formed of crisp comparison values in the nine-point scale of Saaty (Saaty, 1980). Crisp comparison matrices lead to crisp weight vectors to be generated. However, in real world, it is difficult for a decision maker to decide on a precise number that represents the superiority of one item over another, he/she may be uncertain about the exact value. It is more realistic for him/her to elicit his/her preferences by interval judgments rather than exact judgments. Especially in group decision making problems, using interval pairwise comparison matrices provides a more realistic framework. The interval comparison values can reflect the decision maker's uncertainty of judgments.

A variety of methods have been proposed to use interval pairwise comparison matrices to generate weights. It should be mentioned that, only except the study performed by Yu and Cheng (2007), all of these methods are for AHP applications.

Entani et al. (2001) defined the interval weights obtained from the interval pairwise comparison matrices as a center and a radius, where the center is obtained by the principal right eigenvector method and the radius is obtained based on interval regression analysis. Arbel (1989) proposed a linear programming model and Arbel and Vargas (1993) formulated a nonlinear programming model to generate interval weights from interval judgments. Wang et al. (2005a), suggested to use the linear programming method proposed by Arbel (1989) for consistent interval comparison matrices and proposed an eigenvector method based nonlinear programming approach in case of inconsistent interval comparison matrices to generate interval weights. In Wang et al. (2005b), a two-stage logarithmic goal programming method was introduced to deal with interval comparison matrices and in Wang and Elhag (2007), a goal programming method was proposed for interval or crisp comparison matrices, where both of the methods result in interval weight estimations. A numerical example for a group decision making is given in Wang et al. (2005b), in which an interval comparison matrix was constructed by using the maximum and minimum values of judgments of various decision makers. Chandran et al. (2005) proposed a two-stage LP approach, which can be applied for interval, crisp or mixed comparison matrices and generates crisp weight values. Cox (2007) compared simulation techniques and total enumeration to generate crisp weight values from interval pairwise comparison matrices. In Podinovski (2007), symmetrical-lexicographic-optimization method was used for a minimization problem with equally important criteria that generates crisp weight values from interval judgments. Interval regression analysis was proposed by Sugihara et al. (2004), to generate weight intervals from interval or crisp comparison matrices. In Bryson and Joseph (2000), a group decision making problem was handled in which the decision makers defined the individual pairwise comparison matrices in intervals. Logarithmic goal programming techniques were developed for generating a group consensus priority vector which can be interval or crisp. Yu and Cheng (2007) proposed a revision of the fuzzy preference programming method to obtain crisp weight values from interval or crisp comparison matrices.

As it is seen, some of these methods result in crisp weights whereas in some of them, interval weights are obtained. The studies mentioned above, are summarized in Table 2. As it was also mentioned above, except the study of Yu and Cheng (2007), no previous study was encountered in the literature on handling interval judgments in ANP applications.

Table 2 Summary of Previous Studies on Interval Judgments

	Source	Method	Proposed Approach	Information Required from the	Output
1	Entani et al. (2001)	AHP	Interval weights are defined by center and radius. The center is obtained by the principal right eigenvector method, using the center values of the interval pairwise comparison matrix . The radius is obtained based on interval regression analysis.	Interval comparison matrix	weight intervals
2	Arbel (1989)	AHP	A linear programming method is proposed.	Interval comparison matrix	weight intervals
3	Arbel and Vargas (1993)	AHP	A non-linear programming method is proposed.	Interval comparison matrix	weight intervals
4	Wang et al. (2005a)	AHP	The linear programming method proposed by Arbel (1989) is recommended for consistent interval comparison matrices An eigenvector method-based nonlinear programming approach is proposed for inconsistent interval comparison matrices to generate interval weights that can meet predetermined consistency requirements.	Interval comparison matrix	weight intervals
5	Wang et al. (2005b)	AHP	A two-stage logarithmic goal programming method is proposed. The interval comparison matrices can be either consistent or inconsistent. The first stage is devised to minimize the inconsistency of interval comparison matrices and the second stage is developed to generate priorities under the condition of minimal inconsistency.	Interval comparison matrix	weight intervals

Table 2 Continued - Summary of Previous Studies on Interval Judgments

6	Wang and Elhag (2007)	AHP	A goal programming method is proposed The interval comparison matrices can be either consistent or inconsistent	Interval or crisp comparison matrix	weight intervals
7	Chandran et al. (2005)	AHP	A two-stage LP approach is proposed. The model proposed for crisp comparison marices is revised to handle interval judgments, by making each entry of the pairwise comparison matrix to be the geometric mean of the interval bounds.	Interval, crisp or mixed comparison matrix	crisp weights
8	Cox (2007)	AHP	Simulation techniques and total enumeration are compared to generate crisp weight values from interval pair wise comparison matrices.	Interval comparison matrix	crisp weights
9	Podinovski (2007)	AHP	Symmetrical-lexicographic-optimization method is used for a minimization problem with equally important criteria.	Interval comparison matrix	crisp weights
10	Sugihara et al. (2004)	AHP	Interval regression analysis is proposed.	Interval or crisp comparison matrix	weight intervals
11	Bryson and Joseph (2000)	AHP	Group Decision Making problem is handled in which individual pairwise comparison matrices are defined by various DM's in intervals. Logarithmic goal programming techniques are proposed for generating a group consensus priority vector.	priority interval (from each DM)	interval or crisp
12	Yu and Cheng (2007)	ANP	A revision of the fuzzy preference programming method is proposed.	Interval or crisp comparison matrix	crisp weights

Wang et al. (2005a, 2005b), Wang and Elhag (2007) and Arbel and Vargas (1993) mentions many other methods that deal with interval pairwise comparison matrices.

Since judgments in an interval comparison matrix reflect the uncertainty in decision maker's judgments, it is more appropriate to generate interval weight estimates rather than exact values. Wang (2006), Wang et al. (2005b), Wang and Elhag (2007) also defended this idea. Sugihara et al. (2004) expressed that, even if crisp pairwise comparison values are used, the priority weights should be estimated as intervals because of the uncertainty of decision maker's judgments.

2.5 Ranking Problems

Ranking problems in multiple criteria decision making environment, covers ranking of a set of alternatives based on their scores for a set of multiple and conflicting criteria. Multiple criteria decision making approaches involve several methods to handle ranking problems, such as SMART (Von Winterfeldt and Edwards, 1986), TOPSIS (Hwang and Yoon, 1981; Lai et al., 1994; Yoon and Hwang, 1995), outranking methods; ELECTRE II, III, and IV (Roy, 1973, 1977a, 1977b, 1991), PROMETHEE I and II (Brans and Vincke, 1985).

DEA is also a widely used ranking tool in multiple criteria decision making literature (Bouyssou, 1999; Sarkis, 2000; Adler et al., 2002; Mavrotas and Trifillis, 2006).

2.6 Data Envelopment Analysis

Data Envelopment Analysis (DEA) is a mathematical model for measuring the relative efficiency of decision making units (DMU) with multiple inputs and multiple outputs. The relative efficiency is measured as the ratio of weighted sum of outputs to weighted sum of inputs.

DEA was first introduced in by Charnes, Cooper and Rhodes (1978) as a Linear Programming model that formulates choice of the set of input and output weights such that each DMU is allowed to appear in the best possible light (the efficiency of a DMU is maximized relative to the other DMUs).

The basic aim is to separate the efficient DMUs from non-efficient DMUs. The efficiency ratio ranges from zero to one, a DMU is considered to be relatively efficient if it receives a score of one.

The model introduced by Charnes, Cooper and Rhodes (1978) is referred to as the CCR model. Various extensions of the CCR model have been proposed in the literature such as the BCC model developed by Banker, Charnes and Cooper (1984), the Additive Model developed by Charnes et al. (1985) and the SBM (Slacks-Based Measure) model introduced by Tone (2000). These basic DEA models are explained in detail in Cooper et al. (2000).

2.6.1 Multiple Criteria Decision Making Methods and Data Envelopment Analysis

The relation between Data Envelopment Analysis and multiple criteria decision making was initiated by Golany (1988) who applied DEA with multiple objective linear programming.

The MCDM problems consist of methodologies for ranking a set of alternatives under multiple and conflicting criteria. DEA is implemented for measuring the relative efficiency of DMUs with multiple inputs and multiple outputs.

Since, the proposal of using DEA as a tool for evaluating discrete alternative multiple criteria decision making (Oral et al., 1991; Doyle and Green, 1993; Stewart, 1994; Green et al., 1996; Papagapiou et al., 1997; Sarkis, 2000), many successful applications in various fields were made. The relation between DEA and MCDM has gained considerable attention gradually in the literature. Bouyssou (1999) explains the equivalence between the concept of "efficiency" in DEA and that of "convex efficiency" in MCDM. Bouyssou (1999), Sarkis (2000) and Adler et al. (2002) refer to various researches that have examined the relation among DEA and MCDM and applied DEA in MCDM.

Sarkis (2000) evaluated the use of DEA as a MCDM decision aid by comparing the DEA ranking approaches and MCDM techniques throughout a case study application. The DEA ranking results were compared to results achieved by various MCDM models which include outranking and multi attribute utility techniques. It was shown that the results obtained from DEA correlates well with some MCDM tools and DEA seems to perform well as a discrete alternative MCDM tool.

Several methods for using DEA as a MCDM tool have been proposed in the literature. These methods are explained in Bouyssou (1999) and Adler et al. (2002) in detail.

In the application of DEA as a MCDM tool, the DMUs are replaced with the alternatives, the outputs with maximization criteria and inputs with minimization criteria (Sarkis, 2000; Mavrotas and Trifillis, 2006).

The major advantage of DEA is that little information is required from the decision makers, leading to a strongly objective approach for the evaluation of the alternatives (Sarkis, 2000; Mavrotas and Trifillis, 2006). Only the values associated with each criterion for each alternative are required as input.

On the other hand, the major drawback that has been discussed frequently in the literature is its small discriminating power when used for evaluation purposes. That is the case in which most of the alternatives are likely to be efficient. Complete ranking of the alternatives cannot be achieved due to this drawback. Also Tuncer (2006) denotes the drawback that "the score is totally dependent on the position of the DMUs with respect to the efficient frontier formed by efficient DMUs. The removal of even one DMU can change the efficiency scores considerably".

In order to overcome this lack of discrimination drawback, the classical DEA model was extended to some different methods, in which the discriminatory power of DEA was increased. Two basic and commonly used approaches that are utilized for increasing the discriminatory power of DEA are the Cross-Efficiency Method and the Super-Efficiency method.

The cross-efficiency method was introduced by Sexton et al. (1986). In cross-efficiency, the efficiency score of each DMU is calculated using the most favorable set of weights obtained from the LP's solved for each DMU. All of the efficiency scores are summarized in a cross-efficiency matrix and the final score for each alternative is obtained as the corresponding column average of this matrix. Instead of taking the average, the median, minimum or variance of scores could also be used (Adler et al., 2002). Mavrotas and Trifillis (2006) extended the cross-efficiency model for solving a multiple criteria decision analysis problem.

The cross-efficiency method has a drawback that the DMUs which stand close to each other in the frontier are favored and the DMUs which are different from the majority obtain low rankings. The use of this method is appropriate in cases where there is no significant crowding in certain areas in the frontier or when the DMUs that are different from the majority have undesirable values by the DM (Tuncer, 2006; Eryılmaz, 2006).

The super-efficiency method was introduced by Andersen and Petersen (1993). In this method, a DMU is allowed to achieve an efficiency score greater than one by removing the kth constraint in the CCR model. By relaxation of the constraint for unit efficiency at most, ranking of efficient units, in addition to non-efficient units, becomes possible. The super-efficiency method has a drawback that the DMUs that have marginal values are favored and can be assigned an excessively high ranking.

Tuncer (2006) proposed a DEA-based approach, the Method of the Area of the Efficiency Score Graph, for ranking alternatives in a MCDM environment, in which the drawbacks mentioned above, favoring the alternatives in crowding areas or favoring the alternatives that have marginal values, are avoided. The method considers the change in the efficiency scores of the alternatives while reducing the size of the alternative set and favors alternatives that manage to improve quickly and maintain high levels of efficiency.

Eryılmaz (2006) proposed two different hybrid ranking approaches based on PROMETHEE and DEA, in which PROMETHEE is used to construct outranking relations by pairwise comparisons, and a method similar to cross-efficiency is used in aggregation of netflows of alternatives for each criterion efficiency, which results in ranking of the alternatives. One of these approaches is used for ranking when there is imprecise information on weights, and the other approach is used for ranking when weights and preference function parameters are not precisely specified.

2.6.2 Assurance Regions

Requirement of little information from the decision makers have been explained as an advantage of DEA in the literature; however it has also a drawback of lack of DM's preferences in the evaluation. This drawback was eliminated by incorporation of the DM judgments through the addition of Assurance Regions (Sarkis, 2000). Assurance region approach involves usage of the preferences of the DM as weight restrictions in DEA ranking models.

Addition of Assurance Regions also has an advantage of improving the discriminating power of DEA (Adler et al., 2002). The Assurance Region approach is explained in detail in Thompson et al. (1986, 1990,1992). Usage of assurance region constraints is also defined in Sarkis (2000). Hashimoto (1997) introduced assurance region constraints in a DEA super-efficiency model in order to achieve complete ranking of the DMUs. Sueyoshi (1999) proposed assigning specific bounds on the weights in a DEA super-efficiency model. Sarkis (2000) provides an example for assurance region approach, in which the criteria weights are crisp values. The upper and lower bounds were defined by varying the weights by a percentage.

Sarkis (2000) declares that incorporation of the DM judgments through the addition of assurance regions or other methods seems to provide results that are more correlated to some of the traditional MCDM approaches such as PROMETHEE I, PROMETHEE II, ELECTRE III and SMART.

2.6.3 Missing Data in DEA

The basic information in DEA applications is the output/input (maximizing/minimizing criteria) values. The values are crisp, positive values. However, in many applications all the data required may not be available, giving rise to missing values in the data.

The review of literature has shown that, handling missing values in DEA models has been rarely discussed in the literature. O'Neal et al. (2002) proposed eliminating the units that have missing values from the analysis. Although it is a common method, it is not a suitable approach since the efficiency of the remaining units would also be affected due to the comparative evaluation (Smirlis et al., 2006). Kuosmanen (2002) proposed assigning dummy variables to the missing entries (zero for the outputs and sufficiently large number for inputs) and to add some restrictions on weights to reduce the impact of the units having missing values to the efficiency of the remaining units. Kao and Liu (2000) proposed to use intervals modeled by fuzzy sets in lieu of missing values. Other approaches for handling missing values include assigning approximate values, like using the average value of the other units (Smirlis et al., 2006). Smirlis et al. (2006) introduced an interval DEA model, in which the missing values are replaced with appropriate interval estimations, composed of strictly positive and constant upper and lower bounds. As a result of this approach, the efficiency scores of the units are also obtained as intervals.

CHAPTER 3

METHODOLOGIES BEHIND THE PROPOSED MODEL

3.1 Analytic Network Process

The Analytic Network Process method is explained in detail in Saaty (1996).

ANP is a network system which is composed of clusters and their elements (nodes). Interdependency is the most important element of ANP, which is handled by setting links. Links between the elements represent the interrelationship between elements and links between clusters represent the interrelationship between clusters. Links between elements within the same cluster are called inner dependencies, whereas links between an element in one cluster and an element in another cluster are called outer dependencies (Saaty, 1996, 1999). If a link exists from at least one element of a cluster to at least one element of another cluster, the clusters are also connected by an arrow.

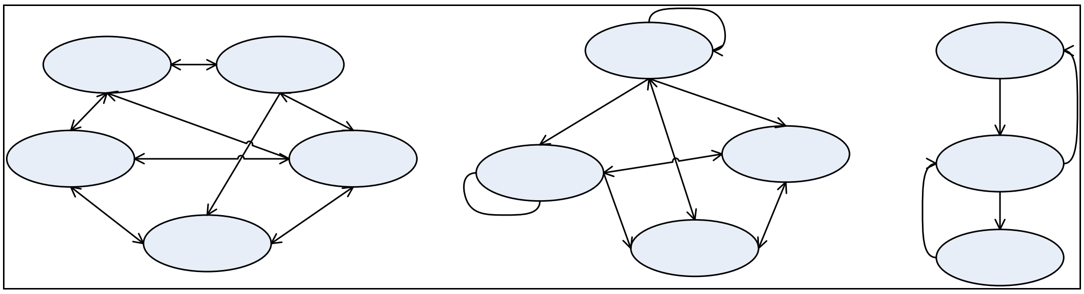

Figure 4 Sample Networks

In ANP, the following pairwise comparisons are made by using the fundamental comparison scale of AHP (the nine-point scale of Saaty).

(a) Cluster comparisons: Paired comparisons are made on the clusters.

(b) Comparisons of elements: Paired comparisons are made on the elements. The elements in a cluster are compared according to their influence on an element in their own cluster and on an element in another cluster to which they are connected.

(c) Comparisons for alternatives: The alternatives are compared with respect to all elements from which they are connected.

The local priorities are obtained from each pairwise comparison matrix by using the eigenvector method (as it is in the AHP).

Eigenvector Method was developed by Saaty (1980). The principal right eigenvector obtained as the unique solution to the following eigenvalue problem is used in the estimation of the priority vector.

$$Aw = \lambda_{\max} w \tag{3.1}$$

where λ_{max} is the largest eigenvalue of A.

The measure of the consistency of the pairwise comparison matrices should be taken into account. The measure of consistency is calculated by the Consistency Ratio (C.R.).

A pairwise comparison matrix is considered to be consistent when the consistency ratio is less than 0.10. A consistency ratio of up to 0.2 is also tolerable (Saaty, 1996).

The consistency of the judgments should be improved by using this ratio.

The eigenvectors of the pairwise comparison matrices of element comparisons and alternative comparisons are then substituted into an overall matrix, called the

Unweighted Supermatrix. The supermatrix is a partitioned matrix, columns of which contain the local priorities derived from the pairwise comparisons of the elements.

For a three level hierarchy with a goal, criteria and alternatives, and the criteria being dependent among themselves, the Unweighted Supermatrix, W, is formed as follows (Saaty, 1996).

$$W = \begin{pmatrix} 0 & 0 & 0 \\ X & Y & 0 \\ 0 & Z & I \end{pmatrix}$$

where X is the column vector of priorities of criteria with respect to the goal (principal right eigenvector of pairwise comparison matrix for the criteria with respect to the goal), Y is the matrix of column eigenvectors of interdependence among the criteria (principal right eigenvectors of interdependency matrices for the criteria), Z is the matrix of column eigenvectors of the alternatives with respect to each criterion (principal right eigenvectors of pairwise comparison matrices for the alternatives under each criterion) and I is the identity matrix.

The local priorities obtained from cluster comparisons are applied as the cluster weights on the Unweighted Supermatrix. They are used to weigh the blocks of matrices that fall in the column under the given cluster. The matrix obtained as a result of this process is a matrix which each of its columns sums to unity (the supermatrix is made column stochastic, which is required for convergence to occur). This matrix is called the Weighted Supermatrix. This concept is similar to Markov Chain that the sum of the probabilities of all states equal to one (Piantanakulchai, 2005).

In the next stage, the Weighted Supermatrix is raised to limiting powers, which would result in convergence of the priorities. When the values are converged, the columns stabilize and become identical for the rest of the powers. The resulting matrix is called the Limit Supermatrix which gives the global priorities of the elements with respect to the goal.

$$\lim_{k \to \infty} W^k \tag{3.2}$$

Saaty (1996) explains the reason for raising the supermatrix to powers as the desire to capture the transmission of influence along all possible paths of the supermatrix.

As Saaty (1996) explains, feedback involves cycles and cycling may be occurred in rising the supermatrix to large powers. When cycling occurs, the powers do not converge to a single matrix. In that case, the average (Cesaro Sum) of the successive matrices of the entire cycle is used as the final priorities.

$$\lim_{k \to \infty} \left(\frac{1}{N} \right) \sum_{i=1}^{N} W_i^k \tag{3.3}$$

Saaty (1996) explains the concept corresponding to the Markov chain process.

3.2 Data Envelopment Analysis

As it was previously explained in Section 2.6, Data Envelopment Analysis is used for measuring the relative efficiency of DMUs with multiple inputs and multiple outputs. The CCR model is explained in detail below.

3.2.1 CCR Model

The relative efficiency of a DMU is measured as the ratio of weighted sum of outputs to weighted sum of inputs. For a case of n units with s outputs and m inputs, the efficiency measure for a given DMU k, h_k is written as:

$$h_k = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \tag{3.4}$$

where y_{rk} denotes the value of output r for DMU k (r = 1,...,s), x_{ik} denotes value of input i for DMU k (i = 1,...,m), u_r denotes weight of output r and v_i denotes weight of input i. The weights, u_r and v_i, are non-negative.

The basic DEA model developed by Charnes, Cooper and Rhodes (1978) that has an objective of maximizing the efficiency value of a given DMU k by selection of the optimal output and input weights is formulated as follows:

$$h_k = \max \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \tag{3.5}$$

s.t.

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1 \qquad \text{for } j = 1,....n \tag{3.6}$$

$$u_r \geq 0 \qquad \text{for } r = 1,...,s \tag{3.7}$$

$$v_i \geq 0 \qquad \text{for } i = 1,...,m \tag{3.8}$$

Note that the first constraint requires that the efficiency of a DMU cannot be greater than one.

This non-linear model is transferred to the following linear programming model (Charnes et al., 1978).

$$h_k = \max \sum_{r=1}^{s} u_r y_{rk} \tag{3.9}$$

s.t.

$$\sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} u_r y_{rj} \geq 0 \qquad \text{for } j = 1,...,n \tag{3.10}$$

$$\sum_{i=1}^{m} v_i x_{ik} = 1 \tag{3.11}$$

$$u_r \geq \varepsilon \qquad \text{for } r = 1,...,s \tag{3.12}$$

$$v_i \geq \varepsilon \qquad \text{for } i = 1,...,m \tag{3.13}$$

The above model, also referred as CCR model, is solved n times, one for each DMU.

3.2.2 Super-Efficiency Model

As it was explained previously, the super-efficiency model was introduced to increase the discriminatory power of DEA.

The super-efficiency model is formulated as follows.

$$h_k = \max \sum_{r=1}^{s} u_r y_{rk} \tag{3.14}$$

s.t.

$$\sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} u_r y_{rj} \geq 0 \qquad \text{for } j = 1,...,n, j \neq k \tag{3.15}$$

$$\sum_{i=1}^{m} v_i x_{ik} = 1 \tag{3.16}$$

$$u_r \geq \varepsilon \qquad \text{for } r = 1,...,s \tag{3.17}$$

$$v_i \geq \varepsilon \qquad \text{for } i = 1,...,m \tag{3.18}$$

3.2.3 Assurance Regions

In assurance region approach, the upper and lower bounds for each input and output weight are used in defining constraints on weight values.

In Sarkis (2000), the generalized assurance region constraints are given as follows.

$$\frac{w_i}{w_j} \geq \frac{LB_i}{UB_j} \tag{3.19}$$

$$\frac{w_i}{w_j} \leq \frac{UB_i}{LB_j} \tag{3.20}$$

where w_i represents the weight of an input/output i and LB_i and UB_i represent the lower and upper bounds on weight of input/output i respectively.

CHAPTER 4

PROJECT PERFORMANCE EVALUATION CRITERIA

4.1 System Development Life Cycle at TÜBİTAK-SAGE

Prior to the presentation of the project performance evaluation criteria, the system development process applied in the R&D projects executed in the Institute is explained in order the reader to assess the project activities more explicitly. The system development process is applied in majority of the projects, approximately at a percentage of 95%, given in scale of contractual budget.

The system development process consists of four primary phases, as demonstrated in Figure 5**Error! Reference source not found.**. These phases are as follows:

1. Conceptual Design
2. Preliminary Design
3. Detailed Design
4. System Test and Evaluation

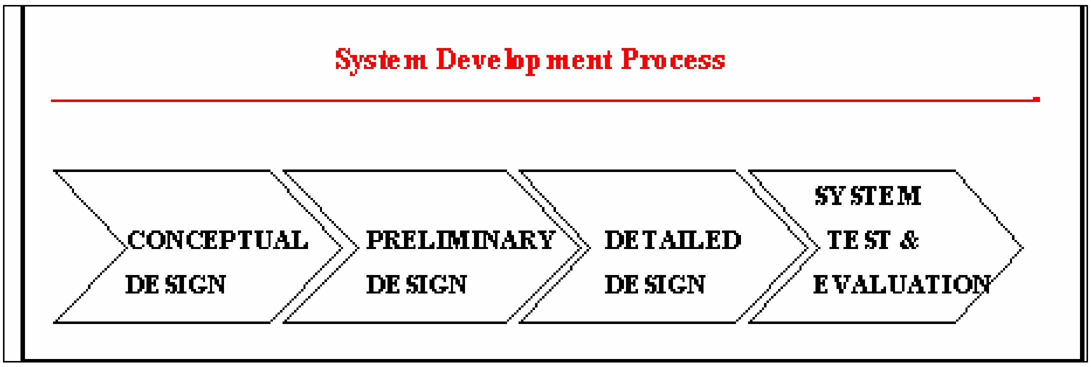

Figure 5 System Development Process

Conceptual Design

Conceptual Design is the first phase of the design process. In this phase, all reasonable system alternatives that may meet the system requirements are identified. System requirements are allocated to system components and items, trade-off analyses are performed and the system architecture is determined.

Preliminary Design

Characteristics of the system components that will meet the requirements allocated to the items in the system architecture defined in the Conceptual Design are determined. The performance of those system components are examined through numerical analysis and prototype testing.

Detailed Design

Detailed analyses and documentation on system components are performed. Prototype testing is performed for the validation of the component/item designs. Design is updated iteratively until the requirements allocated to system components/items are met. The system integration and tests are performed and the performance characteristics of system components that are determined in the preliminary design phase are transformed to performance characteristics of the final product.

System Test and Evaluation

The system is tested to demonstrate that the design meets the specification requirements and the system is operationally effective and suitable. Generally this phase encompasses the tests that are performed for the customer.

At the end of each phase, the status of the design is evaluated, by conducting technical reviews and the decision to continue the present phase or proceed to the next phase is given. Detailed information on technical reviews is given in Section 4.3.

4.2 Determination of the Project Performance Evaluation Criteria

One of the most critical and time consuming tasks of the study was the determination of the criteria for evaluating the project performance. As it was previously mentioned in Chapter 2, a comprehensive literature survey was performed on the R&D project performance evaluation criteria, however very few studies were encountered. The criteria that are found during literature survey and discussions on their applicability to the project performance evaluation system in the Institute are provided in Chapter 2.

For the determination of the project performance evaluation criteria, a study was performed in the Institute with participation of personnel of Programs and Project Management Division. This study was performed approximately within a two-months time in which various brainstorming meetings were conducted on determination of the criteria.

In this stage of the study, the results of the literature survey and the existing project performance evaluation criteria were reviewed, the requirements of the project performance management system were identified and a discussion on project performance measurement criteria was performed. Previous experiences in the Institute and expert advices were also taken into account in the identification of the criteria.

It is needed to emphasize that the evaluation criteria and sub-criteria were determined by taking into account the customer-based projects, which cover wider range in the Institute than the in-house projects with respect to prioritization and magnitude, as it was explained in previous chapters. In addition, it should be mentioned that most of these criteria and sub-criteria are also applicable to evaluation of the in-house projects and the evaluation system developed can also be used for in-house projects by removal of the inapplicable criteria/sub-criteria and inclusion of some other criteria/sub-criteria related to evaluation of in-house project's performance, if required.

After a detailed and long lasting study, a list of 11 criteria, containing 30 sub-criteria was generated. The criteria and the sub-criteria, and the interdependencies among them are listed in Table 3. A detailed description and explanation of the criteria and the sub-criteria, and the interdependency relations are given below.

Table 3 The Criteria and Sub-Criteria Defined for Project Performance Evaluation

CRITERIA		**SUB-CRITERIA**		**DEPEN-DENCY (Depends on)**	
C1	Customer Satisfac-tion	S1	The Paraphrased Dissatisfaction of the Customer in Administrative and Technical Subjects throughout the Project	C2 C6 C10	S5 S7 S18 S26
		S2	The Delays in the Deliveries in Liability of the Institute		
		S3	The Satisfaction of the Customer Regarding the Deliverables		
		S4	Average Response Time to Customer Change Requests		S3
		S5	Average Response Time to Additional Customer Requests		
C2	Schedule Manage-ment	S6	Schedule Deviation	C1 C5 C6 C7 C10	S2 S7 S12,S15 S17 S19 S26 S27
		S7	Milestone Completion		S2 S12,S15 S17 S19 S26 S27

Table 3 Continued - The Criteria and Sub-Criteria Defined for Project Performance Evaluation

CRITERIA		SUB-CRITERIA		DEPEN-DENCY (Depends on)	
C3	Cost Manage-ment	S8	Deviation in Project Expenditure	C2 C7 C10	S19 S26 S27
		S9	Deviation in Project Personnel Cost		S7 S8
C4	Human Resource Manage-ment	S10	Deviation in Manpower	C2 C9 C10	S7 S11 S22 S26
		S11	Turnover Rate		S21 S22 S23
C5	Subcont-ractor Manage-ment	S12	Quality of the Subcontractors		S14 S15
		S13	Subcontractor Review Results		
		S14	Subcontractor Quality Audit Results		
		S15	Acceptance Satisfaction of the Supplied Items		
C6	Overseas Depen-dence	S16	Overseas Procurement Rate		
		S17	Export License Dependence		S16
		S18	Deviation in Overseas Procurement Rate		S16
C7	Risk Manage-ment	S19	Risk Handling	C2 C3 C4 C10	S6,S7 S8,S9 S11 S24,S26
C8	In-house Quality Audit Results	S20	Number of Non-Conformities		

Table 3 Continued - The Criteria and Sub-Criteria Defined for Project Performance Evaluation

CRITERIA		**SUB-CRITERIA**		**DEPEN-DENCY (Depends on)**	
C9	Satisfaction of the Project Personnel	S21	Contribution to the Self-Development of the Institute Personnel	C2 C3 C4 C10	
		S22	Overtime Rate		S7 S10 S26
		S23	Supplementary Payment to the Institute Personnel		S8 S9
C10	Technical Perfor-mance	S24	Technical Performance Measures		S26
		S25	Technical Review Results		
		S26	Test Performance		
		S27	Maturity of the Design		S26
C11	Simpli-city of the Design	S28	Commercially off-the-Shelf Item Usage		
		S29	Common Item Usage among Projects		
		S30	Standard Item Usage		

4.3 Definitions and Explanations of the Criteria and the Sub-Criteria

C1 - Customer Satisfaction

By the term “customer”, external customer is intended. “Customer” defines the organization, which is the claimant of the product/service and responsible for accepting the product/service. Generally, the customers of the projects executed in TÜBİTAK-SAGE are military institutions like Turkish Armed Forces, Ministry of National Defense or other companies in the defense industry.

Customer satisfaction is one of the most vital issues for the Institute. The opinions of the customer are not only important for the success of the projects, but also for the general perception of the current and potential customers in the defense industry. In Turkey, the number of potential customers for the defense companies like TÜBİTAK-SAGE is very limited; therefore the satisfaction of the customer both from the project and the Institute is considerably important.

The following sub-criteria are defined under the Customer Satisfaction criterion.

1. The Paraphrased Dissatisfaction of the Customer in Administrative and Technical Subjects throughout the Project
2. The Delays in the Deliveries in Liability of the Institute
3. The Satisfaction of the Customer Regarding the Deliveries
4. Average Response Time to Customer Change Requests
5. Average Response Time to Additional Customer Requests

S1 - The Paraphrased Dissatisfaction of the Customer in Administrative and Technical Subjects throughout the Project

The customer rarely reflects his satisfaction to the organization throughout the project life cycle. Therefore, the inverse of the paraphrased satisfaction sub-criterion, the paraphrased dissatisfaction of the customer, is decided to be used as a sub-criterion to consider "Customer Satisfaction". Number of complaints received from the customer is defined as the metric to measure this sub-criterion. For a project, the value of this metric is desired to be as low as possible.

The complaints received by official correspondence or any other means of communication like e-mail, meeting, telephone or conversation, which are being recorded by the Institute will be an input for this sub-criterion.

The total number of complaints received from the customer in a given phase will be denoted by *NCC*.

S2 - The Delays in the Deliveries in Liability of the Institute

The delays that occur in the deliveries of the documents or prototypes, the delivery schedule of which are defined in the contract, is a critical factor that would effect customer satisfaction.

This sub-criterion is decided to be measured using the average delay in the delivery dates of the documents or prototypes specified in the contract, *DD*.

DTD_d denotes the delay in the delivery of a deliverable *d* specified in the contract (in calendar days), "*t*" denotes the time that the project's performance evaluation is made and *ND* denotes the total number of deliverables that should have been submitted to the customer until time *t*.

The following ratio will give the average delay in the delivery dates of the documents or prototypes specified in the contract. This ratio is desired to be as low as possible.

$$DD = \frac{\sum_{d=1}^{ND} DTD_d}{ND} \tag{4.1}$$

In calculation of the delay in the delivery of a deliverable, the difference between the realized delivery time and the delivery time defined in the contract is used. If the deliverable has still not delivered in time *t*, then the difference between time *t* and the delivery time defined in the contract is used.

S3 - The Satisfaction of the Customer Regarding the Deliverables

The acceptance satisfaction of the customer about the deliverables is a critical factor to determine customer satisfaction. In accordance with the contract, certain deliverables are submitted to the customer at specified milestones such as Project Management Plan, Quality Assurance Plan, technical drawings, test plans, flow diagrams, etc.. A delivery milestone exists at the end of each phase. In addition to them, some other delivery milestones might be defined in the contract at any time throughout the project. The deliverables are mostly documents and/or prototypes. The deliverables, which are inspected by the customer, are either accepted directly, or some change requests may be proposed. The percentage of the number of deliverables (documentation or prototypes) accepted at the first inspection without any change requests, in the total number of deliverables, is decided to be used as the metric to measure this sub-criterion.

NDA denotes the total number of deliverables accepted at the first inspection without any change request until time *t*. The following percentage is defined as the metric to measure this sub-criterion:

$$AS = \frac{NDA}{ND} \times 100 \tag{4.2}$$

This metric is calculated cumulatively from the beginning of the project and the value of this metric is desired to be as high as possible.

S4 - Average Response Time to Customer Change Requests

Concluding the change requests submitted by the customer as early as possible is a factor that would increase customer satisfaction. In order to measure this sub-criterion, the average deviation between the realized and the expected conclusion times is decided to be used as the metric.

DC_{cr} denotes the realized duration for performing the changes and concluding the customer change request *cr* (in calendar days) and EC_{cr} denotes the expected duration for concluding that customer change request (in calendar days). This metric will be calculated by taking the average of the deviations in the conclusion times of the customer change requests until time *t*. *NDC* denotes the total number of customer change requests received until time *t*. The following ratio is defined as the metric:

$$ART = \frac{\sum_{cr=1}^{NDC}\left(\frac{DC_{cr} - EC_{cr}}{EC_{cr}}\right)}{NDC} \tag{4.3}$$

This number is desired to be negative and as low as possible.

Generally, customers declare a duration for the conclusion of the change requests. The expected conclusion time, EC_{cr}, will be equal to this duration. For the cases that the customer has not declared a duration for the conclusion of a change request, the expected conclusion time will be defined for each change request by the responsible project personnel such as the project manager.

S5 - Average Response Time to Additional Customer Requests

Customers might demand some extra requests besides the contractual responsibilities. In order to be on good terms with the customer, these requests are desired to be completed within minimum time. Completing these requests as early as possible is a factor that would increase customer satisfaction. In order to measure this sub-criterion, the average deviation in the completion times of the extra requests obtained from the customer received by official correspondence or any other means of communication like e-mail, meeting, telephone or conversation throughout the project is decided to be used as a metric.

DR_r denotes the time limit (in calendar days) given by the customer for a customer request r, and DCR_r denotes the realized duration (in calendar days) for concluding the request. This metric will be calculated by taking the average of the deviations in the conclusion times of the customer requests until time t. NR denotes the total number of additional requests submitted by the customer until time t. The following ratio is defined as the metric:

$$ARTR = \frac{\sum_{r=1}^{NR}\left(\frac{DCR_r - DR_r}{DR_r}\right)}{NR} \tag{4.4}$$

This number is desired to be negative and as low as possible.

C2 - C3 - Schedule Management and Cost Management

Schedule and cost management are two of the major factors of project management which deal with the processes required to accomplish timely execution of project tasks and timely completion of the project within the allocated budget.

The project tasks and costs should be monitored and controlled regularly, so that progress can be tracked and any deviation should be identified in order to take the actions necessary to avoid or handle the problems.

Baselining

It is important that project plans (schedules and budgets) are baselined having determined authorized dates, milestones, budgets and resources against which progress can be measured.

As duration, dates, deliverables and costs may change over time; baselining allows tracking the progress achieved and the deviations that occurred against a predetermined baseline. Therefore, after the planning efforts are completed, the plans are baselined and any adjustments to the baseline plans are subjected to formal change control.

TÜBİTAK-SAGE uses a project management tool for this action. The project schedule plans are prepared by using this tool, and after baselined, the plans are updated regularly by the project manager or related project personnel. The baseline start and finish dates and durations are compared to actual values. The budgets are also baselined with the project plans and the planned and actual values are compared.

Earned Value Approach

Earned Value approach has been the most popular method so far to track the schedule and cost deviations of the projects.

There are three critical elements used in Earned Value approach: The Budgeted Cost of Work Scheduled (BCWS), the Actual Cost of Work Performed (ACWP) and the Budgeted Cost of Work Performed (BCWP).

The Budgeted Cost of Work Scheduled (BCWS) is the amount of budget that is expected to be consumed to accomplish a specific work. In other words, it is the baseline cost. The Actual Cost of Work Performed (ACWP) is the actual cost incurred for the work performed. Finally, the Budgeted Cost of Work Performed (BCWP) is a measure of the amount of work accomplished, stated in terms of the budget assigned to that specific tasks accomplished.

Cost Variance is obtained by the difference between BCWP and ACWP and the Schedule Variance is obtained by the difference between BCWP and BCWS.

Applying the Earned Value approach for calculation of the schedule and cost variance was not found suitable for the Institute because of the following reasons:

In Earned Value approach, schedule and cost variances are calculated by using BCWP. BCWP is not an effective measure for the Institute because, as a result of the R&D nature of the projects, there occur a lot of unplanned expenditure which should also be taken into account in evaluating the status of the project.

Furthermore, Earned Value approach interprets the schedule variance in terms of cost. It was decided that a more accurate analysis was required in terms of amount of work performed.

The following sub-criteria are defined under the Schedule Management criterion.

1. Schedule Deviation
2. Milestone Completion

S6 - Schedule Deviation

The schedule deviation, *SD*, is obtained by comparing the actual percentage of work completed (from the updated plan) to the planned percentage that should have been completed (from the baseline plan).

PPWC denotes the planned percentage of work that should have been completed at time t and *APWC* denotes the actual percentage of work completed at time t. This metric is calculated by the following formula:

$$SD = PPWC - APWC \tag{4.5}$$

The value of this metric is desired to be as low as possible.

S7 - Milestone Completion

A milestone is any major event in a project and used to monitor the project's progress. The customer or the developing organization can define milestones such as review dates, deliverable dates, test dates, etc.. Milestone dates can be addressed as schedule constraints.

Milestone completion is also an important factor to track the progresses and deviations in a project, therefore the status of the milestones that should be completed in the evaluation period should also be taken into account.

MsD_m denotes the delay in the completion time of a milestone m (in calendar days) and *NMs* denotes the number of milestones that should have been completed until time t.

The following ratio will give the average delay in the completion time of milestones. This ratio is desired to be as low as possible.

$$MsC = \frac{\sum_{m=1}^{NMs} MsD_m}{NMs}$$

In calculation of the delay in the completion time of a milestone, the difference between the realized completion time and the planned completion time is used. If the milestone has still not completed in time t, then the difference between time t and the planned completion time is used.

The following sub-criteria are defined under the Cost Management criterion.

1. Deviation in Project Expenditure
2. Deviation in Project Personnel Cost

S8 - Deviation in Project Expenditure

The deviation in project expenditure, *PED*, is obtained by comparing the Actual Cost of Work Performed (*ACWP*) to the Budgeted Cost of Work Scheduled (*BCWS*). This metric is calculated by the following formula:

$$\frac{ACWP - BCWS}{BCWS} \times 100 \qquad (4.6)$$

When the project expenditure is higher than the planned value, a positive value is obtained. Exceeding the planned budget is an undesirable case for a project. Contrarily, when the project expenditure is less than the planned value, a negative value is obtained. This is also an undesirable case since it implies inessential blocking of financial resources which could have been used in other projects or investments in the Institute. Since both of these two cases are undesirable for a project, the absolute value of the above ratio is desired to be minimized.

$$PED = \left| \frac{ACWP - BCWS}{BCWS} \times 100 \right| \qquad (4.7)$$

S9 - Deviation in Project Personnel Cost

Mainly, two types of personnel are present at TÜBİTAK-SAGE; The ones with indefinite time contract called "Permanent Personnel" and the ones with fixed time contract called "Project Personnel". Permanent Personnel are stable; their salaries are financed by governmental funds. Project Personnel are financed by the projects in which they are working. The Project Personnel are also stable in the Institute, when the project in which they have been working is terminated; they are transferred to another recently executed or ongoing project. The number of personnel that will be financed from each project, therefore the Project Personnel cost is budgeted at the beginning of the projects. The Project Personnel financed is continuously tracked and regulated according to the available budget of the projects.

Deviation in Project Personnel Cost is another important factor for Cost Management. This deviation, *PPCD*, is obtained by comparing the actual Project Personnel cost to the budgeted Project Personnel cost.

PPCP denotes the planned Project Personnel cost until time *t* and *PPCA* denotes the actual Project Personnel cost until time *t*. This metric is calculated by the following formula:

$$PPCD = \frac{PPCA - PPCP}{PPCP} \times 100 \qquad (4.8)$$

This number is desired to be negative and as low as possible.

C4 - Human Resource Management

Another critical action for TÜBİTAK-SAGE is the management of human resources since several projects are executed simultaneously with limited human resources.

Two sub-criteria are defined under this criterion; Deviation in Manpower and Turnover Rate.

S10 - Deviation in Manpower

The planned values and the actual values of utilization of human resources should be monitored continuously in order to manage the human resource utilization and take the necessary actions when any problem of resource allocation occurs.

In the Institute, the manpower allocated to the projects is planned within the project schedule plans; the realized manpower is also tracked.

The deviation in manpower, *MPD*, is obtained by comparing the actual manpower (in man month) allocated to the project to the planned manpower (in man month).

MPA denotes the actual manpower (in man month) and *MPP* denotes the planned manpower (in man month). This metric is calculated by the following formula:

$$\frac{MPA - MPP}{MPP} \times 100 \tag{4.9}$$

When the actual manpower is higher than the planned value, a positive value is obtained. Exceeding the planned manpower is an undesirable case for a project. Contrarily, when the actual manpower is less than the planned value, a negative value is obtained. This is also an undesirable case since it implies inessential blocking of human resources which could have been used in other projects. Since both of these two cases are undesirable for a project, the absolute value of the above ratio is desired to be minimized.

$$MPD = \left| \frac{MPA - MPP}{MPP} \times 100 \right| \tag{4.10}$$

S11 - Turnover Rate

A significant issue in project execution is finding and keeping skilled personnel. High turnover rate is an undesirable factor for the projects, since it reflects the loss of experienced personnel, being familiar to the project and inclusion of new inexperienced and unfamiliar personnel for whom additional time and effort is needed to become familiar with the project and the project team members.

Depending on the managerial, technical and personal reasons, turnover is a no surprising issue in projects. Turnover might be tolerable for some the personnel having relatively low workload in the project, however there are some critical personnel whose departure would effect the project in a bad manner. On the other hand inclusion of some critical personnel would affect the project in the adverse way.

In order to capture the critical project personnel, the personnel allocating a workforce of at least 40% of the workforce allocated by the project manager in a given project is being considered.

PCI denotes the number of critical personnel included to the project in a given evaluation period, *PCD* denotes the number of critical personnel departed from the project in that given evaluation period and *PCT* denotes the total number of critical personnel working in the project at the end of that evaluation period.

The turnover rate is obtained by the following formula:

$$TOR = \left(\frac{PCI + PCD}{PCT} \right) \times 100 \tag{4.11}$$

This ratio is desired to be as low as possible.

C5 - Subcontractor Management

Subcontractor management is performed to manage the acquisition of products or services from suppliers to perform the project activities.

Subcontractor management involves the following activities: (CMMI-SE/SW/IPPD/SS, V1.1)

- Selecting suppliers
- Establishing agreements with suppliers and executing the supplier agreements
- Accepting the acquired products
- Transitioning the acquired products to the project

Capability Maturity Model Integration model (CMMI-SE/SW/IPPD/SS, V1.1) was taken as reference in definition of Subcontractor Management sub-criteria. These sub-criteria are defined as follows:

1. Quality of the Subcontractors
2. Subcontractor Review Results (Program review and technical review results)
3. Subcontractor Quality Audit Results
4. Acceptance Satisfaction of the Supplied Items

S12 - Quality of the Subcontractors

The quality of the subcontractors directly affects the quality and the delivery schedule of the products or services supplied. Therefore, this criterion has considerable effect on the project performance. This sub-criterion is determined to be measured by a metric that involves the grades of the subcontractors.

A Subcontractor Management System is also being constructed at TÜBİTAK-SAGE, in which the suppliers are going to be evaluated and graded with respect to their performance. After the identification of the potential suppliers, supplier selection will be made from the list of candidate suppliers according to predefined evaluation criteria. Selecting the right suppliers is a critical factor in subcontractor management. The subcontractors are going to be evaluated throughout the projects after the acceptance of the products or services supplied. All the subcontractors will be graded according to these evaluations.

GR_s denotes the evaluation grade of a subcontractor s (out of one hundred) and NS denotes the total number of subcontractors that have been worked with from the beginning of the project until time t. This metric, denoted by QS, is calculated by taking the average of the grades of the subcontractors of the project.

$$QS = \frac{\sum_{s=1}^{NS} GR_s}{\text{NS}} \tag{4.12}$$

The value of this metric is desired to be as high as possible.

S13 - Subcontractor Review Results

With the implementation of the Subcontractor Management System that is being constructed, subcontractor's progress and performance are going to be monitored regularly and evaluated with predefined performance measures (schedule, effort, cost, and technical performance). Program reviews and technical reviews will be conducted with the subcontractor. The non-conformities identified in these reviews are desired to be corrected within the given time limits.

NCSI denotes the total number of non-conformities identified in the subcontractor reviews until time t and *NCSC* denotes the total number of non-conformities corrected on time until time t. This sub-criterion is measured by the following metric.

$$SRR = \frac{\text{NCSC}}{\text{NCSI}} \times 100 \tag{4.13}$$

The value of this metric is desired to be as high as possible.

S14 - Subcontractor Quality Audit Results

With the implementation of the Subcontractor Management System that is being constructed, subcontractors are going to be subjected to quality audits in order to identify the non-conformities and take corrective actions. The metric for this sub-criterion is decided to be the average number of non-conformities identified in subcontractor quality audits per subcontractor, denoted by *NNCS*.

$NNCS_{sq}$ denotes the number of non-conformities identified in the qth quality audit of subcontractor *s* (the subcontractors may be submitted to quality audits at various stages of the project depending on the scope of their tasks). The following ratio will give the average number of non-conformities per subcontractor.

$$SQR = \frac{\sum_{s=1}^{NS} \sum_{q} NNCS_{sq}}{NS} \tag{4.14}$$

S15 - Acceptance Satisfaction of the Supplied Items

The acceptance of the products or services supplied is performed according to the predefined procedures.

IS denotes the total number of items that are supplied by subcontractors until time *t* and *IA* denotes the total number of items accepted until time *t*. The acceptance satisfaction sub-criterion is measured by the following metric:

$$SAS = \frac{IA}{IS} \times 100 \tag{4.15}$$

The value of this metric is desired to be as high as possible.

C6 -Overseas Dependence

Overseas dependence is a major factor that affects both the project and the product after delivery. Because of technological reasons, in most of the defense projects, several items have to be procured from international suppliers.

It is desired to minimize the overseas dependence and perform procurements from domestic suppliers as much as possible.

Three criteria are defined under Overseas Dependence; Overseas Procurement Rate, Export License Dependence and Deviation in Overseas Procurement Rate.

S16 - Overseas Procurement Rate

The percentage of the budget allocated to overseas procurements in the total budget spent (*ACWP*) is decided to be used as the metric to measure overseas dependence.

BOP denotes the total budget allocated to overseas procurements until time t.

The metric will be calculated by the following formula:

$$OPR = \frac{BOP}{ACWP} \times 100 \quad (4.16)$$

The value of this metric is desired to be as low as possible.

S17 - Export License Dependence

Another factor that is important in overseas dependence is the export license dependence. There exist some critical items, which are inevitable for the project, and which require an export license from the government of the supplier's country. Since the items demanded are used in defense field, because of political reasons taking an export license is a long lasting and difficult action. The delays occurred in procurement of the items may lead to significant schedule deviation. Furthermore, requirement of an export license brings a considerable risk of export ban which may give rise to the termination of project. Therefore, it is desired to minimize the dependence on items that require export license.

The percentage of the budget allocated to overseas procurements with export license in the total budget allocated to overseas procurements is decided to be used as the metric to measure this sub-criterion.

BEXP denotes the total budget allocated to overseas procurements with export license until time *t*.

The metric will be calculated by the following formula:

$$EXPD = \frac{BEXP}{BOP} \times 100 \tag{4.17}$$

The value of this metric is desired to be as low as possible.

S18 - Deviation in Overseas Procurement Rate

The comparison among the planned and actual budget allocated to overseas procurements is another criterion that should be taken into account.

BOPP stands for the budget planned to be allocated to overseas procurements.

The following formula gives the ratio of actual and planned overseas procurement rate.

$$OPRD = \left. \frac{BOP}{ACWP} \middle/ \frac{BOPP}{BCWS} \right. \tag{4.18}$$

The value of this ratio is desired to be as low as possible.

C7 - Risk Management

A Risk is any undesirable situation that has a potential of occurrence and that would have a negative consequence on a project.

Risk Management Guide for DoD Acquisition defines Risk as a measure of the potential inability to achieve overall program objectives within defined cost, schedule, and technical constraints.

Risks are inherent to any project, additionally, as a result of the uncertain nature of R&D studies, the projects being executed in TÜBİTAK-SAGE inevitably involves risks.

Risk management involves the actions of identifying and measuring risks, developing and managing the necessary endeavors for handling the risks, and continuous monitoring of these risks.

A single sub-criterion is defined under Risk Management: Risk Handling.

S19 - Risk Handling

Risk handling is the process which includes the techniques and methods to reduce or control the risks.

Risk is measured with two components: (1) the probability/likelihood of occurrence, and (2) the severity of consequence.

In order to measure the magnitude of the identified risks, risk rating is used by taking the product of these two components, where scores are used to measure likelihood and severity.

Risk Score = (Probability/likelihood of occurrence score) x (Severity of consequence score)

Table 4 and Table 5 demonstrate examples of scoring used for probability/likelihood of occurrence and severity of consequence. In TÜBİTAK-SAGE, risk scoring is being performed in the same way. Risks are monitored continuously, risk scores are updated and the identification of new risks is being performed.

Table 4 Scoring of Severity of Consequence of a Risk

Score	Severity of Consequence
5	Catastrophic
4	Critical
3	Major
2	Significant
1	Negligible

Table 5 Scoring of Probability/Likelihood of Occurrence of a Risk

Score	Probability/Likelihood of Occurrence
5	Maximum
4	High
3	Medium
2	Low
1	Minimum

To measure the risk handling performance, the total score of the risks associated in two successive evaluation periods is decided to be compared.

RS_p denotes the sum of the risk scores in evaluation period p, and RS_{p+1} denotes the sum of the risk scores in evaluation period $p+1$.

Risk handling metric will be calculated by the following ratio:

$$RH = \frac{RS_{p+1}}{RS_p} \times 100 \qquad (4.19)$$

The risks that are identified in that evaluation period will be taken account starting from the following evaluation period.

The value of this metric is desired to be as low as possible.

C8 - In-house Quality Audit Results

The quality management system being applied in TÜBİTAK-SAGE intends the continuous improvement of projects by performing the identification of non-conformities occurred in ongoing projects, removal of the non-conformities and avoidance their reoccurrence.

As requirement of the quality management system, the ongoing projects are subjected to internal quality audits in order to identify the non-conformities and take relevant corrective actions.

Besides the audits, a non-conformity can be identified at any phase during the project's life cycle. These non-conformities identified are documented with the necessary corrective actions to be done and monitored continuously.

A single sub-criterion is defined under this criterion, Number of Non-Conformities.

S20 - Number of Non-Conformities

The metric for this sub-criterion is decided to be the total number of ongoing non-conformities in a given evaluation period, NNC. By the term "ongoing" the non-conformities of which the corrective actions has not been completed is intended. These non-conformities may be recently identified in that evaluation period or previously defined and still continuing.

C9 - Satisfaction of the Project Personnel

Satisfaction and motivation of the project personnel are other important criteria in the evaluation of the project performance.

The project personnel are concerned whether an interesting, challenging, and professionally developing experience is provided by the project, whether support is provided for their personal development and whether advantageous conditions and a good working atmosphere exist.

Three sub-criteria are defined under the criterion; Satisfaction of the Project Personnel, Contribution to the Self-Development of the Institute Personnel, Overtime Rate and Supplementary Payment to the Institute Personnel.

S21 - Contribution to the Self-Development of the Institute Personnel

This sub-criterion is decided to be measured by the amount of trainings provided to the Institute personnel. The ratio of the budget allocated to trainings of the Institute personnel to the total project expenditure is defined as the metric for this sub-criterion.

BT denotes the total budget allocated to trainings until time *t*.

The metric, denoted by *TRAIN*, will be calculated by the following formula:

$$TRAIN = \frac{BT}{ACWP} \times 100 \tag{4.20}$$

The value of this metric is desired to be as high as possible.

S22 - Overtime Rate

Number of overtime hours per project personnel is decided to be the metric to measure this sub-criterion.

PT denotes the total number of personnel working in the project in a given evaluation period and *OT* denotes the total number of overtime (in hours) in a given evaluation period.

The metric, denoted by *OTR*, will be calculated by the following formula:

$$OTR = \frac{OT}{PT} \tag{4.21}$$

The value of this metric is desired to be as low as possible.

S23 - Supplementary Payment to the Institute Personnel

Besides the salary given to the personnel at TÜBİTAK-SAGE, additional payments are made both to the Permanent Personnel and Project Personnel from the revenues obtained from the projects.

The magnitude of the projects being executed in TÜBİTAK-SAGE varies significantly; consequently, the contractual budgets of the projects vary also. Therefore comparing the payments made from each project would not be an efficient method. In order to be able to compare the payments made on the same scale, the total revenue of the projects should be taken into account.

PP denotes the total amount of payments made to the Institute personnel from a given project's income until time *t* and *PR* denotes the total revenue of that project up to that date.

The metric will be the ratio of total payment made to the Institute personnel from the project income to the total revenue of the project up to that date. The metric, denoted by S*P*, will be calculated by the following formula:

$$SP = \frac{PP}{PR} \times 100 \qquad (4.22)$$

The value of this metric is desired to be as high as possible.

C10) Technical Performance

The following sub-criteria are defined under the criterion "Technical Performance".

1. Technical Performance Measures
2. Technical Review Results
3. Test Performance
4. Maturity of the Design

S24 - Technical Performance Measures

Technical Performance Measurement (TPM) is the set of measurement activities used to provide insight into progress in the definition and the development of the technical solution and the associated risks and the issues (Gary, R. J. and Jones, 2005).

TPM is used to forecast the values to be achieved through the planned technical program effort, to measure differences between the actual versus planned values and to determine the impact of these differences on system effectiveness (Systems Engineering Management Guide). TPM provides early detection or prediction of technical problems and helps project management in to make better decisions throughout the life cycle to meet the specified requirements and mission needs.

After the determination of the parameters to be monitored (TPM parameters), TPM is implemented by using the following indicators (Systems Engineering Management Guide):

a. Planned Value - The expected value of a parameter at a given point in the development cycle.
b. Demonstrated Value - The value estimated or measured in a particular test or analysis.
c. Specification Requirement - The value or range of values contained in or allocated from a contractual development specification.
d. Current Estimate - The value of a parameter predicted for the end product of the contract.
e. Demonstrated Technical Variance – The difference between the planned value and the demonstrated value of a parameter.
f. Predicted Technical Variance – The difference between the specification requirement and the current estimate of the parameter.

The indicators are illustrated by an example in Figure 6 (Systems Engineering Management Guide).

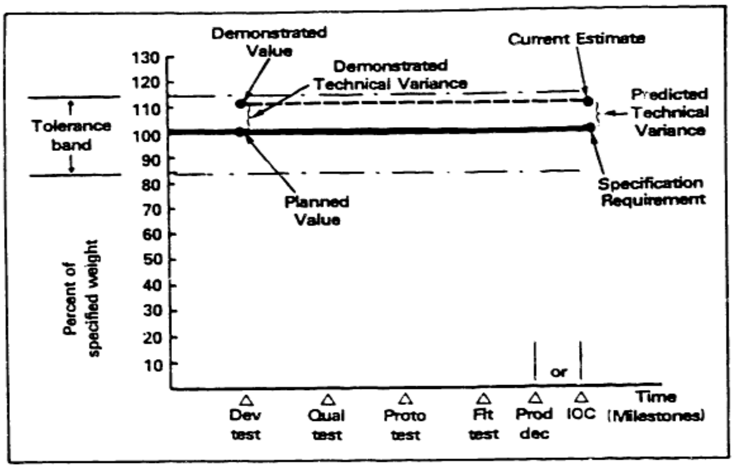

Figure 6 TPM Indicators (Systems Engineering Management Guide)

In the customer-based projects being executed in the institute, TPM parameters are determined by using the requirements defined in the System Requirements Document, a contractual document prepared by the customer. Therefore most of the TPM parameters are customer defined requirements. In addition to these requirements, at the beginning of the Conceptual Design phase, a survey is performed for the similar systems to the system that will be developed by the project personnel, and if encountered in the literature, additional target requirements are set for the project, in order to increase the competitive strength of the developed system. Some of these additional requirements are also defined as TPM parameters. Furthermore, during the progressive stages of the projects, customer may define some additional requirements which are not defined in the System Requirements Document. Some of these requirements are also monitored by defining as TPM parameters.

Demonstrated Technical Variance is decided to be used to measure the technical performance. The percentage of the TPM parameters whose demonstrated values are worse than the planned values in a given evaluation period is decided to be the metric.

NT denotes the total number of TPM parameters and *NTW* denotes the number of TPM parameters whose demonstrated values are worse than the planned values in a given evaluation period. The following ratio is defined:

$$TECHPERF = \frac{NTW}{NT} \times 100 \qquad (4.23)$$

The value of this metric is desired to be as low as possible.

S25 - Technical Review Results

MIL-HDBK-61A defines technical reviews as the series of activities by which the technical progress on a project is assessed relative to its technical or contractual requirements.

Technical Reviews are conducted internally (among Institute personnel) or with the customer at specified transition points among phases. The aim of conducting technical reviews is to observe technical progress, to identify and correct potential problems and to evaluate the technical adequacy of the existing design and the appropriateness of the configuration items and their documentations to the contractual requirements.

Formal technical reviews conducted are as follows with the timing as demonstrated in Figure 7 (Systems Engineering Management Guide, MIL-STD-499A).

System Requirements Review (SRR)

System requirements review is the first major review. It is conducted in the conceptual design phase, after the system level functions and requirements are allocated to lower level system components. This review is generally conducted with the customer. The purpose of the review is to ensure that system requirements have been completely and properly identified and the requirements are achievable. Another purpose is to arrive at a mutual understanding between the customer and the contractor on system requirements.

System Design Review (SDR)

System design review is performed at the end of the conceptual design phase. The system architecture determined in the conceptual design phase is examined during this review. This review is conducted to evaluate the system level design studies and the optimization, traceability, correlation, completeness and the risks associated with the allocated technical requirements.

The successful completion of this review designates that the system level design studies are completed and subsystem or component level studies can be started and gives way to the approval to proceed to preliminary design phase.

Preliminary Design Review (PDR)

Preliminary design review is performed at the end of the preliminary design phase, prior to the start of detailed design phase.

This review is conducted to evaluate the adequacy of top level design efforts and the completeness of the development specifications. The top level configuration items are reviewed. The progress, technical adequacy, associated risks of the selected design approach is evaluated.

The successful completion of this review gives way to the approval to proceed to detailed design phase.

Critical Design Review (CDR)

Critical design review is performed at the end of the detailed design phase. This review is conducted to evaluate the detailed system design and the related documentation. Configuration items are reviewed to verify the compatibility of the design with the requirements and to evaluate the existence and compatibility of the interface. The associated risks are also evaluated.

Critical design review is the last major design review, the successful completion of this review gives way to the approval to proceed to system test and evaluation phase.

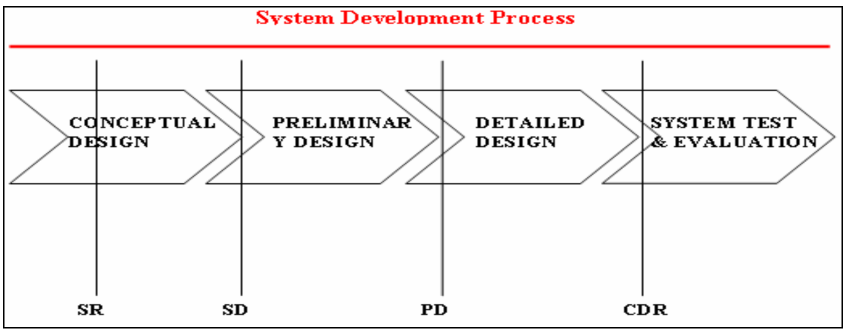

Figure 7 Technical Reviews

The non-conformities identified in the technical reviews are being documented. Technical review results are decided to be evaluated by the number of non-conformities identified per configuration item in a given technical review.

NNCR denotes the total number of non-conformities identified in a technical review in a given evaluation period and *NCIR* denotes the total number of configuration items reviewed in the given technical review.

The following ratio will give the average number of non-conformities per configuration item reviewed.

$$TECHREW = \frac{NNCR}{NCIR} \tag{4.24}$$

The value of this metric is desired to be as low as possible.

S26 - Test Performance

"Test and evaluation" is the process in which a system, subsystem or components are compared against requirements and specifications by testing. Test and evaluation should be conducted throughout the system development life cycle to assess progress of design and performance, to assess and reduce technical risks, to demonstrate that the design meets the specification requirements and to estimate the operational effectiveness and operational suitability of the system. The successful accomplishment of test and evaluation objectives gives way to the approval to proceed from one system development phase to another.

All system elements in the work breakdown structure must receive appropriate test and evaluation.

The test performance sub-criterion will be measured by the ratio of successful tests among all the verification tests performed. The criteria compasses all the verification tests conducted throughout the system development life cycle with or without participation of the customer.

TS denotes the number of successful verification tests until time *t* and *TT* denotes the total number of verification tests performed until time *t*.

The metric, denoted by *TESTPERF*, will be calculated by the following formula:

$$TESTPERF = \frac{TS}{TT} \times 100 \qquad (4.25)$$

The value of this metric is desired to be as high as possible.

S27 - Maturity of the Design

The number of class I engineering changes per configuration item is decided to be the metric to measure this sub-criterion.

The proposed engineering changes for configuration documentations or configuration items are being documented by Engineering Change Proposals. These proposals are submitted to the configuration control board and the proposed engineering changes are performed for the approved proposals.

NEC denotes the total number of class I engineering changes made in a given evaluation period and *NCI* denotes the total number of configuration items.

The following ratio will give the average number of class I engineering changes made per configuration item.

$$ENGC = \frac{NEC}{NCI} \qquad (4.26)$$

The value of this metric is desired to be as low as possible.

C11 - Simplicity of the Design

The following sub-criteria are defined under the criterion "Simplicity of the Design".

1. Commercially off-the-Shelf Item Usage
2. Common Item Usage among Projects
3. Standard Item Usage

S28 - Commercially off-the-Shelf Item Usage

Usage of the COTS items as much as possible is desirable since COTS item usage decreases the time, effort and thus costs considerably.

The metric to measure this sub-criterion is decided to be the ratio of the total cost of COTS items in the BOM to the total cost of all the items in the BOM.

BOMCC denotes the total cost of COTS items in the BOM and *BOMCI* denotes the total cost of items in the BOM. The metric, denoted by *COTSU*, will be calculated by the following formula:

$$COTSU = \frac{BOMCC}{BOMCI} \times 100 \qquad (4.27)$$

The value of this metric is desired to be as high as possible.

S29 - Common Item Usage among Projects

An item developed in a project may be directly used or used after some modification in another project. Usage of common items among projects is desirable since it decreases the time, effort and thus costs considerably.

The metric to measure this sub-criterion is decided to be the ratio of the total cost of common items in the BOM to the total cost of all the items in the BOM.

BOMCCM denotes the total cost of common items in the BOM. The metric, denoted by *CIU*, will be calculated by the following formula:

$$CIU = \frac{BOMCCM}{BOMCI} \times 100 \tag{4.28}$$

The value of this metric is desired to be as high as possible.

S30 - Standard Item Usage

The metric to measure this sub-criterion is decided to be the ratio of the number of unique items in the BOM to the total number of items in the BOM.

BOMU denotes the number of unique items in the BOM and BOMI denotes the total number of items in the BOM. The metric, denoted by *SIU*, will be calculated by the following formula:

$$SIU = \frac{BOMU}{BOMI} \times 100 \tag{4.29}$$

The value of this metric is desired to be as low as possible.

4.4 Scaling of the Sub-Criteria Metrics

The metrics were scaled between zero and one hundred. Detailed explanation on scaling is given below. The metrics and the scaling are summarized in Table 17 in Appendix B.

S1 - The Paraphrased Dissatisfaction of the Customer in Administrative and Technical Subjects throughout the Project

An upper limit is defined for the total number of customer complaints that can be tolerated for each phase. This number varies for each project and each period, depending upon the magnitude and the scope of the projects. When this limit is exceeded, the top management is informed for the necessary corrective actions to be taken.

The upper limit is denoted by NCC_{max}. The ratio of the total number of complaints to this limit number will be used as the metric.

$$CDIS = \frac{NCC}{NCC_{\max}} \times 100 \tag{4.30}$$

The value of this metric is desired to be as low as possible. If, in a phase, the number of complaints comes up to be equal to or higher than the predefined upper limit, the metric will be given a value of one hundred (as the worst case). Contrarily, when there exits no complaints, the metric will take a value of zero. Between these limits the values can be distributed linearly. The formulation is as given below:

$$CDIS = \begin{cases} \dfrac{NCC}{NCC_{\max}} \times 100 & \text{if } NCC \le NCC_{\max} \\ 100 & \text{if } NCC \ge NCC_{\max} \end{cases} \tag{4.31}$$

The projects will be evaluated according to this sub-criterion by taking the average of the scaled values, obtained for each phase, from the start of the project up to the current phase, in which the performance of the project is evaluated.

S2 - The Delays in the Deliveries in Liability of the Institute

An upper limit is defined for the average delay in the delivery of deliverables that can be tolerated. This number varies for each project depending upon the magnitude and the scope of the projects.

The upper limit is denoted by DD_{max}. The ratio of the average delay in delivery of the deliverables to this limit number will be used as the metric.

$$DD = \left(\frac{\sum_{d=1}^{ND} DTD_d \Big/ ND}{DD_{\max}} \right) x100 \qquad (4.32)$$

The value of this metric is desired to be as low as possible. If the average delay in the deliveries is equal to or higher than the upper limit, the metric will be given a value of one hundred (as the worst case). Contrarily, when there exits no delay, the metric will take a value of zero. The value of the metric increases linearly from zero delay to maximum allowable ratio. The formulation is as given below.

$$DD = \begin{cases} \left(\frac{\sum_{d=1}^{ND} DTD_d \Big/ ND}{DD_{\max}} \right) x100 & \text{if } \frac{\sum_{d=1}^{ND} DTD_d}{ND} \leq \mathrm{DD}_{\max} \\ 100 & \text{if } \frac{\sum_{d=1}^{ND} DTD_d}{ND} \geq \mathrm{DD}_{\max} \end{cases} \qquad (4.33)$$

As it was previously mentioned, the value of DD_{max} varies for each project depending upon the magnitude and the scope of the projects. In this study it is decided to be thirty calendar days for each project.

S3 - The Satisfaction of the Customer Regarding the Deliverables

The value of this metric changes linearly in between zero and one hundred, therefore additional scaling efforts are not required.

S4 - Average Response Time to Customer Change Requests

This metric is scaled in between zero and one hundred in order to be in the same scale with the other sub-criteria. The scaling is made as follows:

An upper limit is defined for the realized duration for concluding a customer change request that can be tolerated. In tolerable limits, the realized duration can be at most five times of the expected conclusion duration ($DC_{cr} \leq 5EC_{cr}$). When $DC_{cr} = 5EC_{cr}$, the deviation percent $\left((DC_{cr} - EC_{cr})/EC_{cr}\right)$ becomes 4. Therefore the tolerable upper limit for *ART* is set to 4 (this value is equivalent to the value obtained when all of the customer change requests are concluded within maximum time). The lowest value of *ART* is determined to be 0 (this value is equivalent to the value obtained when all of the customer change requests are concluded on time). Zero will remain the same as the lowest scaled value, if negative values are obtained for *ART*, the metric will be assigned a value of zero (as the best case). For scaling, 4 will be assigned a value of one hundred (as the worst case), and the values in between will take values linearly. The value of this metric is desired to be as low as possible. The formulation is as given below.

$$ART = \begin{cases} 0 & \text{if} \quad \dfrac{\sum_{cr=1}^{NDR}\left(\dfrac{DC_{cr} - EC_{cr}}{EC_{cr}}\right)}{NDC} < 0 \\ \left(\dfrac{\sum_{cr=1}^{NDR}\left(\dfrac{DC_{cr} - EC_{cr}}{EC_{cr}}\right)}{NDC}\right) x25 & \text{if} \quad 0 \leq \dfrac{\sum_{cr=1}^{NDR}\left(\dfrac{DC_{cr} - EC_{cr}}{EC_{cr}}\right)}{NDC} \leq 4 \\ 100 & \text{if} \quad \dfrac{\sum_{cr=1}^{NDR}\left(\dfrac{DC_{cr} - EC_{cr}}{EC_{cr}}\right)}{NDC} \geq 4 \end{cases} \qquad (4.34)$$

S5 - Average Response Time to Additional Customer Requests

This metric is scaled in between zero and one hundred by the same formalization used in metric of S4 - "Average Response Time to Customer Change Requests", as follows.

An upper limit is defined for the realized duration for concluding a customer request that can be tolerated. In tolerable limits, the realized duration can be at most five times of the time limit given by the customer ($DCR_r \leq 5DR_r$). When $DCR_r = 5DR_r$, the deviation percent $\left((DCR_r - DR_r)/DR_r\right)$ becomes 4. Therefore the upper limit for *ARTR* is set to 4 (this value is equivalent to the value obtained when all of the customer requests are concluded within maximum time). The lowest value of *ARTR* is determined to be 0 (this value is equivalent to the value obtained when all of the customer requests are concluded on time). Zero will remain the same as the lowest scaled value, if negative values are obtained for *ARTR*, the metric will be assigned a value of zero (as the best case). For scaling, 4 will be assigned a value of one hundred (as the worst case), and the values in between will take values linearly. The value of this metric is desired to be as low as possible. The formulation is as given below.

$$ARTR = \begin{cases} 0 & \text{if} \quad \dfrac{\sum_{r=1}^{NR}\left(\dfrac{DCR_r - DR_r}{DR_r}\right)}{NR} < 0 \\ \left(\dfrac{\sum_{r=1}^{NR}\left(\dfrac{DCR_r - DR_r}{DR_r}\right)}{NR}\right) x25 & \text{if} \quad 0 \leq \dfrac{\sum_{r=1}^{NR}\left(\dfrac{DCR_r - DR_r}{DR_r}\right)}{NR} \leq 4 \\ 100 & \text{if} \quad \dfrac{\sum_{r=1}^{NR}\left(\dfrac{DCR_r - DR_r}{DR_r}\right)}{NR} \geq 4 \end{cases} \quad (4.35)$$

S6 - Schedule Deviation

This metric is scaled between zero and one hundred, by using the following ratio.

$$SD = \frac{PPWC - APWC}{PPWC} \times 100 \tag{4.36}$$

If the actual percentage of work completed is less than the planned percentage that should have been completed (i.e. the progress is behind the schedule), the metric will take a positive value in between zero and one hundred. If the actual percentage of work completed is equal to or greater than the planned percentage (i.e. the progress is on time or ahead of the schedule), the metric will take a value of zero. The value of this metric is desired to be as low as possible. The formulation is as given below.

$$SD = \begin{cases} \frac{PPWC - APWC}{PPWC} \times 100 & \text{if } A\text{PWC} \leq PPWC \\ 0 & \text{if } A\text{PWC} \geq PPWC \end{cases} \tag{4.37}$$

In most of the projects, the schedule plans are prepared separately for each phase, and it is mandatory to prepare the plans instantly at the beginning of each phase. However, in some projects, preparation of the schedule plans takes a very long time and therefore, there might be some projects for which the schedule plan has not been prepared yet, at the time that performance evaluation is made. In that case, the PPWC and APWC values can not be obtained. The absence of the schedule plan is a weakness for a project, therefore in cases that the schedule plan has not been prepared yet, this metric will take a value of one hundred, representing the worst case.

S7 - Milestone Completion

An upper limit is defined for the average delay in the completion times of the milestones that can be tolerated. This number varies for each project depending upon the magnitude and the scope of the projects.

The upper limit is denoted by MsC_{max}. The ratio of the average delay in the completion times of the milestones to this limit number will be used as the metric.

$$MsC = \left(\frac{\left(\sum_{m=1}^{NMs} MsD_m \middle/ NMs \right)}{MsC_{\max}} \right) x100 \tag{4.38}$$

The value of this metric is desired to be as low as possible. If the average delay in completion times of the milestones is equal to or higher than the upper limit, the metric will be given a value of one hundred (as the worst case). Contrarily, if there exits no delay, the metric will take a value of zero. The value of the metric increases linearly from zero delay to maximum allowable ratio. The formulation is as given below.

$$MsC = \begin{cases} \left(\dfrac{\left(\sum_{m=1}^{NMs} MsD_m \middle/ NMs \right)}{MsC_{\max}} \right) x100 & \text{if} \quad \dfrac{\sum_{m=1}^{NMs} MsD_m}{NMs} \leq MsC_{\max} \\ 100 & \text{if} \quad \dfrac{\sum_{m=1}^{NMs} MsD_m}{NMs} \geq MsC_{\max} \end{cases} \tag{4.39}$$

As it was previously mentioned, the value of MsC_{max} varies for each project depending upon the magnitude and the scope of the projects. In this study it is decided to be thirty calendar days for each project.

S8 - Deviation in Project Expenditure

The tolerable upper limit for the project expenditure is set to be at most twice of the planned expenditure ($ACWP \leq 2BCWS$). When *ACWP* is equal to this limit value, this metric will be equal to one hundred. It will also taken to be equal to be to one hundred (as the worst case) when *ACWP* exceeds this limit. The formulation is as given below.

$$PED = \begin{cases} \left| \dfrac{ACWP - BCWS}{BCWS} \times 100 \right| & \text{if } ACWP \leq 2BCWS \\ 100 & \text{if } ACWP \geq 2BCWS \end{cases} \qquad (4.40)$$

It is mandatory to prepare the budget plans instantly at the beginning of the projects. However, in some projects, preparation of these plans takes a very long time and therefore, there might be some projects for which the budget plan has not been prepared yet, at the time that performance evaluation is made. In that case, the *BCWS* value can not be obtained. The absence of the budget plan is a weakness for a project, therefore in cases that the budget plan has not been prepared yet; this metric will take a value of one hundred, representing the worst case.

S9 - Deviation in Project Personnel Cost

If the actual project personnel cost is less than the planned value, a negative value is obtained. This is a desirable case, since the remaining financial resources can be allocated for other expenditures and the metric will be given a value of zero in that case.

Contrarily, if the actual project personnel cost is higher than the planned value, a positive value is obtained. The tolerable upper limit for the actual project personnel cost is set to be at most twice of the planned value ($PPCA \leq 2PPCP$). If the actual project personnel cost is equal to or higher than this limit value, the value of this metric will be equal to one hundred (as the worst case). The formulation is as given below.

$$PPCD = \begin{cases} 0 & \text{if } PPCA \le PPCP \\ \dfrac{PPCA - PPCP}{PPCP} \times 100 & \text{if } PPCP \le PPCA \le 2PPCP \\ 100 & \text{if } PPCA \ge 2PPCP \end{cases} \tag{4.41}$$

S10 - Deviation in Manpower

The tolerable upper limit for the actual manpower is set to be at most twice of the planned value ($MPA \le 2MPP$). If the actual manpower is equal to or higher than this limit value, the value of this metric will be equal to one hundred (as the worst case). The formulation is as given below.

$$MPD = \begin{cases} \left| \dfrac{MPA - MPP}{MPP} \times 100 \right| & \text{if } MPA \le 2MPP \\ 100 & \text{if } MPA \ge 2MPP \end{cases} \tag{4.42}$$

As it was previously explained, the manpower allocated to the projects is planned within the project schedule plans and there might be some projects in which the schedule plan has not been prepared yet, at the time that performance evaluation is made. In that case, the *MPP* value can not be obtained. The absence of the manpower plan is a weakness for a project, therefore in cases that the planned manpower does not exist; this metric will take a value of one hundred, representing the worst case.

S11 - Turnover Rate

The value of this metric is desired to be as low as possible. If the sum of *PCI* and *PCD* is equal to or exceeds *PCT*, the metric will be given a value of one hundred (as the worst case). The formulation is as given below.

$$TOR = \begin{cases} \left(\dfrac{PCI + PCD}{PCT}\right) \times 100 & \text{if } (PCI + PCD) \leq PCT \\ 100 & \text{if } (PCI + PCD) \geq PCT \end{cases} \tag{4.43}$$

The projects will be evaluated according to this sub-criterion by taking the average of the scaled values, obtained for each phase, from the start of the project up to the current phase, in which the performance of the project is evaluated.

S12 - Quality of the Subcontractors

The value of this metric changes linearly in between zero and one hundred, therefore additional scaling efforts are not required.

S13 - Subcontractor Review Results

The value of this metric changes linearly in between zero and one hundred, therefore additional scaling efforts are not required.

S14 - Subcontractor Quality Audit Results

An upper limit is defined for the average number of non-conformities per subcontractor that can be tolerated for each period. This number varies for each project depending upon the magnitude and the scope of the projects. When this limit is exceeded, the project manager is informed for the necessary corrective actions to be taken.

The upper limit is denoted by $NNCS_{max}$. The ratio of the average number of non-conformities to this limit number will be used as the metric.

$$SQR = \frac{\left(\dfrac{\sum_{s=1}^{NS} \sum_{q} NNCS_{sq}}{NS} \right)}{NNCS_{\max}} \times 100 \qquad (4.44)$$

The value of this metric is desired to be as low as possible. When the average number of non-conformities per subcontractor will be equal to or exceeds the upper limit, the metric will be given a value of one hundred (as the worst case). The formulation is as given below.

$$SQR = \begin{cases} \dfrac{\left(\dfrac{\sum_{s=1}^{NS} \sum_{q} NNCS_{sq}}{NS} \right)}{NNCS_{\max}} \times 100 & \text{if } \dfrac{\sum_{s=1}^{NS} \sum_{q} NNCS_{sq}}{NS} \le NNCS_{\max} \\ 100 & \text{if } \dfrac{\sum_{s=1}^{NS} \sum_{q} NNCS_{sq}}{NS} \ge NNCS_{\max} \end{cases} \qquad (4.45)$$

S15 - Acceptance Satisfaction of the Supplied Items

The value of this metric changes linearly in between zero and one hundred, therefore additional scaling efforts are not required.

S16 - Overseas Procurement Rate

The value of this metric changes linearly in between zero and one hundred, therefore additional scaling efforts are not required.

For some projects, it may be the case that no expenditure has been made until the time that performance evaluation is made and both *BOP* and *ACWP* become zero. In that case, since there is no overseas procurement yet, it can be concluded that there is no overseas dependence for the time being and the metric will take a value of zero, representing the best case. The formulation is as given below.

$$OPR = \begin{cases} \dfrac{BOP}{ACWP} \times 100 & \text{if } ACWP > 0 \\ 0 & \text{if } ACWP = 0 \end{cases} \tag{4.46}$$

S17 - Export License Dependence

The value of this metric changes linearly in between zero and one hundred, therefore additional scaling efforts are not required.

For some projects, it may be the case that no expenditure has been made or no overseas procurement has been performed until the time that performance evaluation is made, and both *BEXP* and *BOP* become zero. In that case, since there is no overseas procurement yet, it can be concluded that there is no export license dependence for the time being and the metric will take a value of zero, representing the best case. The formulation is as given below.

$$EXPD = \begin{cases} \dfrac{BEXP}{BOP} \times 100 & \text{if } BOP > 0 \\ 0 & \text{if } BOP = 0 \end{cases} \tag{4.47}$$

S18 - Deviation in Overseas Procurement Rate

When the project's overseas procurement ratio is lower than the planned value, the ratio defined for OPRD will be less than one. When the overseas procurement ratio is exactly the same as expected, the ratio will be one and when the planned value is exceeded, a number greater than one will be obtained. The tolerable upper limit for the deviation is that, the actual ratio can be at most twice of the planned ratio $\left(\frac{BOP}{ACWP} \leq 2\frac{BOPP}{BCWS}\right)$. When the overseas procurement ratio will be equal to or exceeds this limit, the metric will be given a value of one hundred (as the worst case). The value of this metric is desired to be as low as possible.

For some projects, it may be the case that no expenditure was planned for overseas procurements and no expenditure has been made for overseas procurements, and both the numerator and the denominator of the metric become zero. In that case, since there is no deviation in the overseas procurement rate, the metric will take a value of zero, representing the best case.

Contrarily, for some projects, it may be the case that no expenditure was planned for overseas procurements and some expenditure has been made for overseas procurements, and the denominator of the metric becomes zero. In that case, since there is an unplanned overseas dependence, the metric will take a value of one hundred, representing the worst case. The formulation is as given below.

$$OPRD = \begin{cases} \left(\dfrac{BOP}{ACWP} \Big/ 2 \times \dfrac{BOPP}{BCWS} \right) \times 100 & \text{if } \dfrac{BOP}{ACWP} \leq 2 \dfrac{BOPP}{BCWS} \\ 100 & \text{if } \dfrac{BOP}{ACWP} \geq 2 \dfrac{BOPP}{BCWS} \\ 100 & \text{if } BOPP = 0 \text{ and } BOP > 0 \\ 0 & \text{if } BOPP = 0 \text{ and } BOP = 0 \end{cases} \quad (4.48)$$

S19 - Risk Handling

When the total risk score is increased from one evaluation period to another (which is an undesirable situation), the risk handling metric will be given a value of one hundred (as the worst case). Similarly, when the total risk score remains the same from one evaluation period to another, the metric will also be given a value of one hundred since it is also an undesirable situation which reflects that risks are not being managed effectively. This metric takes a value in between zero (reflecting that the risk score is zero at that period) and one hundred. The formulation is as given below.

$$RH = \begin{cases} \dfrac{RS_{p+1}}{RS_p} \times 100 & \text{if } RS_{p+1} \leq RS_p \\ 100 & \text{if } RS_{p+1} \geq RS_p \end{cases} \quad (4.49)$$

S20 - Number of Non-Conformities

An upper limit is defined for the total number of non-conformities that can be tolerated for each period. This number varies for each project depending upon the magnitude and the scope of the projects. When this limit is exceeded, the top management is informed for the necessary corrective actions to be taken.

The upper limit is denoted by NNC_{max}. The ratio of the total number of non-conformities to this limit number will be used as the metric.

$$NNCQ = \frac{NNC}{NNC_{\max}} \times 100 \tag{4.50}$$

The value of this metric is desired to be as low as possible. When the number of non-conformities in an evaluation period will be equal to or exceeds the upper limit for the number of non-conformities, the metric will be given a value of one hundred (as the worst case). Contrarily, when there exits no non-conformities, the metric will take a value of zero. The value of the metric increases linearly from zero non-conformity to maximum allowable non-conformities. The formulation is as given below.

$$NCCQ = \begin{cases} \dfrac{NNC}{NNC_{\max}} \times 100 & \text{if } NNC \leq NNC_{\max} \\ 100 & \text{if } NNC \geq NNC_{\max} \end{cases} \tag{4.51}$$

The projects will be evaluated according to this sub-criterion by taking the average of the scaled values, obtained for each phase, from the start of the project up to the current phase, in which the performance of the project is evaluated.

As it was previously mentioned, the value of NNC_{max} varies for each project depending upon the magnitude and the scope of the projects. In this study it is decided to be two for each project.

S21 - Contribution to the Self-Development of the Institute Personnel

The optimum value for the budget allocated to trainings of the Institute personnel from a project's total expenditure is assumed to be 10%. This assumption is made based on the past experiences and the past data. Therefore, this metric takes values between zero and ten, and is scaled between zero and one hundred by using the following formula.

$$TRAIN = 10 \times \left(\frac{BT}{ACWP} \times 100 \right) \tag{4.52}$$

If, for a project, the optimum value is exceeded, the metric will take a value of one hundred (as the best case).

For some projects, it may be the case that no expenditure has been made until the time that performance evaluation is made, and both BT and $ACWP$ become zero. In that case, since no training has been provided from that project for the time being, the metric will take a value of zero, representing the worst case. The formulation for the metric is given below.

$$TRAIN = \begin{cases} 10 \times \left(\frac{BT}{ACWP} \times 100 \right) & \text{if } \left(\frac{BT}{ACWP} \times 100 \right) \leq 10 \\ 100 & \text{if } \left(\frac{BT}{ACWP} \times 100 \right) \geq 10 \\ 0 & \text{if } ACWP = 0 \end{cases} \tag{4.53}$$

S22 - Overtime Rate

The upper limit for the number of overtime hours per personnel is assumed to be 10 hours per month which is approximately 45% of the maximum allowable limit defined in labour law. The upper limit will be defined according to the length of the evaluation period. When the number of overtime hours per project personnel is greater than or equal to this limit value, this metric will be equal to one hundred (as the worst case). The minimum value will be zero and the values in between will be linearly changed.

l denotes the length of the period (in months) that project's performance evaluation is made. This metric is formulated as given below.

$$OTR = \begin{cases} \dfrac{\left(\dfrac{OT}{PT}\right)}{10 \times l} \times 100 & \text{if } \dfrac{OT}{PT} \leq 10 \times l \\ \\ 100 & \text{if } \dfrac{OT}{PT} \geq 10 \times l \end{cases} \tag{4.54}$$

The projects will be evaluated according to this sub-criterion by taking the average of the scaled values, obtained for each phase, from the start of the project up to the current phase, in which the performance of the project is evaluated.

S23 - Supplementary Payment to the Institute Personnel

The optimum value for the total amount of payments made to the Institute personnel from a project's income is assumed to be 4% of the project's income. This assumption is made based on the past experiences and the past data. Therefore, this metric takes values between zero and four, and is scaled between zero and one hundred by the following formula.

$$SP = 25 \times \left(\frac{PP}{PR} \times 100 \right) \qquad (4.55)$$

If, for a project, the optimum value is exceeded, the metric will take a value of one hundred (as the best case). The formulation for the metric is given below.

$$SP = \begin{cases} 25 \times \left(\dfrac{PP}{PR} \times 100 \right) & \text{if } \left(\dfrac{PP}{PR} \times 100 \right) \le 4 \\ 100 & \text{if } \left(\dfrac{PP}{PR} \times 100 \right) \ge 4 \end{cases} \qquad (4.56)$$

S24 - Technical Performance Measures

The value of this metric changes linearly in between zero and one hundred, therefore additional scaling efforts are not required.

S25 - Technical Review Results

An upper limit is defined for the average number of non-conformities per configuration item, reviewed in the technical reviews like SRR, PDR, CDR, etc., that can be tolerated for each period. This number varies for each project depending upon the magnitude and the scope of the projects. If this limit is exceeded, the project manager is informed for the necessary corrective actions to be taken.

The upper limit is defined by TNC_{max}. The ratio of the average number of non-conformities per configuration item reviewed to this limit number will be used as the metric.

$$TECHREW = \left(\frac{\frac{NNCR}{NCIR}}{TNC_{\max}} \right) \times 100 \qquad (4.57)$$

The value of this metric is desired to be as low as possible. If the ratio of the average number of non-conformities per configuration item reviewed in an evaluation period is greater than or equal to the upper limit, the metric will be given a value of one hundred (as the worst case). Contrarily, if there exits no non-conformities, the metric will take a value of zero. The value of the metric increases linearly from zero non-conformity to the upper limit. The formulation is as given below.

$$TECHREW = \begin{cases} \left(\dfrac{\dfrac{NNCR}{NCIR}}{TNC_{\max}} \right) \times 100 & \text{if } \dfrac{NNCR}{NCIR} \leq TNC_{\max} \\ 100 & \text{if } \dfrac{NNCR}{NCIR} \geq TNC_{\max} \end{cases} \tag{4.58}$$

The projects will be evaluated according to this sub-criterion by taking the average of the scaled values, obtained for each phase, from the start of the project up to the current phase, in which the performance of the project is evaluated.

As it was previously mentioned, the value of TNC_{max} varies for each project depending upon the magnitude and the scope of the projects. In this study it is decided to be fifteen for each project.

S26 - Test Performance

The value of this metric changes linearly in between zero and one hundred, therefore additional scaling efforts are not required.

S27 - Maturity of the Design

An upper limit is defined for the average number of class I engineering changes made per configuration item that can be tolerated for each period. This number varies for each project depending upon the magnitude and the scope of the projects. If this limit is exceeded, the project manager is informed for the necessary corrective actions to be taken.

The upper limit is denoted by $ENGC_{max}$. The ratio of the average number of class I engineering changes made per configuration item to this limit number will be used as the metric.

$$ENGC = \left(\frac{\frac{NEC}{NCI}}{ENGC_{\max}} \right) \times 100 \tag{4.59}$$

The value of this metric is desired to be as low as possible. If the ratio of the average number of class I engineering changes made per configuration item in an evaluation period is greater than or equal to the upper limit, the metric will be given a value of one hundred (as the worst case). Contrarily, if there exits no class I engineering changes, the metric will take a value of zero. The value of the metric increases linearly from zero class I engineering change to the upper limit. The formulation is as given below.

$$ENGC = \begin{cases} \left(\frac{\frac{NEC}{NCI}}{ENGC_{\max}} \right) \times 100 & \text{if } \frac{NEC}{NCI} \leq ENGC_{\max} \\ 100 & \text{if } \frac{NEC}{NCI} \geq ENGC_{\max} \end{cases} \tag{4.60}$$

The projects will be evaluated according to this sub-criterion by taking the average of the scaled values, obtained for each phase, from the start of the project up to the current phase, in which the performance of the project is evaluated.

As it was previously mentioned, the value of $ENGC_{max}$ varies for each project depending upon the magnitude and the scope of the projects. In this study it is decided to be 0.25 for each project.

S28 - Commercially off-the-Shelf Item Usage

There will be a targeted value for the ratio of the total cost of COTS items in the BOM to the total cost of all the items in the BOM, representing the best case. This value, denoted by $COTSU_{max}$, varies for each project depending upon the developed system in the projects. This value will be determined at the initial phase of the projects, during the costing process. The worst case for his metric is having zero COTS item. Therefore, the value of this metric varies in between 0 and $COTSU_{max}$, $COTSU_{max}$ will be given a value of one hundred and 0 will be given a value of zero. The values in between will change linearly and this metric is scaled between zero and one hundred by the following formula.

$$COTSU = \frac{\frac{BOMCC}{BOMCI}}{COTSU_{\max}} \times 100 \tag{4.61}$$

If, for a project, the targeted value is exceeded, the metric will take a value of one hundred (as the best case). The formulation for the metric is given below.

$$COTSU = \begin{cases} \left(\frac{\frac{BOMCC}{BOMCI}}{COTSU_{\max}} \right) \text{x}100 & \text{if } \frac{BOMCC}{BOMCI} \leq COTSU_{\max} \\ 100 & \text{if } \frac{BOMCC}{BOMCI} \geq COTSU_{\max} \end{cases} \tag{4.62}$$

S29 - Common Item Usage among Projects

There will be a targeted value for the ratio of the total cost of common items in the BOM to the total cost of all the items in the BOM, representing the best case. This value, denoted by CIU_{max}, varies for each project depending upon the developed system in the projects. This value will be determined at the initial phase of the projects, during the costing process. The worst case for his metric is having zero common items. Therefore, the value of this metric varies in between 0 and CIU_{max}, CIU_{max} will be given a value of one hundred and 0 will be given a value of zero. The values in between will change linearly and this metric is scaled between zero and one hundred by the following formula.

$$CIU = \frac{\frac{BOMCCM}{BOMCI}}{CIU_{\max}} \times 100 \tag{4.63}$$

If, for a project, the targeted value is exceeded, the metric will take a value of one hundred (as the best case). The formulation for the metric is given below.

$$CIU = \begin{cases} \left(\dfrac{\frac{BOMCCM}{BOMCI}}{CIU_{\max}} \right) x100 & \text{if } \dfrac{BOMCCM}{BOMCI} \leq CIU_{\max} \\ \\ 100 & \text{if } \dfrac{BOMCCM}{BOMCI} \geq CIU_{\max} \end{cases} \tag{4.64}$$

S30 - Standard Item Usage

There will be a targeted range for the ratio of the ratio of the number of unique items in the BOM to the total number of items in the BOM, representing the worst and best cases. These values, denoted by SIU_{min} and SIU_{max}, vary for each project depending upon the developed system in the projects. These values will be determined at the initial phase of the projects, during the costing process. Therefore, the value of this metric varies in between SIU_{min} and SIU_{max}. SIU_{min}, being the best case, will be given a value of zero, and SIU_{max} being the worst case, will be given a value of one hundred. The values in between will change linearly and this metric is scaled between zero and one hundred by the following formula.

$$SIU = \frac{100}{SIU_{\max} - SIU_{\min}}\left(\frac{BOMU}{BOMI} - SIU_{\min}\right) \tag{4.65}$$

If, for a project, the ratio is below SIU_{min}, the metric will take a value of zero (as the best case). Similarly, if the ratio is above SIU_{max}, the metric will take a value of one hundred (as the worst case).The formulation for the metric is given below.

$$SIU = \begin{cases} 100 & \text{if } \dfrac{BOMU}{BOMI} \geq SIU_{\max} \\ \dfrac{100}{SIU_{\max} - SIU_{\min}}\left(\dfrac{BOMU}{BOMI} - SIU_{\min}\right) & \text{if } SIU_{\min} \leq \dfrac{BOMU}{BOMI} \leq SIU_{\max} \\ 0 & \text{if } \dfrac{BOMU}{BOMI} \leq SIU_{\min} \end{cases} \tag{4.66}$$

4.5 Interdependencies among the Criteria and the Sub-Criteria

S1 - The Paraphrased Dissatisfaction of the Customer in Administrative and Technical Subjects throughout the Project

This sub-criterion depends on the following sub-criteria:

S5 - Average Response Time to Additional Customer Requests: When these requests are not completed on time, the customer would be dissatisfied.

S7 - Milestone Completion: Existence of uncompleted milestones makes the customer unsatisfied.

S18 - Deviation in Overseas Procurement Rate: The overseas dependence is desired to be kept as low as possible in Turkish defense industry. In most of the projects, the items that would be purchased from other countries and the budget allocated to overseas procurements is presented to the customer for approval at the beginning of the project. Customers generally desire to keep the overseas procurement rate as low as possible and therefore they become unsatisfied if this budget is exceeded.

S26 - Test Performance: Any failure that would occur during the verification tests performed with participation of the customer, would give rise to mistrust of the customer to the performing organization. Conversely, successfully completed tests would increase the confidence of he customer.

Note that this sub-criterion does not have any dependency on S12 - “Quality of the Subcontractors”. In most of the projects, the customer does not pay attention to the subcontractors of the performing organization. Therefore, no dependency is defined among those two sub-criteria.

S4 - Average Response Time to Customer Change Requests

This sub-criterion depends on S3 - “The Satisfaction of the Customer Regarding the Deliveries”, since the conclusion time of a change request would reflect the seniority of the change request which also reflects the satisfaction of the customer regarding the related deliverable

S6 - Schedule Deviation and S7 - Milestone Completion

These sub-criteria both depend on the following sub-criteria:

S2 - The Delays in the Deliveries in Liability of the Institute: The delivery dates are defined as milestones in project plans and late deliveries would automatically cause delay in project schedule.

S12 - Quality of the Subcontractors: The quality of the subcontractors directly affects the quality and the delivery dates of the products or services supplied. The delay in deliveries of the supplied items from the subcontractors may cause delay in the schedule plan and also may cause miscompletion of some milestones.

S15 - Acceptance Satisfaction of the Supplied Items: The unacceptable items and the delay in delivery milestones because of the corrections may cause delay in the schedule plan and also miscompletion of some milestones.

S17 - Export License Dependence: The delays occurred in procurement of the items because of the export licenses may cause delay in the schedule plan and also miscompletion of some milestones.

S19 - Risk Handling: If risk management can not be applied in appropriate manner and risk handling can not be performed, the risks that can not be avoided may cause delay in the schedule plan and also miscompletion of some milestones.

S26 - Test Performance: The unplanned repetitions of the unsuccessful tests may cause delay in the schedule plan and also miscompletion of some milestones.

S27 - Maturity of the Design: If the design can not reach to a specific maturity level, repetitive revisions and the corresponding efforts required for designs, analyses, productions, tests and documentation may cause delay in the schedule plan and also miscompletion of some milestones.

S6 – “Schedule Deviation” depends on S7 – “Milestone Completion”, since uncompleted milestones would automatically cause delay in project schedule.

Note that no dependency is defined for these two sub-criteria on S28 - "Commercially off-the-Shelf Item Usage" and S29 - "Common Item Usage among Projects", since COTS items and common items that would be used are assumed to be planned at the beginning of the planning periods.

S8 - Deviation in Project Expenditure

This sub-criterion depends on the following sub-criteria:

S19 - Risk Handling: If risk management can not be applied in appropriate manner and risk handling can not be performed, the risks that would not be avoided may cause unplanned expenditures.

S26 - Test Performance: The unplanned repetitions of the unsuccessful tests may cause unplanned expenditures.

S27 - Maturity of the Design: If the design can not reach to a specific maturity level, repetitive revisions and the corresponding productions and tests may cause unplanned expenditures.

Note that no dependency was defined for this sub-criterion on S28 - "Commercially off-the-Shelf Item Usage" and S29 - "Common Item Usage among Projects", since COTS items and common items that would be used are assumed to be planned at the beginning of the planning periods.

S9 - Deviation in Project Personnel Cost

This sub-criterion depends on the following sub-criteria:

S7 - Milestone Completion: The delay in the achievement of the milestones might result in the delay of the successful completion of a project. In this case, the Project Personnel has to be financed for a longer period than expected, using the budget of the project.

S8 - Deviation in Project Expenditure: If the expenditures in a project occur higher than the budgeted value, Project Personnel cost may be rearranged and lowered by financing less personnel from the project in order to balance the project's overall budget.

Note that this sub-criterion does not have any dependency on S22 - "Overtime Rate", since no extra payment is made for overtime.

S10 - Deviation in Manpower

This sub-criterion depends on the following sub-criteria:

S7 - Milestone Completion: The miscompletion of some milestones may lead to a requirement for overtime and therefore may cause the actual manpower be higher than the planned manpower.

S11 - Turnover Rate: The unplanned departure or inclusion of personnel would cause a deviation from the planned manpower.

S22 - Overtime Rate: It is assumed that overtime is not included in preparation of project plans. Unplanned overtime may cause a deviation from the planned manpower.

S26 - Test Performance: The unplanned repetitions of tests due to the unsuccessful ones may cause a deviation from the planned manpower.

S11 - Turnover Rate

This sub-criterion depends on the sub-criteria under the criterion C9- "Satisfaction of the Project Personnel", since the unsatisfied personnel may depart from the project or even quit from the Institute.

S12 - Quality of the Subcontractors

This sub-criterion depends on the sub-criteria S14 - “Subcontractor Quality Audit Results” and S15 - “Acceptance Satisfaction of the Supplied Items”, since the outputs of these two sub-criteria would be an input for the evaluation of the subcontractors.

S17 - Export License Dependence

This sub-criterion depends on S16 - “Overseas Procurement Rate”, since when the number of items supplied by overseas procurements increases, the export license dependence may correspondingly increase.

S18 - Deviation in Overseas Procurement Rate

This sub-criterion depends on S16 - “Overseas Procurement Rate”, since when there exits unplanned or not adequately budgeted overseas procurements, both Overseas Procurement Rate and Deviation in Overseas Procurement Rate would increase.

S19 - Risk Handling

This sub-criterion depends on the following sub-criteria:

S6 - “Schedule Deviation” and S7 - “Milestone Completion”: It is assumed that risks related to schedule management were defined. Scores of these risks would depend on the probability/likelihood of occurrence of schedule deviation or milestone miscompletion.

S8 - “Deviation in Project Expenditure” and S9 - “Deviation in Project Personnel Cost”: It is assumed that risks related to cost management were defined. Scores of these risks would depend on the probability/likelihood of occurrence of cost deviations.

S11 - Turnover Rate: It is assumed that risks related to departure of critical personnel were defined. Scores of these risks would depend on the probability/likelihood of occurrence of these departures.

S24 - “Technical Performance Measures” and S26 - “Test Performance”: It is assumed that risks related to unreached values of the technical performance measures and having unsuccessful tests were defined. Scores of these risks would depend on the probability/likelihood of occurrence of these events.

S22 - Overtime Rate

This sub-criterion depends on the following sub-criteria:

S7 - Milestone Completion: The miscompletion of some milestones may lead to a requirement for overtime.

S10 - Deviation in Manpower: The lack of the required manpower may lead to delays in some of the project tasks, which would also cause deviation in manpower. In such cases, overtime may be required for timely completion of project tasks.

S26 - Test Performance: Overtime may be required for the unplanned repetitions due to unsuccessful tests.

S23 - Supplementary Payment to the Institute Personnel

This sub-criterion depends on the sub-criteria S8 - “Deviation in Project Expenditure” and S9 - “Deviation in Project Personnel Cost”, since when the expenditures or personnel cost in a project occur higher than the budgeted values, this supplementary payment may be rearranged and lowered in order to balance the project’s overall budget. Adversely, if the expenditures or personnel cost occur lower than the budgeted values, this supplementary payment may be increased.

S24 - Technical Performance Measures

This sub-criterion depends on S26 - "Test Performance", since the unreached values of the technical performance measures are verified by the tests performed.

S27 - Maturity of the Design

This sub-criterion depends on S26 - "Test Performance", since the unsuccessful tests would lead to design changes.

4.6 Missing Data in the Sub-Criteria Values

Because of the absence of retrospective data, there may occur some missing values in some projects for some of the sub-criteria. Even if all the required data had been recorded systematically, missing values may exist. Missing values would occur not only because of the absence of records, but also because of the status of the projects at the time that performance evaluation is made. The sub-criteria and the situations in which missing data may take place because of the status of the projects is explained below.

S2 - The Delays in the Deliveries in Liability of the Institute

There may have occur some projects in which no deliverable has been submitted to the customer until the time that performance evaluation is made. Most of the projects have deliverables like Project Management Plan or Quality Assurance Plan in their first one or two months, but there are some projects in which there is not any delivery until the end of the Conceptual Design phase.

S3 - The Satisfaction of the Customer Regarding the Deliverables

Because of the same reason mentioned above, missing data may exist for the projects in which no deliverable has been submitted until the time that performance evaluation is made.

Furthermore, a project may be in such a situation that, some deliverables have been submitted, but they are under investigation of the customer and no response has been obtained at the time that performance evaluation is made.

S4 - Average Response Time to Customer Change Requests

In case of the two situations that may take place for S2, missing data may exist for this sub-criterion similarly. Also, for the situation in which all the deliverables submitted until that time have been accepted by the customer without any change request, missing data would occur.

S5 - Average Response Time to Additional Customer Requests

For some projects, it may be the case, that no additional requests have been submitted by the customer until the time that performance evaluation is made, resulting in missing data.

S7 - Milestone Completion

If no milestone is reached for a particular project until the time that performance evaluation is made, then this results in missing data.

S9 - Deviation in Project Personnel Cost

In some of the projects only Permanent Personnel are working and no Project Personnel are financed. Also, there might be some projects, in which Project Personnel is planned to be recruited after the performance evaluation period.

Furthermore, some of the projects are of cost-plus-fixed benefit type and are being financed by TÜBİTAK. In that type of projects, Project Personnel are also financed by TÜBİTAK and the sub-criterion is not applicable.

S12 - Quality of the Subcontractors

There might be some projects without any subcontractor, or the existing subcontractors have not been graded until the time that performance evaluation is made, resulting in missing data.

S13 - Subcontractor Review Results

There might be some projects without any subcontractor, or no review has been conducted until the time that performance evaluation is made.

S14 - Subcontractor Quality Audit Results

There might be some projects without any subcontractor, or no quality audit has been conducted until the time that performance evaluation is made.

S15 - Acceptance Satisfaction of the Supplied Items

There might be some projects without any subcontractor, or no item has been supplied from the existing subcontractors until the time that performance evaluation is made.

For all of the sub-criterion related to subcontractor management, note that especially, in the early stages of projects, no subcontractor might be required. There might even be some projects (especially software projects or test and evaluation projects) in which no subcontractor is required throughout the entire project duration.

S19 - Risk Handling

Risk management is chosen not to be applied in some projects. Application of risk management in a given project depends on the top management's decision. For these projects, no data would exist for this sub-criterion.

S23 - Supplementary Payment to the Institute Personnel

For any project, if there does not exist any revenue until the time that performance evaluation is made, missing data will occur.

Furthermore, some of the projects (cost-plus-fixed profit type) are being financed by TÜBİTAK. There does not exist any revenue in that type of projects, the unspent money from the project budget is returned back to TÜBİTAK, therefore this sub-criterion is not applicable for that type of projects.

S24 - Technical Performance Measures

Technical performance measurement is chosen not to be applied in some projects. Application of technical performance measurement in a given project depends on the top management's decision. For those projects, no data would exist for this sub-criterion. Furthermore, technical performance measurement starts to be applied after some time from the initiation of a project, especially after the Conceptual Design phase.

S25 - Technical Review Results

There might be some projects in which no formal technical review has been conducted until the time that performance evaluation is made, resulting in missing data.

S26 - Test Performance

There might be some projects in which no verification tests are made until the time that performance evaluation is made, resulting in missing data. The verification tests take place after some stages of the system development process, especially after the Preliminary Design phase.

S27 - Maturity of the Design

This sub-criterion is applicable when the design process reaches some maturity level, especially after the Conceptual Design phase. The metric used for this sub-criterion is number of class I engineering changes per configuration item. The engineering changes are used after a document is issued with formal revision, which also represents that the design has reached some maturity level.

Furthermore, in some projects, configuration management is chosen not to be applied and therefore changes are made without being recorded. Application of configuration management practices in a project depends on the top management's decision.

S28 - Commercially off-the-Shelf Item Usage, S29 - Common Item Usage among Projects, S30 - Standard Item Usage

These sub-criteria are applicable when the design process reaches some maturity level, especially after the Conceptual Design phase.

Furthermore, Standard Item Usage sub-criterion is not applicable for software projects; therefore no data would exist in these projects for this sub-criterion.

CHAPTER 5

THE PROPOSED MODEL

The structure of the problem is a four level hierarchy with a goal (project performance), criteria and sub-criteria (for project performance evaluation) and alternatives (projects). There are interdependencies among the sub-criteria and therefore among the criteria. ANP was used in order to handle the interdependencies. ANP was not used for the entire project ranking process; it was used for obtaining the upper and lower bounds on sub-criteria weights. Finally, a model based on DEA was used for evaluating and ranking the projects with respect to their performance, by using the weight bounds obtained from ANP.

5.1 The ANP Model

As it was explained before, ANP was used for handling the interdependencies among the sub-criteria and criteria when obtaining their relative weights. By analyzing different pairwise comparison matrices with ANP, upper and lower bounds on sub-criteria weights were determined.

After the determination of the project performance evaluation criteria and sub-criteria, the interdependencies were defined by a detailed study. The relationship of interdependencies is represented in Figure 8. In this Figure, an arrow that leaves from a given criterion, say C1 and feeds into another criterion, say C2, represents that criterion C2 is influenced by criterion C1.This is similar for the interdependency relationships among the sub-criteria.

The model constructed, is a hybrid ANP model consisting of both a hierarchy and a network. The model is given in Figure 9.

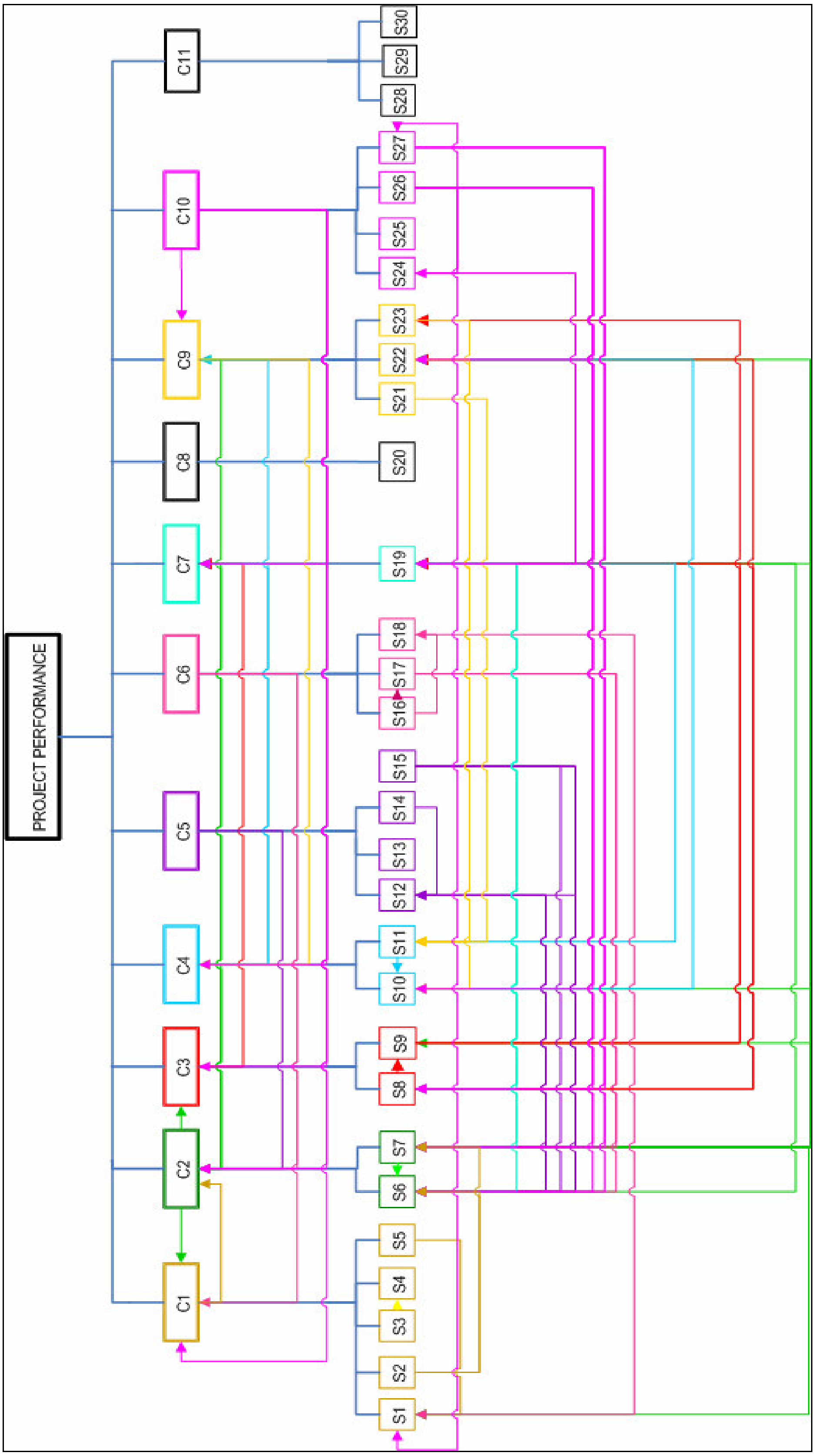

Figure 8 Interdependencies among the Criteria and the Sub-Criteria

Figure 8 Interdependencies among the Criteria and the Sub-Criteria

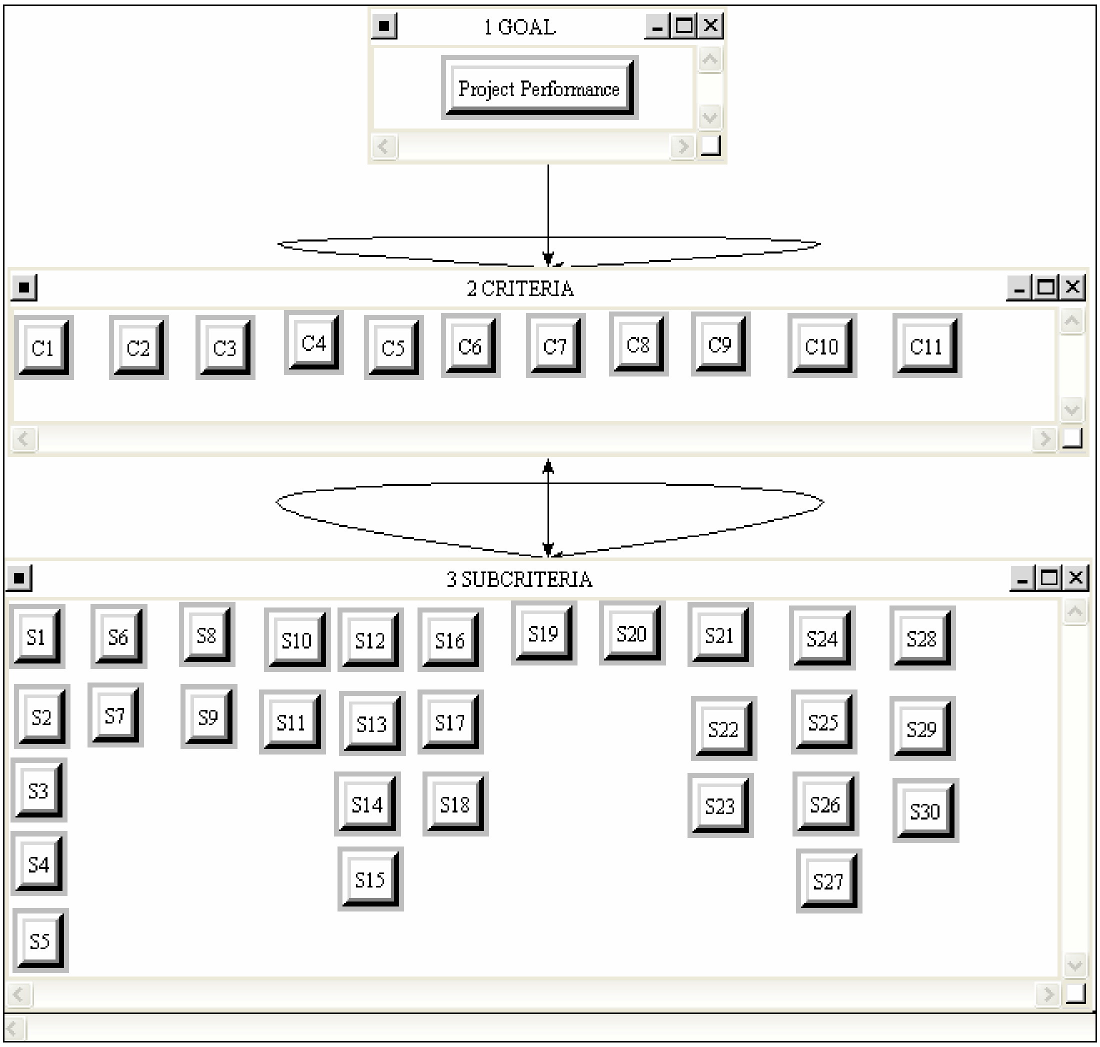

Figure 9 The Model

5.1.1 Construction of the Pairwise Comparison Matrices

Determination of the level of importances and influences among the project performance evaluation criteria and sub-criteria required a group decision making approach, in which judgments from personnel having different range of experience in the institute were considered. After building the structure and the interdependency relationships as an ANP model, a questionnaire was conducted among those personnel to obtain the pairwise judgments on the level of importances and influences. The questionnaire which is represented in Appendix C consists of five steps of pairwise comparisons. Saaty's nine-point scale (Saaty, 1980), given in Table 6 was used in evaluations.

Table 6 Saaty's Nine-Point Scale (Saaty, 1980)

Intensity of Pairwise Comparison	**Definition**	**Explanation**
1	Equal	Two activities contribute equally to the objective
3	Moderately	Experience and judgment slightly favor one activity over another
5	Strongly	Experience and judgment strongly favor one activity over another
7	Very Strongly	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Extremely	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	For compromise between the above values	

The questionnaire was a comprehensive questionnaire consisting of many pairwise comparisons. In order to provide simplicity, it was decided that using singular numbers of Saaty's nine-point scale would be enough, and the intermediate values, which are used when compromise is needed between the adjacent values, were not used in the evaluation scale of the questionnaire.

In the first step, without considering the interdependence between criteria, the decision makers were asked to evaluate the importance of each criterion pairwise with respect to project performance. They responded to questions such as: "Which criterion should be emphasized more for evaluation of project performance: C2 or C6, and how much more?" Therefore, the decision makers compared the importance of all pairs of the eleven criteria with respect to the project performance.

In the second step, the levels of influences in interdependencies among the criteria were evaluated. The decision makers were asked to pairwise compare the level of influence of two criteria on a given criterion. They responded to questions such as: "Which criterion influences criterion C1 more: C2 or C6, and how much more?" A pairwise comparison matrix was constructed for each criterion.

Third step was composed of pairwise comparisons for evaluation of the importance of all sub-criteria beneath a given criteria with respect to that criteria, without considering the interdependencies. The decision makers responded to questions such as: "Which criterion should be emphasized more for C1: S1 or S2, and how much more?" A pairwise comparison matrix was constructed for each criterion.

In fourth step, the levels of influences in interdependencies among the sub-criteria were evaluated. The decision makers were asked to pairwise compare the level of influence of two sub-criteria on a given sub-criterion. They responded to questions such as: "Which sub-criterion influences sub-criterion S1 more: S5 or S7, and how much more?" A pairwise comparison matrix was constructed for each sub-criterion.

Finally, in the last step, the feedbacks that take place from the sub-criteria to the criteria were considered. The logic behind the feedback can be explained as follows: Consider a criterion C1 depends on sub-criterion S1. Since C1 depends on S1, it can be concluded that S1 influences C1 and a backward link is put from S1 to C1. Consider that S1 depends on S7, which is beneath another criterion C2. Since C1 depends on S1 and S1 depends on S7, thus C1 indirectly depends on S7. Therefore a backward link is put from S7 to C1. The decision makers were asked to pairwise compare the level of influence of two criteria from a given sub-criterion. They responded to questions such as: "Which criterion is influenced from sub-criterion S7 more: C1 or C2, and how much more?"

Note that in the questionnaire, each pair of criteria/sub-criteria was judged only once. Reciprocal values were assigned for the reverse comparisons.

The questionnaire was conducted to six personnel from different areas of specialization in the institute. Three participants were personnel who had experience as a project manager (one of them as also the previous head of the programs department), one participant was the head of the quality assurance department, one participant was the head of programs department, and the last participant was the author of the thesis, who has experience in project management division.

The total number of pairwise comparison questions in the questionnaire was 274. The participants answered these questions within approximately two hours time. The questionnaire was conducted to the participants by the author of the thesis, and the necessary explanations were made to the participants on the pairwise comparison questions when required.

The questionnaire results obtained from all of the participants were evaluated by considering the highest and lowest judgments and constructing interval pairwise comparison matrices with these judgments.

Note that in evaluation of the judgments, extreme judgments which caused inconsistency were identified and asked to be reconsidered by the decision maker having made that judgment.

5.1.2 Determination of Sub-Criteria Weight Intervals

From the interval pairwise comparison matrices, weight intervals for the sub-criteria were determined by using the results obtained from the following three different processes.

1) Determination of crisp priorities from the interval pairwise comparison matrices

In the first process, crisp priority vectors were derived from the interval pairwise comparison matrices and the Unweighted Supermatrix was built by using these priorities. The method proposed by Chandran et al. (2005) was used to derive the priorities from the interval pairwise comparison matrices.

Among the methods that were investigated during literature review, this method was decided to be implemented since it is an understandable and easily applicable method which requires little computational time and can be solved by readily available softwares used for LPs. The aforementioned factors are important since the proposed method is for real applications in the Institute.

The method proposed by Chandran et al. (2005) is a two stage linear programming approach for estimating the weights for a pairwise comparison matrix. They have also proposed an extension for the approach in which an interval pairwise comparison matrix is considered.

In the first stage, a linear program is being solved that provides a consistency bound for a specified pairwise comparison matrix. In the second stage, that consistency bound is used in a linear program whose solution results in a priority vector.

For an *n*x*n* interval pairwise comparison matrix

$$A = \begin{pmatrix} 1 & \cdots\cdots & [l_{1n}, u_{1n}] \\ \vdots & & \vdots \\ \vdots & [l_{ij}, u_{ij}] & \vdots \\ [l_{n1}, u_{n1}] & \cdots\cdots & 1 \end{pmatrix} \qquad (5.1)$$

Where l_{ij} is the lower bound on the pairwise comparison value of i with respect to j, and u_{ij} is the upper bound on the pairwise comparison value of i with respect to j.

The diagonal elements are equal to 1 $(l_{ii} = u_{ii} = 1)$ and the matrix has the reciprocal property $(l_{ij} = 1/u_{ji})$.

$$l_{ij} \le w_i / w_j \le u_{ij} \text{ for } i, j = 1,2,...,n; \quad i < j \qquad (5.2)$$

Let

$$w_i / w_j = a_{ij}\varepsilon_{ij} \text{ for } i, j = 1,2,...,n \tag{5.3}$$

where decision variable w_i is the weight of element i, a_{ij} is the entry for row i and column j in the matrix A and decision variable ε_{ij} is the error factor in estimating a_{ij}.

The following decision variables are introduced in the model.

$$x_i = \ln(w_i)$$
$$y_{ij} = \ln(\varepsilon_{ij})$$
$$z_{ij} = |y_{ij}|$$

In an interval comparison matrix, given as above, instead of *aij*, there exists an interval defined by l_{ij} and u_{ij}.

The geometric mean of the interval bounds is used instead of each entry *aij*.

$$a_{ij} = (l_{i,j} \times u_{i,j})^{1/2} \tag{5.4}$$

The first stage linear program, which provides a consistency bound for the pairwise comparison matrix is as follows:

$$Minimize \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} z_{ij} \tag{5.5}$$

$s.t.$

$$x_i - x_j - y_{ij} = \ln a_{ij} \quad \text{for i}, j = 1,...,n;\ i \neq j \tag{5.6}$$

$$z_{ij} \geq y_{ij} \quad \text{for i}, j = 1,...,n;\ i < j \tag{5.7}$$

$$z_{ij} \geq y_{ji} \quad \text{for i}, j = 1,...,n;\ i < j \tag{5.8}$$

$$x_1 = 0 \tag{5.9}$$

$$x_i - x_j \geq \ln l_{ij} \quad \text{for i}, j = 1,...,n;\ i < j \tag{5.10}$$

$$x_i - x_j \leq \ln u_{ij} \quad \text{for i}, j = 1,...,n;\ i < j \tag{5.11}$$

$z_{ij} \geq 0 \qquad \text{for } i, j = 1,...,n \qquad (5.12)$

$x_i, y_{ij} \text{ unrestricted} \qquad \text{for } i, j = 1,...,n \qquad (5.13)$

Constraint (5.6) is obtained by taking the natural logarithm of equation (5.3).

If the decision maker's judgment for pairwise comparison of i with respect to j (a_{ij}) is greater than the true value (overestimated) and $\varepsilon_{ij}>1$, then the reverse occurs for a_{ji} in the same amount (it is lower than the true value (underestimated) and $\varepsilon_{ji}<1$). Therefore, $\varepsilon_{ij} = 1/\varepsilon_{ji}$ for $i, j = 1,...,n$. By taking the natural logarithm of both sides, $y_{ij} = -y_{ji}$ for $i, j = 1,...,n$. In constraints (5.7) and (5.8), for each i and j, the magnitude of the error for the element that is overestimated is determined by taking the highest of y_{ij} and y_{ji}.

Since the solution set to constraints (5.6)–(5.8) is infinitely large, value of any w_i can be fixed arbitrarily without loss of generality. In constraint (5.9) w_1 is set to 1 arbitrarily (i.e., $\ln(w_1) = 0$). Note that, the final weights obtained from the model were normalized to sum to one. Constraints (5.10) and (5.11) are obtained by taking the natural logarithm of equation (5.2).

Constraint (5.12) ensures z_{ij} being positive since it is absolute value of y_{ij}. Finally x_i and y_{ij} are unrestricted in sign.

The objective function minimizes the sum of natural logarithms of positive error terms. In other words, it minimizes the product of the errors that are greater than or equal to one (for overestimated entries).

The solution set obtained from the first stage linear program consists of all priority vectors that minimize the product of all errors greater than or equal to one. There may be alternative optimal solutions to the first stage model.

The second stage linear program selects from this set of alternative optima the priority vector that minimizes the maximum of errors ε_{ij}. The second stage linear program is as follows.

$$Minimize\ z_{\max} \tag{5.14}$$

$s.t.$

$$\sum_{i=1}^{n-1} \sum_{j=i+1}^{n} z_{ij} = z^* \tag{5.15}$$

$$x_i - x_j - y_{ij} = \ln a_{ij} \quad \text{for } \mathrm{i}, j = 1,...,n;\ i \neq j \tag{5.16}$$

$$z_{ij} \geq y_{ij} \quad \text{for } \mathrm{i}, j = 1,...,n;\ i < j \tag{5.17}$$

$$z_{ij} \geq y_{ji} \quad \text{for } \mathrm{i}, j = 1,...,n;\ i < j \tag{5.18}$$

$$\mathrm{z}_{\max} \geq z_{ij} \quad \text{for } \mathrm{i}, j = 1,...,n;\ i < j \tag{5.19}$$

$$x_1 = 0 \tag{5.20}$$

$$x_i - x_j \geq \ln l_{ij} \quad \text{for } \mathrm{i}, j = 1,...,n;\ i < j \tag{5.21}$$

$$x_i - x_j \leq \ln u_{ij} \quad \text{for } \mathrm{i}, j = 1,...,n;\ i < j \tag{5.22}$$

$$z_{ij} \geq 0 \quad \text{for } \mathrm{i}, j = 1,...,n \tag{5.23}$$

$$\mathrm{x_i}, y_{ij} \text{ unrestricted} \quad \text{for } \mathrm{i}, j = 1,...,n \tag{5.24}$$

z^* denotes the optimal objective function value obtained from the first stage model. By constraint (5.15), it is ensured that only those solution vectors that are optimal in the first stage linear program are feasible in the second stage linear program.

In constraint (5.19), for each i and j, the greater of z_{ij} is taken to be as z_{max}, natural logarithm of maximum error, which is minimized in the objective function. Constraint (5.23) denotes the z_{max} being positive. The remaining constraints in the second stage model are same with the corresponding constraints in the first stage model.

The only input to this model is the interval pairwise comparison matrix. Only specifying the values in the upper triangular part of the matrix are adequate since the matrix has reciprocal property. The outputs of the second stage linear program are the z_{max}*, natural logarithm of maximum error and the priority vector under the consistency bound defined by the first stage linear program.

Note that, in Chandran et al. (2005), for group decision-making problems, obtaining the interval bounds by considering the highest and lowest judgments, and computing the priority vectors by solving the first stage and the second stage linear programs is also proposed as an alternative method instead of computing the geometric mean of the individual judgments.

The priorities obtained from this model are then substituted into the Unweighted Supermatrix.

2) Determination of crisp priorities from the lower bounds of the interval pairwise comparison matrices

In the second process, priorities derived from the lower bounds of the pairwise comparison judgments by using the eigenvector method were used in construction of the Unweighted Supermatrix.

3) Determination of crisp priorities from the upper bounds of the interval pairwise comparison matrices

Finally, in the third process, priorities derived from the upper bounds of the pairwise comparison judgments by using the eigenvector method were used in construction of the Unweighted Supermatrix.

In calculation of the eigenvectors, the algorithm proposed by Saaty (1980), that involved dividing each element in a column by its column sum and then summing the elements in each row of the resultant matrix and dividing by the number of elements in the row, was used.

The matrices formed with the upper bounds of the pairwise comparison judgments and the matrices formed with the lower bounds of the pairwise comparison judgments were tried to be made as consistent as possible. The Super Decisions software (http://www.superdecisions.com, 2007), in which the model was also constructed for checking purposes, reports an inconsistency report with the consistency ratio and the most inconsistent entry for each pairwise comparison matrix. For the matrices, exceeding the consistency ratio limit of 0.1, the decision makers who have made that judgment were required to review their corresponding judgments. After these reconsiderations, there still remained some matrices having inconsistency index above 0.1, even above 0.2, however, it was an acceptable situation, since the entries in the matrices are the bounds obtained from judgments of different decision makers.

As it was previously explained, ANP was only used in estimation of the sub-criteria weights, not for the ranking of the alternatives. Therefore, the alternatives were not included in the supermatrices.

The Unweighted Supermatrix used in the method is in the form as given below.

$$W = \begin{pmatrix} 0 & 0 & 0 \\ X & Y & F \\ 0 & Z & H \end{pmatrix}$$

where X is the column vector of priorities of criteria with respect to the goal (principal right eigenvector of pairwise comparison matrix for the criteria with respect to project performance), Y is the matrix of column eigenvectors of interdependence among the criteria (principal right eigenvectors of interdependency matrices for the criteria), Z is the matrix of column eigenvectors of the sub-criteria with respect to each criterion that they belong (principal right eigenvectors of pairwise comparison matrices for the sub-criteria under each criterion they belong), H is the matrix of column eigenvectors of interdependence among the sub-criteria (principal right eigenvectors of interdependency matrices for the sub-criteria) and F is the matrix of column eigenvectors of the feedbacks from the sub-criteria to the criteria (principal right eigenvectors of feedback matrices for the sub-criteria).

All clusters were assigned to have equal importance and influence.

The three Unweighted supermatrices obtained from the above three processes were multiplied by the cluster weights and the corresponding Weighted supermatrices were calculated. Finally, by raising the Weighted Supermatrices to limiting powers, Limit Supermatrices were obtained.

The Unweighted Supermatrices, Cluster Matrix, Weighted Supermatrices and the Limit Supermatrices are given in Appendix D.

Excel (version 2003) was used in implementation of the ANP application. The Unweighted Supermatrices and the cluster matrix were constructed in Excel. The calculation of the Weighted Supermatrices and the Limit Supermatrices were also made by using Excel.

For checking purposes, the model was also constructed and solved in the software Super Decisions (http://www.superdecisions.com, 2007) and the results obtained from Excel calculations and Super Decisions were compared in all of the three approaches. As it was expected, same results were obtained from these two tools.

The sub-criteria priorities obtained from the three different processes were used to determine the lower and upper bounds on sub-criteria weights. For a given sub-criterion, the minimum among the three results was considered as the lower bound and the maximum was considered as the upper bound. These bounds were then used as assurance region constraints in a DEA model, through which the project ranking was obtained.

5.2 The DEA Model

As it was explained in Section 2.5, ranking methods includes ranking of a set of alternatives based on their scores for a set of multiple and conflicting criteria. Besides ranking methods, there are sorting/classification methods in which alternatives are assigned into two or more predefined homogeneous classes.

In this study, a ranking method, DEA is proposed. It was decided that a ranking method was required to be applied rather than a sorting or classification method, since the necessity of the Institute is to order the projects with respect to their performances and to observe the differences among the performance scores of the projects.

DEA was decided to be used as the ranking tool since it allows the projects to stand out with their predominant sides and to be evaluated in their best possible light.

5.2.1 Super-Efficiency DEA Model with Assurance Region Constraints

Due to its advantage of discriminatory power, the usage of the super-efficiency method was decided to be the most appropriate approach for obtaining the project ranking. During scaling of the metrics, values above or below some defined boundary values were assigned the best or worst values (0 or 100), which lead to the elimination of the marginal values (The scaling was presented in detail in the previous chapter). Therefore, the drawback of favoring the marginal values would not take place for our model.

As it was previously mentioned in Chapter 2, in the application of DEA as a MCDM tool, the DMUs are replaced with the alternatives, the outputs with maximization criteria and inputs with minimization criteria. Among the 30 sub-criteria for the project performance evaluation, 21 of them are minimization sub-criteria and the rest 9 are maximization sub-criteria.

The approach given by Sarkis (2000) was used when applying the lower and upper bounds on sub-criteria weights, determined by ANP, as assurance region constraints. The super-efficiency DEA model with assurance region constraints is given as follows (Model SDA).

Model SDA:

$$h_k = \max \sum_{r=1}^{s} u_r y_{rk} \tag{5.25}$$

s.t.

$$\sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} u_r y_{rj} \geq 0 \text{ for } j = 1,...,n, j \neq k \tag{5.26}$$

$$\sum_{i=1}^{m} v_i x_{ik} = 1 \tag{5.27}$$

$$u_r \geq \varepsilon \text{ for } r = 1,...,s \tag{5.28}$$

$$v_i \geq \varepsilon \text{ for } i = 1,...,m \tag{5.29}$$

Assurance Regions:

$$\frac{u_r}{u_h} \geq \frac{LB_r}{UB_h} \quad \text{for } r, h = 1,2,...,s; \ r < h \quad \text{LB for max. vs. max. sub-criteria} \tag{5.30}$$

$$\frac{v_i}{v_z} \geq \frac{LB_i}{UB_z} \quad \text{for } i, z = 1,2,...,m; \ i < z \quad \text{LB for min. vs min. sub-criteria} \tag{5.31}$$

$$\frac{u_r}{v_i} \geq \frac{LB_r}{UB_i} \quad \text{LB for max. vs. min. sub-criteria} \tag{5.32}$$

$$\frac{u_r}{u_h} \leq \frac{UB_r}{LB_h} \quad \text{for } r, h = 1,2,...,s; \ r < h \quad \text{UB for max. vs. max. sub-criteria} \tag{5.33}$$

$$\frac{v_i}{v_z} \leq \frac{UB_i}{LB_z} \quad \text{for } i, z = 1,2,...,m; \ i < z \quad \text{UB for min. vs min. sub-criteria} \tag{5.34}$$

$$\frac{u_r}{v_i} \leq \frac{UB_r}{LB_i} \quad \text{UB for max. vs. min. sub-criteria} \tag{5.35}$$

where

h_k is the efficiency measure for project *k*,

n denotes the number of projects,

s denotes the number of maximization sub-criteria,

m denotes the number of minimization sub-criteria,

y_{rk} is the value of maximization sub-criterion r for project k ($r = 1,...,s$),

x_{ik} is the value of minimization sub-criterion i for project k ($i = 1,...,m$),

u_r is the weight of maximization sub-criterion r,

v_i is the weight of minimization sub-criterion i.

(5.25) - (5.29) is the super-efficiency model given in Section 3.2.2. Constraints (5.30) - (5.35) are the assurance region constraints. Constraints (5.30) and (5.33) define the lower and upper bounds for the ratios among the weights of maximization sub-criteria, respectively. Similarly, the lower and upper bounds for the ratios among the weights of minimization sub-criteria are defined by constraints (5.31) and (5.34), respectively. Finally, constraints (5.32) and (5.35) define the lower and upper bounds for the ratios of the weights of maximization sub-criteria versus minimization sub-criteria, respectively. It should be mentioned that constraints (5.32) and (5.35) could have been defined in a different manner, by using the ratios of the weights of minimization sub-criteria versus maximization sub-criteria.

5.2.2 Handling Missing Data

To handle the missing values, two distinct approaches were used.

As the first approach, one of the methods used in the literature, assigning the average value of the other projects to the missing values were used. The average of the available values for a given sub-criterion was calculated and assigned to the missing data for that sub-criterion and Model SDA was solved with these data.

Secondly, the interval DEA approach proposed by Smirlis et al. (2006) was used. The missing values were replaced by interval estimations and efficiency scores were obtained as intervals.

Smirlis et al. (2006) specified that the interval bounds can be determined by using different estimation techniques, and when no estimation can be made, the column minimum and maximum may be used as the interval bounds. In order to provide objectivity and stability in the system, instead of using estimations, the best and worst values were decided to be used as interval bounds in the model. The upper bounds were set to 100 and the lower bounds were set to 0.

Let ${x_{ij}}^L$ and ${x_{ij}}^U$ denote the lower and upper bound for minimizing sub-criterion i, and ${y_{rj}}^L$ and ${y_{rj}}^U$ denote the lower and upper bound for maximizing sub-criterion r, respectively. The missing values are assumed to be standing within these intervals, as follows.

for minimizing sub-criteria, $x_{ij} \in [{x_{ij}}^L, {x_{ij}}^U]$ (5.36)

for maximizing sub-criteria, $y_{rj} \in [{y_{rj}}^L, {y_{rj}}^U]$ (5.37)

The following transformations were made in Model SDA, as Smirlis et al. (2006) proposed.

The values x_{ij} and y_{rj} are expressed in terms of new variables s_{ij} and t_{rj}, which locate the level of minimizing sub-criteria and maximizing sub-criteria within the bounded intervals $[{x_{ij}}^L, {x_{ij}}^U]$ and $[{y_{rj}}^L, {y_{rj}}^U]$.

$$x_{ij} = x_{ij}^L + s_{ij}(x_{ij}^U - x_{ij}^L) \text{ for } i = 1,...,m;\ j = 1,...,n \text{ with } 0 \le s_{ij} \le 1 \quad (5.38)$$

$$y_{rj} = y_{rj}^L + t_{rj}(y_{rj}^U - y_{rj}^L) \text{ for } r = 1,...,s;\ j = 1,...,n \text{ with } 0 \le t_{rj} \le 1 \quad (5.39)$$

By using these expressions, the term $v_i x_{ij}$ can be written as $v_i x_{ij}^L + v_i s_{ij}(x_{ij}^U - x_{ij}^L)$ and the term $u_r y_{rj}$ can be written as $u_r y_{rj}^L + u_r t_{rj}(y_{rj}^U - y_{rj}^L)$. In these expressions, the terms $v_i s_{ij}$ and $u_r t_{rj}$ are replaced by new variables $q_{ij} = v_i s_{ij}$ and $p_{rj} = u_r t_{rj}$ which meet the conditions $0 \le q_{ij} \le v_i \;\; 0 \le p_{rj} \le u_r \;\; \forall \text{i, j, r}$.

Therefore, the term $v_i x_{ij}$ can be written as $v_i x_{ij}^L + q_{ij}(x_{ij}^U - x_{ij}^L)$ and the term $u_r y_{rj}$ can be written as $u_r y_{rj}^L + p_{rj}(y_{rj}^U - y_{rj}^L)$.

After making these transformations, Model SDA becomes as follows (Model SDAI):

Model SDAI:

$$h_k = \max \sum_{r=1}^{s} u_r y_{rk}^L + p_{rk}(y_{rk}^U - y_{rk}^L) \tag{5.40}$$

s.t.

$$\sum_{i=1}^{m} v_i x_{ij}^L + q_{ij}(x_{ij}^U - x_{ij}^L) - \sum_{r=1}^{s} u_r y_{rj}^L + p_{rj}(y_{rj}^U - y_{rj}^L) \geq 0 \text{ for } j = 1,...,n, j \neq k \tag{5.41}$$

$$\sum_{i=1}^{m} v_i x_{ik}^L + q_{ik}(x_{ik}^U - x_{ik}^L) = 1 \tag{5.42}$$

$$p_{rj} - u_r \leq 0 \text{ for } r = 1,...,s; \; j = 1,...,n \tag{5.43}$$

$$q_{ij} - v_i \leq 0 \text{ for } i = 1,...,m; \; j = 1,...,n \tag{5.44}$$

$$u_r \geq \varepsilon \text{ for } r = 1,...,s \tag{5.45}$$

$$v_i \geq \varepsilon \text{ for } i = 1,...,m \tag{5.46}$$

$$p_{rj} \geq 0 \text{ for } r = 1,...,s; \; j = 1,...,n \tag{5.47}$$

$$q_{ij} \geq 0 \text{ for } i = 1,...,m; \; j = 1,...,n \tag{5.48}$$

Constraint set (5.30) – (5.35)

As Smirlis et al. (2006) indicated, the efficiency score of a project *k*, estimated from the above model (Model SDAI), would be the efficiency score for that project, in which it is in its most favorable position (minimizing sub-criteria would be set to the lower bound and maximizing sub-criteria would be set to the upper bound) while all the rest projects are in their least favorable position (minimizing sub-criteria would be set to the upper bound and maximizing sub-criteria would be set to the lower bound).

For $j = k$, $x_{ik} = x_{ik}^L$, $y_{rk} = y_{rk}^U$ (5.49)

For $j \neq k$, $x_{ij} = x_{ij}^U$, $y_{rj} = y_{rj}^L$ (5.50)

Therefore, Model SDAI can be written as follows, which would result in the highest possible efficiency for project k, h_k^U.

<u>Model SDAI-U:</u>

$$h_k = \max \sum_{r=1}^{s} u_r y_{rk}^U \quad (5.51)$$

s.t.

$$\sum_{i=1}^{m} v_i x_{ij}^U - \sum_{r=1}^{s} u_r y_{rj}^L \geq 0 \text{ for } j = 1,...,n, j \neq k \quad (5.52)$$

$$\sum_{i=1}^{m} v_i x_{ik}^L = 1 \quad (5.53)$$

$$u_r \geq \varepsilon \text{ for } r = 1,...,s \quad (5.54)$$

$$v_i \geq \varepsilon \text{ for } i = 1,...,m \quad (5.55)$$

Constraint set (5.30) – (5.35)

Similarly, the lowest possible efficiency for project k, h_k^L can be obtained from Model SDAI when project k is set to its most unfavorable position (minimizing sub-criteria would be set to the upper bound and maximizing sub-criteria would be set to the lower bound) while all the rest projects are set to their best favorable position (minimizing sub-criteria would be set to the lower bound and maximizing sub-criteria would be set to the upper bound). This model, which would result in h_k^L is written as follows.

Model SDAI-L:

$$h_k = \max \sum_{r=1}^{s} u_r y_{rk}^L \tag{5.56}$$

s.t.

$$\sum_{i=1}^{m} v_i x_{ij}^L - \sum_{r=1}^{s} u_r y_{rj}^U \geq 0 \text{ for } j = 1,...,n, j \neq k \tag{5.57}$$

$$\sum_{i=1}^{m} v_i x_{ik}^U = 1 \tag{5.58}$$

$$u_r \geq \varepsilon \text{ for } r = 1,...,s \tag{5.59}$$

$$v_i \geq \varepsilon \text{ for } i = 1,...,m \tag{5.60}$$

Constraint set (5.30) – (5.35)

As a summary, by solving Model SDAI-U and Model SDAI-L, upper and lower bounds of the efficiency score of the projects can be obtained, corresponding to their most favorable and most unfavorable positions.

It should be mentioned that, in the above models, for the available sub-criteria values, both the upper and lower bounds should be equated to the crisp available values.

As a summary, the proposed model is illustrated in Figure 10.

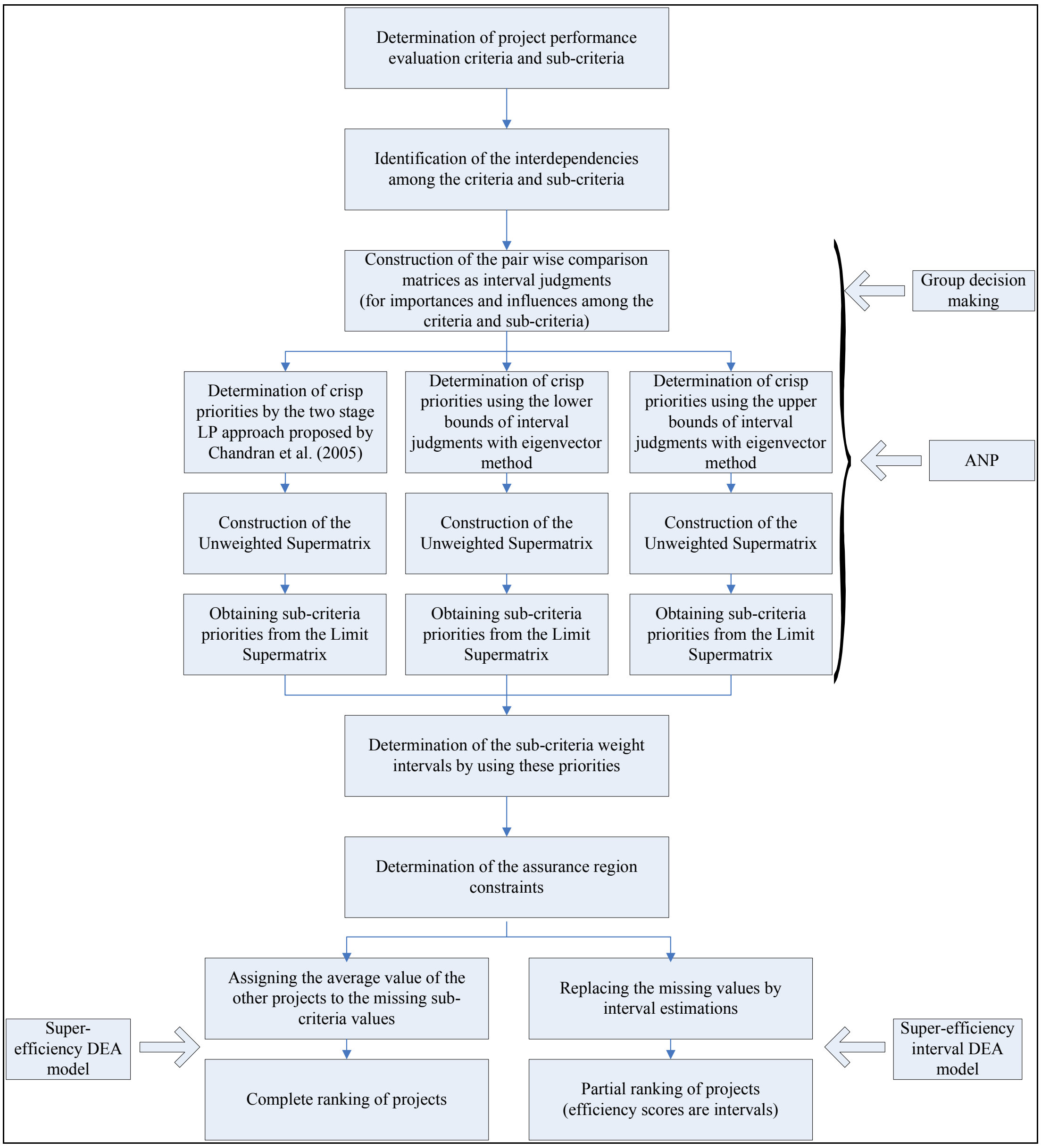

Figure 10 The Proposed Model

CHAPTER 6

IMPLEMENTATION OF THE MODEL

6.1 Results of the ANP Model

In the first process, in which the Unweighted Supermatrix was built by using crisp priority vectors obtained from the interval pairwise comparison matrices, the convergence is reached at the forty-seventh (47th) power. In the second and third processes, in which the Unweighted Supermatrices were built by using priority vectors obtained from the lower and upper bounds of the pairwise comparison judgments, convergence occurred in sixty-sixth (66th) power and in fortieth (40th) power, respectively.

In raising all three supermatrices to limiting powers, cycling occurred between C8 and its sub-criteria S20, and also between C11 and sub-criteria S28, S29, S30 beneath it. A cycle length of two was realized; therefore final priorities of these sub-criteria were calculated by taking the average (Cesaro Sum) of two successive matrices as given in equation (3.3).

The weight intervals for the sub-criteria obtained from the ANP Model are given in Table 7.

Table 7 Weight Intervals Obtained from ANP

Sub-Criterion	Lower Bound on Weight	Upper Bound on Weight
S1	0.0041	0.0374
S2	0.0032	0.0460
S3	0.0097	0.0150

Table 7 Continued - Weight Intervals Obtained from ANP

Sub-Criterion	Lower Bound on Weight	Upper Bound on Weight
S4	0.0052	0.0078
S5	0.0073	0.0134
S6	0.0039	0.0933
S7	0.0290	0.0583
S8	0.0164	0.0290
S9	0.0027	0.0274
S10	0.0028	0.0074
S11	0.0027	0.0130
S12	0.0071	0.0900
S13	0.0025	0.0208
S14	0.0045	0.0355
S15	0.0245	0.0439
S16	0.0864	0.1636
S17	0.0524	0.1089
S18	0.0210	0.0996
S19	0.0220	0.0281
S20	0.0273	0.0404
S21	0.0046	0.0077
S22	0.0012	0.0038
S23	0.0020	0.0309
S24	0.0647	0.0810
S25	0.0150	0.0343
S26	0.0684	0.1774
S27	0.0076	0.1149
S28	0.0070	0.0080
S29	0.0029	0.0438
S30	0.0007	0.0392

It is needed to emphasize that these bounds on weights will remain unchanged and will be constantly added to the DEA super-efficiency model, unless a change in the sub-criteria and/or the pairwise judgments is made.

6.2 A Case Study Implementation of the DEA Model

As a case study, the proposed model was decided to be implemented for ranking the ongoing customer-based projects in the Institute at the end of year 2006, with respect to their performances. By the end of year 2006, eighteen customer-based projects were present in the Institute; three of which had already initiated in December. A one month's time is a very short time to evaluate a project, therefore these three recently initiated projects were not taken into account and performance evaluation of the remaining fifteen projects was made. The data belonging to the sub-criteria metrics for these fifteen projects were collected by a comprehensive study. It took approximately three months to gather all the data and obtain the values of the sub-criteria metrics. The reason for such a long period of time is that, since most of the sub-criteria were newly introduced, the data related to them have not been recorded in the Institute in a systematic manner. The major part of the data was collected by analyzing the records of various divisions such as Project Management, Procurement, Budget, Accounting, Human Resources etc.. Filtering the required data from these records for calculating the metric values was the most time consuming part of data collection. No record have been kept in the institute, related to metrics of twelve sub-criteria, therefore the required data could not be obtained and it became possible to make the performance evaluation of the projects with respect to the remaining eighteen sub-criteria, listed below.

S1 - The Paraphrased Dissatisfaction of the Customer in Administrative and Technical Subjects throughout the Project
S2 - The Delays in the Deliveries in Liability of the Institute
S6 - Schedule Deviation
S7 - Milestone Completion
S8 - Deviation in Project Expenditure
S9 - Deviation in Project Personnel Cost
S10 - Deviation in Manpower
S11 - Turnover Rate
S16 - Overseas Procurement Rate

S17 - Export License Dependence

S19 - Risk Handling

S20 - Number of Non-Conformities

S21 - Contribution to the Self-Development of the Institute Personnel

S22 - Overtime Rate

S23 - Supplementary Payment to the Institute Personnel

S24 - Technical Performance Measures

S25 - Technical Review Results

S27 - Maturity of the Design

Sixteen of the above sub-criteria are minimization sub-criteria and the rest two are maximization sub-criteria.

For eighteen sub-criteria, 306 additional constraints were added to the super-efficiency DEA formulation as assurance region constraints.

As it was expected, missing data occurred for some sub-criteria in some projects. The two different approaches explained in previous chapters, assigning the average value of the other projects and the interval DEA approach, were both implemented. The input values in these two approaches are presented in Appendix E and the discussion of the results is provided below.

6.3 Discussion of the Results

6.3.1 Discussion of the Results of the first DEA Approach

The efficiency scores reflect the relative performances of the projects and the ranking with respect to efficiency reflects the ranking of the projects with respect to their relative performances. The complete ranking, obtained from the first approach in which the average values of the other projects were assigned to the missing values, is given in Table 8. The last column displays the difference between the efficiency values of the two consecutive projects. This column is to analyze the distances among the positions of the projects in ranking, which reflect the relative performances of the projects with respect to each other.

Table 8 Efficiency Values Obtained from the First DEA Approach

#	Project	Efficiency Value	Difference
1	P5	0.381	-
2	P3	0.240	0.141
3	P15	0.217	0.023
4	P11	0.215	0.003
5	P2	0.182	0.032
6	P9	0.172	0.011
7	P12	0.168	0.004
8	P13	0.160	0.008
9	P14	0.156	0.004
10	P8	0.150	0.006
11	P10	0.144	0.006
12	P7	0.129	0.015
13	P4	0.058	0.072
14	P6	0.050	0.008
15	P1	0.045	0.005

When these results are analyzed, it is seen that low efficiency values are obtained for the projects, which are also generally close to each other. P5 is the first in the ranking with a noticeable difference (the efficiency of P5 is discriminatively higher than the efficiency of P3), having an efficiency value of 0.381. P3, P15 and P11 follow P5 with efficiency values of 0.240, 0.217 and 0.215, respectively. Especially, the efficiency values of P15 and P11 are very close to each other. There is also a relatively high distance between the positions of P11 and P2. The last project in the ranking is P1, with an efficiency value of 0.045. P6 and P4 follow P1 with efficiency values of 0.050 and 0.058, respectively. P1, P6 and P4 are discriminatively in the lower positions with respect to the other projects (the efficiency of P4 is discriminatively lower than the efficiency of P7).

There are two main reasons for obtaining low efficiency values. The first reason is that, all of the projects have poor values in some of the sub-criteria. Secondly, the missing data values are also assigned poor values when the average of the values of the remaining projects is a poor value. It was observed that, in the second approach, in which the missing values were replaced by intervals of best and worst values, high values, even above one, are obtained as upper bounds of the efficiency scores. The results of the second DEA approach are provided in Section 6.3.2.

The reason of the ranking is discussed in the following pages. Before analyzing the ranking, the relative importance of the sub-criteria obtained from the ANP model should be examined in order to comment on their effects in the DEA model.

According to the weight intervals, the sub-criteria can be categorized in three classes with respect to their relative importance. This categorization can be seen in Table 9. As it can be seen from this table, sub-criteria S10, S21 and S22 have the lowest importance, since even the upper bound of their weights are very low with respect to other weight limits. Conversely, sub-criteria S16, S17 and S24 have the highest importance, having considerably high weights with respect to other sub-criteria (even the upper bound of their weights are high). The upper bound for weight of S16 is 0.164, which is the greatest value among the results.

Table 9 Categorization According to the Weight Intervals Obtained from ANP

Sub-Criterion	**Lower Bound on Weight**	**Upper Bound on Weight**
S22	0.0012	0.0038
S10	0.0028	0.0074
S21	0.0046	0.0077
S23	0.0020	0.0309
S9	0.0027	0.0274
S11	0.0027	0.0130
S2	0.0032	0.0460

Table 9 Continued - Categorization According to the Weight Intervals Obtained from ANP

S6	0.0039	0.0933
S1	0.0041	0.0374
S27	0.0076	0.1149
S25	0.0150	0.0343
S8	0.0164	0.0290
S19	0.0220	0.0281
S20	0.0273	0.0404
S7	0.0290	0.0583
S17	0.0524	0.1089
S24	0.0647	0.0810
S16	0.0864	0.1636

There is no missing data for S16, also the projects have discrepant values for this sub-criterion, and therefore it becomes a discriminating factor for all of the projects.

Although S24 is a very important sub-criterion, its value is missing in 12 projects (projects except P1, P2 and P4), avoiding the discriminating power of this sub-criterion among those 12 projects. S24 becomes a distinctive factor for two of the remaining projects, P1 and P2, which have the highest and lowest values for this sub-criterion, respectively.

There is no missing data for S17, but 13 of the projects (projects except P1 and P2) have a value of 0, the best value, in this sub-criterion; therefore S17 does not play a discriminating role for these 13 projects. Two remaining projects, P1 and P2, have very poor values for S17, which becomes a distinctive disadvantage for them.

Values of the sub-criteria S19 and S25 are missing in most of the projects; therefore these sub-criteria do not have discriminating effects for most of the projects. S25 only has a considerable effect for P1 and P10, which have the lowest and highest values for this sub-criterion, respectively.

Values of the sub-criterion S27 are also missing in most of the projects; however, because of the high value of the upper bound of its weight, this sub-criterion becomes distinctive for P5 and P3 which have the lowest and highest values for this sub-criterion, respectively.

The reasons of the ranking of the projects at the uppermost and lowermost positions are discussed in detail in the following pages.

Project P5 – First in the ranking:

The value of minimizing sub-criterion S27 is equal to 33.33 for this project, which is the lowest value among all the projects. Most of the projects have missing value for this sub-criterion, and their values are made equal to the average value, 49.25. From the ANP application, the upper bound for the weight of this sub-criterion was obtained as 0.1149, which is in the second order when the upper limits of sub-criterion weights are listed. Although the value of this sub-criterion is not too distant from the values of the remaining projects, because of the high value of the upper bound of its weight, having the lowest value for this sub-criterion leads to a considerable advantage to this project. This is the main reason that this project outranks the other uppermost projects P3, P5 and P11; especially P3, which has the highest value for this sub-criterion

The value of minimizing sub-criterion S16 is very close to the best value for this project (2.26). P7 and P13 have also small values for this sub-criterion, and for projects P6, P11, P12 and P14, P15, the value of this sub-criterion is 0. This sub-criterion has a considerably high weight with respect to other sub-criteria. Even the lower bound of this sub-criterion weight has a very high value compared to the weights of the remaining sub-criteria. Therefore, having a value of 0 in this sub-criterion is a considerable advantage for this project.

The value of maximizing sub-criterion S23 is equal to the best value (100) for this project. There are only two other projects, P2 and P3, in which the value of this sub-criterion is also 100. The upper bound for the weight of this sub-criterion was obtained as 0.0308 from the ANP application. This is also one of the reasons for this project to outrank P15 and P11.

The value of minimizing sub-criterion S11 is equal to the best value (0) for this project. There are only two other projects, P14 and P15, in which the value of this sub-criterion is also 0. The upper bound for the weight of this sub-criterion was obtained as 0.013 from the ANP application.

Having best values in the sub-criteria S9 and S20 is not a distinctively advantageous case for this project, since there are many other projects in which the values of these sub-criteria are also equal to the best value.

Although the values of the sub-criteria S2 and S7 are equal to the worst value (100) for this project, there are many other projects in which the values of these sub-criteria are also equal to the worst value. Therefore, having these values is not a noteworthy disadvantage for this project. The same comment can be made for sub-criterion S19, which is equal to a poor value.

This project has the worst value (50) in the minimizing sub-criterion S1, whereas most of the projects have the best value of 0 in this sub-criterion. However this does not become a considerable disadvantage for this project since the weight of this sub-criterion has a lower bound of 0.004 and DEA allows the projects to be evaluated in their best possible light.

Project P3 – Second in the ranking:

This project has a better value for the minimizing sub-criterion S6 (5.00) compared to most of the remaining projects. From the ANP application, the upper bound for the weight of this sub-criterion was obtained as 0.0933, which is in the fourth order when the upper limits of sub-criterion weights are listed. Because of the high value of the upper bound of its weight, having a good value for this sub-criterion is a considerable advantage to this project.

As it was mentioned before, similar to P5 and P2, the value of maximizing sub-criterion S23 is equal to the best value (100) for this project. The upper bound for the weight of this sub-criterion was obtained as 0.0308 from the ANP application. This is also one of the reasons for this project to outrank P15 and P11.

The value of maximizing sub-criterion S21 is equal to the best value (100) for this project. However, this value does not lead to a considerable advantage to this project since the upper bound of this sub-criterion weight obtained from ANP is very low with respect to other weight limits.

Although the values of the sub-criteria S2 and S7 are equal to the worst value for this project, there are many other projects in which the values of these sub-criteria are also equal to the worst value. Therefore, having these values is not a disadvantage for this project. The same comment can be made for sub-criterion S19, which is equal to a poor value.

Having the worst value (100) in the sub-criterion S20 is a minor disadvantage for this project, since there are many other projects in which the value of this sub-criterion is equal to the best value and the upper bound for the weight of this sub-criterion was obtained as 0.0404.

Similar to above, having the highest value among all the projects (53.24) in the minimizing sub-criteria S9 is also a minor disadvantage for this project, since the upper bound for the weight of this sub-criterion was obtained as 0.0274. This is a minor disadvantage, but this is also one of the reasons for this project to be outranked by P5.

Having the highest value among all the projects (88.89) in the minimizing sub-criterion S11 is not a disadvantageous case for this project, since the upper bound of this sub-criterion weight is not so high with respect to other weight limits.

This project has the second worst value (45.42) in the minimizing sub-criterion S16, which has a considerably high weight with respect to other sub-criteria. Even the lower bound of this sub-criterion weight has a very high value compared to the weights of the remaining sub-criteria. Although this is a considerable disadvantage for this project, it does not avoid P3 being the second in ranking, since this project is in advantageous position with respect to some other sub-criteria and DEA allows the projects to be evaluated in their best possible light, but it becomes one of the main reasons that it is outranked by P5.

The value of minimizing sub-criterion S27 is equal to 61.11 for this project, which is the highest value among all the projects. Most of the projects have missing value for this sub-criterion, and their values are made equal to the average value, 49.25. From the ANP application, the upper bound for the weight of this sub-criterion was obtained as 0.1149, which is in the second order when the upper limits of sub-criterion weights are listed. Although the value of this sub-criterion is not too distant from the values of the remaining projects, because of the high value of the upper bound of its weight, having the highest value for this sub-criterion leads to a considerable disadvantage to this project, especially when compared with P5. This disadvantage does not avoid P3 being the second in ranking, but it becomes one of the main reasons that it is outranked by P5, as it was mentioned before.

<u>Project P15 – Third in the ranking:</u>

This project has the best value for the minimizing sub-criterion S6 (2.00) among all the projects. From the ANP application, the upper bound for the weight of this sub-criterion was obtained as 0.0933, which is in the fourth order when the upper limits of sub-criterion weights are listed. Because of the high value of the upper bound of its weight, having the best value for this sub-criterion is a considerable advantage to this project.

The value of minimizing sub-criterion S16 is equal to the best value (0) for this project. There are four more projects, P6, P11, P12 and P14, in which the value of this sub-criterion is also 0. This sub-criterion has a considerably high weight with respect to other sub-criteria. Even the lower bound of this sub-criterion weight has a very high value compared to the weights of the remaining sub-criteria. Therefore, having a value of 0 in this sub-criterion is a considerable advantage for this project.

The values of the sub-criteria S2 and S7 are equal to the best value (0) for this project. There are various projects in which the values of these sub-criteria are equal to the worst value or worse values. The upper bounds for the weights of these sub-criteria were obtained as 0.046 and 0.0583, respectively. Therefore, having these sub-criterion values is a considerable advantage for this project.

As it was mentioned before, similar to P5 and P14, the value of minimizing sub-criterion S11 is equal to the best value (0) for this project. The upper bound for the weight of this sub-criterion was obtained as 0.013 from the ANP application.

Having best values in the sub-criteria S1, S9 and S20 is not a distinctively advantageous case for this project, since there are many other projects in which the values of these sub-criteria are also equal to the best value.

The value of maximizing sub-criterion S21 is equal to the worst value (0) for this project. This does not lead to a considerable disadvantage to this project since the upper bound of this sub-criterion weight obtained from ANP is very low with respect to other weight limits.

Having the worst value (100) in the sub-criteria S8 is a minor disadvantage for this project, since the upper bound for the weight of this sub-criterion was obtained as

0.029. Although it is a minor disadvantage, this is one of the reasons for this project to be outranked by P5 and P3.

Project P11 – Fourth in the ranking:

Similar to P15, the values of the sub-criteria S2 and S7 are equal to the best value (0) for this project. There are various projects in which the values of these sub-criteria are equal to the worst value or worse values. The upper bounds for the weights of these sub-criteria were obtained as 0.046 and 0.0583, respectively. Therefore, having these sub-criterion values is a considerable advantage for this project.

As it was previously mentioned, similar to P15, P6, P12 and P14, the value of minimizing sub-criterion S16 is equal to the best value (0) for this project. This sub-criterion has a considerably high weight with respect to other sub-criteria. Even the lower bound of this sub-criterion weight has a very high value compared to the weights of the remaining sub-criteria. Therefore, having a value of 0 in this sub-criterion is a considerable advantage for this project.

Similar to P3, this project has a better value for the minimizing sub-criterion S6 (5.88) compared to most of the remaining projects. From the ANP application, the upper bound for the weight of this sub-criterion was obtained as 0.0933, which is in the fourth order when the upper limits of sub-criterion weights are listed. Because of the high value of the upper bound of its weight, having a good value for this sub-criterion is a considerable advantage to this project.

Having best values in the sub-criteria S1 and S20 is not a distinctively advantageous case for this project, since there are many other projects in which the values of these sub-criteria are also equal to the best value.

Having the lowest value among all the projects (1.35) in the minimizing sub-criterion S22 is not a considerable advantage for this project, since the upper bound of this sub-criterion weight is very low with respect to other weight limits.

The value of maximizing sub-criterion S21 is equal to the worst value (0) for this project. This does not lead to a considerable disadvantage to this project since the upper bound of this sub-criterion weight obtained from ANP is very low with respect to other weight limits.

Similar to P15, having the worst value (100) in the sub-criteria S8 is a minor disadvantage for this project, since the upper bound for the weight of this sub-criterion was obtained as 0.029. Although it is a minor disadvantage, this is one of the reasons for this project to be outranked by P5 and P3.

<u>Project P4 – The third from the bottom in the ranking:</u>

This project has a poor value (19.90) in the minimizing sub-criterion S16 compared to most of the remaining projects. This sub-criterion has a considerably high weight with respect to other sub-criteria. Even the lower bound of this sub-criterion weight has a very high value compared to the weights of the remaining sub-criteria. Having a poor value in this sub-criterion is a considerable disadvantage for this project.

This project has the second worst value for the minimizing sub-criterion S6 (41.41) among all the projects. From the ANP application, the upper bound for the weight of this sub-criterion was obtained as 0.0933, which is in the fourth order when the upper limits of sub-criterion weights are listed. Because of the high value of the upper bound of its weight, having a poor value for this sub-criterion is a considerable disadvantage to this project.

The value of maximizing sub-criterion S23 is equal to the worst value (0) for this project. There are only two other projects, P6 and P7, in which the value of this sub-criterion is also 0. The upper bound for the weight of this sub-criterion was obtained as 0.0308 from the ANP application.

Although the values of the sub-criteria S2 and S7 are equal to the worst value (100) for this project, there are many other projects in which the values of these sub-criteria are also equal to the worst value. Therefore, having these values is not a noteworthy disadvantage for this project. The same comment can be made for sub-criterion S19, which is equal to a poor value.

This project has a better value for the maximizing sub-criterion S21 (82.79) compared to most of the remaining projects. However, this does not lead to a considerable advantage to this project since the upper bound of this sub-criterion weight obtained from ANP is very low with respect to other weight limits.

Having best values in the sub-criteria S1 and S9 is not a distinctively advantageous case for this project, since there are many other projects in which the values of these sub-criteria are also equal to the best value.

Having the second best value among all the projects (8.69) in the minimizing sub-criterion S10 is not a considerable advantage for this project, since the upper bound of this sub-criterion weight is very low with respect to other weight limits.

<u>Project P6 – The second last in the ranking:</u>

As it was mentioned before, similar to P4 and P7, the value of maximizing sub-criterion S23 is equal to the worst value (0) for this project. The upper bound for the weight of this sub-criterion was obtained as 0.0308 from the ANP application.

Having the second worst value (40.89) in the sub-criteria S9 among all the projects is a minor disadvantage for this project, since the upper bound for the weight of this sub-criterion was obtained as 0.0274. This is also one of the reasons for this project to be outranked by P4.

Although the values of the sub-criteria S2 and S7 are equal to the worst value (100) for this project, there are many other projects in which the values of these sub-criteria are also equal to the worst value. Therefore, having these values is not a noteworthy disadvantage for this project. The same comment can be made for sub-criterion S19, which is equal to a poor value.

Having the best value in the sub-criterion S1 is not a distinctively advantageous case for this project, since there are many other projects in which the value of this sub-criterion is also equal to the best value. This is also one of the reasons for this project to be outranked by P4.

As it was previously mentioned, similar to P15, P11, P12 and P14, the value of minimizing sub-criterion S16 is equal to the best value (0) for this project. This sub-criterion has a considerably high weight with respect to other sub-criteria. Even the lower bound of this sub-criterion weight has a very high value compared to the weights of the remaining sub-criteria. Having a value of 0 in this sub-criterion should have been a considerable advantage for this project; however this advantage can not prevent this project to be at the end of the ranking.

<u>Project P1 – The last in the ranking:</u>

The value of minimizing sub-criterion S17 is equal to 75.37 for this project, which is the worst value among all the projects. There is only one other project, P2, in which this sub-criterion has also a poor value. All the remaining projects have a value of 0 (which is the best value) for this sub-criterion. This sub-criterion has a considerably high weight with respect to other sub-criteria, having an upper bound of 0.1089, which is in the third order when the upper limits of sub-criterion weights are listed. Even the lower bound of this sub-criterion weight has a high value compared to the weights of the remaining sub-criteria. Therefore, having the worst value, which is also very distant from the best value obtained by all the remaining thirteen projects causes a distinctive disadvantage for this project and becomes the main reason for the project to be the last in the ranking.

This value also causes a noticeable disadvantage for P2 and causes that project to be in lower positions in the ranking.

The value of minimizing sub-criterion S24 is equal to 20 for this project, which is the worst value among all the projects. Most of the projects have missing value for this sub-criterion, and their values are made equal to the average value, 14.76. This sub-criterion has a considerably high weight with respect to other sub-criteria. Even the lower bound of this sub-criterion weight has a high value compared to the weights of the remaining sub-criteria. Therefore, having the worst value among all the projects causes a distinctive disadvantage for this project and becomes another important reason for the project to be the last in the ranking.

The value of minimizing sub-criterion S27 is equal to 55.67 for this project, which is the second worst value among all the projects. Most of the projects have missing value for this sub-criterion, and their values are made equal to the average value, 49.25. The upper bound for the weight of this sub-criterion was obtained as 0.1149, which is in the second order when the upper limits of sub-criterion weights are listed. Although the value of this sub-criterion is not too distant from the values of the remaining projects, because of the high value of the upper bound of its weight, having the highest value for this sub-criterion leads to a considerable disadvantage to this project.

Having a poor value (87.50) in the sub-criterion S20 is also a disadvantage for this project, since there are many other projects in which the value of this sub-criterion is equal to the best value and the upper bound for the weight of this sub-criterion was obtained as 0.0404.

This project has the second worst value (32.5) in the minimizing sub-criterion S1, which has an upper bound of 0.0374. Most of the projects have the best value of 0 in this sub-criterion, causing a disadvantage for this project.

This project has a worse value for the maximizing sub-criterion S21 (3.82) compared to most of the remaining projects. However, this does not lead to a considerable disadvantage to this project since the upper bound of this sub-criterion weight obtained from ANP is very low with respect to other weight limits.

Although the values of the sub-criteria S2 and S7 are equal to the worst value (100) for this project, there are many other projects in which the values of these sub-criteria are also equal to the worst value. Therefore, having these values is not a noteworthy disadvantage for this project. The same comment can be made for sub-criterion S19, which is equal to a poor value.

Having the worst value among all the projects (53.69) in the minimizing sub-criterion S10 is not a considerable disadvantage for this project, since the upper bound of this sub-criterion weight is very low with respect to other weight limits.

Having the best value in the sub-criterion S9 is not a distinctively advantageous case for this project, since there are many other projects in which the value of this sub-criterion is also equal to the best value.

The value of minimizing sub-criterion S25 is equal to 9.33 for this project, which is the best value among all the projects. Most of the projects have missing value for this sub-criterion, and their values are made equal to the average value, 51.33. The upper bound for the weight of this sub-criterion was obtained as 0.0343. This is an advantage for this project; however it can not prevent this project to be the last in the ranking.

6.3.2 Discussion of the Results of the Second DEA Approach

In the second approach, the missing values were replaced by interval estimations and efficiency scores were obtained as intervals. Therefore, partial ranking was obtained, instead of complete ranking.

Efficiency intervals of the projects obtained from the model are presented in Figure 11. In this figure, the crisp efficiency values obtained from the first approach are also denoted by the vertical lines. As it can be seen from the figure, especially the upper bounds are further away from the crisp values obtained from the first approach. This is an expected result, since the efficiency values obtained from the first approach were already close to zero for most of the projects, and in the second approach, for the least favorable position of a project, the efficiency values moves closer to zero, whereas for the most favorable position of a project, very high efficiency values up to 1.76 are obtained.

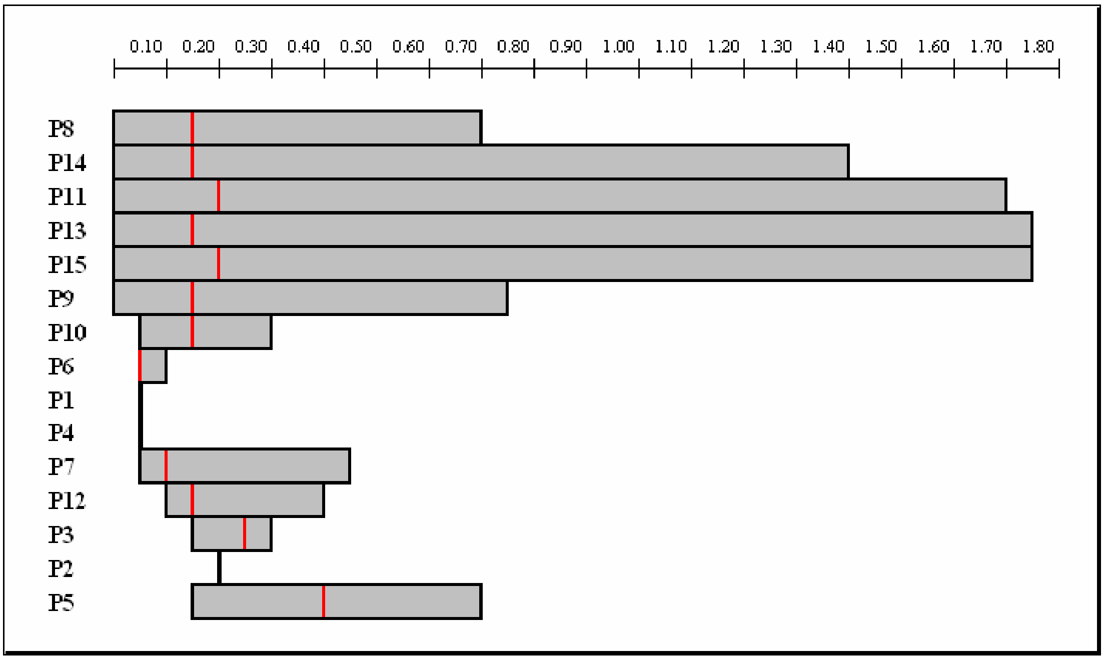

Figure 11 Efficiency Intervals Obtained from the Second DEA Approach

Crisp efficiency values obtained from the first approach, efficiency intervals obtained from this approach and the length of the intervals are given in Table 10.

Table 10 Efficiency Values Obtained from the First and Second DEA Approaches

Project	First Approach	Second Approach			Number of Missing Data
	Crisp Efficiency Value	Lower Bound on Efficiency	Upper Bound on Efficiency	Interval Lenght	
P1	0.045	0.042	0.045	0.003	-
P2	0.182	0.175	0.182	0.007	-
P4	0.058	0.052	0.064	0.012	2
P6	0.050	0.030	0.086	0.056	4
P3	0.240	0.165	0.317	0.152	3
P10	0.144	0.030	0.314	0.284	2
P12	0.168	0.084	0.381	0.296	4
P7	0.129	0.061	0.457	0.396	4
P5	0.381	0.212	0.681	0.470	3
P8	0.150	0.000	0.698	0.698	5
P9	0.172	0.010	0.763	0.752	5
P14	0.156	0.000	1.413	1.413	6
P11	0.215	0.000	1.711	1.711	5
P13	0.160	0.000	1.750	1.750	7
P15	0.217	0.000	1.757	1.757	4

From the results, it is observed that, one of the reasons of the increase in the interval length is the number of missing data (as the missing data for a project increases, interval length for efficiency increases). Projects P1 and P2 does not contain any missing value, as it was expected, the lower and upper bounds of efficiency of these projects are very close to each other. Conversely, in P11 and P13 wide efficiency intervals are obtained since the number of missing data in these projects is seven and six, respectively.

There are two other main factors that affect the length of the intervals; the priority of the sub-criterion whose data is missing (as the priority increases, interval length for efficiency increases) and the values of the project in other sub-criteria.

As it was previously explained, the sub-criteria S16, S17 and S24 have the highest importance. The value of S24 is missing in 12 projects and when these projects are evaluated for their most favorable position, this sub-criterion will have a considerable contribution in obtaining high efficiency values as upper bounds. There is no missing data for S16 and S17 in any of the projects.

Project P4 has a poor value (19.90) in the minimizing sub-criterion S16 compared to most of the remaining projects, which has a considerably high weight. At the same time, the value of minimizing sub-criterion S6, whose weight upper bound is in the fourth order when the upper limits of sub-criterion weights are listed, is equal to the second worst value among all the projects (41.41). Because of these considerable disadvantages, the upper bound of efficiency value of this project can not further increase more than a certain value and the efficiency interval of this project is very narrow.

Project P6 has poor values in many sub-criteria such as S23, S9, S2, S11 and S20. These poor values prevent the upper bound of efficiency value of this project from further increasing more than a certain value.

Project P3 has the second worst value (45.42) in the minimizing sub-criterion S16, which has a considerably high weight with respect to other sub-criteria. At the same time, the value of minimizing sub-criterion S27, whose weight upper bound is in the second order when the upper limits of sub-criterion weights are listed, is equal to the highest value among all the projects (61.11). Because of these considerable disadvantages, the upper bound of efficiency value of this project can not further increase up to a certain value.

From the efficiency intervals, only the following conclusions can be made for ranking.

Project P6, having an upper bound of 0.086 for efficiency value, is behind the projects, P3, P2 and P5 in the ranking.

Project P1, having an upper bound of 0.045 for efficiency value, is behind the projects P7, P12, P3, P2 and P5 in the ranking.

Project P4, having an upper bound of 0.064 for efficiency value, is behind the projects P12, P3, P2 and P5 in the ranking.

According two these results, the projects can be separated in two groups. The projects in the first group, which are P2, P3, P5, P7, P8, P9, P10, P11, P12, P13, P14, and P15 are in the first position in the ranking. The second group consists of the rest of the projects, P1, P4 and P6, which are in the second position in the ranking. The projects within the same group are indifferent from each other and at least one of the projects in the second group is dominated by at least one of the projects in the first group.

It is not possible to make any further conclusion about the ranking, other than the above clauses. Therefore, it can be concluded that, for this case study, the first approach provided more conclusive results than the second approach with a greater discriminating power.

It is observed that, in both of the approaches, projects P1, P4 and P6 are dominated by the other projects and take place at the last positions in the ranking.

6.4 Implementation of Other Applications for Comparison

For comparison purposes, the case study described in Section 6.2 was also solved by two other approaches given in Sections 6.4.1 and 6.4.2.

6.4.1 Weighted Sum Approach

Weighted Sum Method is one of the most commonly used MCDM methods. This method is based on aggregating the global value of each alternative by taking a weighted sum of the ratings of each alternative over all criteria.

For comparison purposes, the score of the projects were also calculated by implementing this approach, by using the crisp sub-criteria weights obtained from ANP in Section 5.1.2, with the two stage linear programming approach proposed by Chandran et al. (2005).

The interdependencies among the criteria and the sub-criteria were handled by using ANP; therefore the weights obtained from the Limit Supermatrix can be used in weighted sum method as if the criteria and the sub-criteria are independent.

The sub-criteria weights obtained from the above approach are listed in descending order in Table 11. Likewise the interval weights, sub-criteria S22, S10 and S21 have the lowest importance and sub-criteria S16, S17 and S24 have the highest importance, having considerably high weights with respect to other sub-criteria.

Table 11 The Crisp Sub-Criteria Weights obtained from ANP

Sub-Criterion	**Weight**
S22	0.0032
S10	0.0074
S21	0.0077
S11	0.0088
S9	0.0111
S23	0.0114
S1	0.0163
S2	0.0177
S8	0.0271
S19	0.0281
S25	0.0291
S6	0.0324
S20	0.0325
S27	0.0390
S7	0.0583
S24	0.0810
S17	0.1072
S16	0.1304

Similar to the first approach in DEA, for handling the missing data, the average value of the other projects were assigned to the missing values. Since the sub-criteria values, both maximizing and minimizing, are summed up in this approach, the values of the minimizing criteria were replaced by the complement values to 100. The sub-criteria values used in this approach can be seen from Table 28 in Appendix E.

The score of the projects, and the complete ranking obtained from this approach is given in Table 12. In order to bring the scores to the same scale with the efficiency values, the scores are also divided by 100. The last column displays the difference between the scores of the two consecutive projects. As it was explained before, this column is to analyze the distances among the positions of the projects in ranking, which reflect the relative performances of the projects with respect to each other.

Table 12 The Scores Obtained from the Weighted Sum Approach

#	**Project**	**Score**	**Score Divided by 100**	**Difference (In Scores Divided by 100)**
1	P15	52.996	0.530	-
2	P11	52.637	0.526	0.004
3	P7	51.113	0.511	0.015
4	P9	49.551	0.496	0.016
5	P12	48.323	0.483	0.012
6	P13	47.716	0.477	0.006
7	P5	46.626	0.466	0.011
8	P8	46.082	0.461	0.005
9	P14	45.728	0.457	0.004
10	P6	43.982	0.440	0.017
11	P4	42.108	0.421	0.019
12	P10	41.110	0.411	0.010
13	P3	36.084	0.361	0.050
14	P1	33.402	0.334	0.027
15	P2	32.449	0.324	0.010

It is seen that the ranking is different from the one obtained from the first DEA approach. The scores of the projects are close to each other. P15 is the first in the ranking, with a score of 0.530. P11, P7 and P9 follow P15 with scores of 0.526, 0.511 and 0.496, respectively. The last project in the ranking is P2, with a score of 0.324. P1 and P3 follow P2 with scores of 0.334 and 0.361, respectively.

It is observed that, there are noticeable differences for the rank of P5, P3, P2 and P7, when compared to the ranking obtained from the first approach. Projects P5 and P3, which are in the uppermost position in the first approach, are in noticeably lower positions in the third approach; P3 is even the third from the bottom in ranking and P2 is even in the last position. The ranking of the rest of the projects are similar in both approaches. This difference in ranking is because of difference in frameworks of these two approaches. DEA provides a more fair evaluation by highlighting the predominant sides of the projects and allowing each project to appear in their best possible light. Detailed discussion on the results obtained from this approach and comparison with the other approaches is provided in Section 6.5.

6.4.2 Defining Sub-Criteria Weight Intervals by Varying the Crisp Priorities Obtained From ANP

For comparison purposes, the weight intervals to be added as assurance region constraints in the DEA model were also defined by implementing the approach used by Sarkis (2000), by varying the crisp weights obtained from ANP in Section 5.1.2 The crisp sub-criteria weights obtained from the two stage linear programming approach proposed by Chandran et al. (2005) are presented in descending order in Table 11.

The upper and lower bounds on weights were obtained by varying the sub-criteria weights for a level of dispersion. Sarkis (2000) implemented various dispersions from 0.1% to 99.9% and concluded that as higher dispersions are given, the correlation of the results obtained from DEA with some MCDM methods decreases. Also taking this comment into consideration, the sub-criteria weights were decided to be varied by a percentage of 25%. All the sub-criteria weights were varied by the same amount and the variations were made symmetrical (i.e. the upper and lower bounds were made at an equal distance from the crisp sub-criteria weights).

The upper and lower bounds on weights were calculated as shown in Table 13.

Table 13 The Weight Intervals Obtained by 25% Dispersion

Sub-Criterion	**Crisp Weight**	**Lower Bound on Weight**	**Upper Bound on Weight**
S1	0.0163	0.0122	0.0204
S2	0.0177	0.0132	0.0221
S6	0.0324	0.0243	0.0405
S7	0.0583	0.0437	0.0729
S8	0.0271	0.0204	0.0339
S9	0.0111	0.0083	0.0138
S10	0.0074	0.0056	0.0093
S11	0.0088	0.0066	0.0110
S16	0.1304	0.0978	0.1630
S17	0.1072	0.0804	0.1340
S19	0.0281	0.0210	0.0351
S20	0.0325	0.0244	0.0407
S21	0.0077	0.0058	0.0096
S22	0.0032	0.0024	0.0039
S23	0.0114	0.0086	0.0143
S24	0.0810	0.0607	0.1012
S25	0.0291	0.0218	0.0364
S27	0.0390	0.0293	0.0488

These weight bounds were added as assurance region constraints in the DEA model used the first approach in which the average values of the other projects were assigned to the missing values.

The complete ranking, obtained from the first DEA approach is given in Table 14. For the purpose of analyzing the distances among the positions of the projects in ranking, the difference between the efficiency values of the two consecutive projects is displayed in the last column.

Table 14 Efficiency Values Obtained from the Approach in which the Weight Intervals are Obtained by Varying Crisp Weights

#	Project	Efficiency Value	Difference
1	P5	0.132	-
2	P3	0.110	0.021
3	P12	0.102	0.008
4	P7	0.101	0.001
5	P15	0.077	0.024
6	P9	0.076	0.001
7	P10	0.076	0.000
8	P11	0.074	0.002
9	P2	0.073	0.001
10	P13	0.051	0.022
11	P4	0.049	0.002
12	P8	0.046	0.003
13	P14	0.045	0.001
14	P6	0.043	0.003
15	P1	0.016	0.027

It is seen that, lower efficiency values are obtained when compared to the first DEA approach, but the ranking is similar. The rank of the uppermost projects, P5 and P3, the rank of the lowermost projects, P6 and P1, and the rank of P9 are exactly the same. Besides, the rank of P4, P8 and P13 are similar. There is a noticeable difference only for the rank of P7.

P5 is the first in the ranking with a relatively high distance from P3, having an efficiency value of 0.132. P3, P12 and P7 follow P5 with efficiency values of 0.110, 0.102 and 0.101, respectively. There is also a relatively high distance between the positions of P7 and P15. The last project in the ranking is P1, with an efficiency value of 0.016. P6 and P4 follow P1 with efficiency values of 0.043 and 0.045, respectively. P1 is noticeably in the lowermost position in the ranking. Detailed discussion on the results obtained from this approach and comparison with the other approaches is provided in Section 6.5.

6.5 Overall Comparison of the Implemented Approaches

Four approaches that were implemented are summarized below; the ranking and the efficiency values obtained from each approach are presented in .Table 15.

1st Approach: The proposed method. Interval sub-criteria weights obtained from ANP were used as assurance region constraints in the super-efficiency DEA model in which the average values of the other projects were assigned to the missing values.

2nd Approach: The proposed method. Interval sub-criteria weights obtained from ANP were used as assurance region constraints in the super-efficiency DEA model in which the missing values were replaced by interval estimations and efficiency scores were obtained as intervals.

3rd Approach: Weighted Sum Method. The score of the projects were calculated by taking a weighted sum, by using the crisp sub-criteria weights obtained from ANP with the two stage LP approach proposed by Chandran et al. (2005). The average values of the other projects were assigned to the missing values.

4th Approach: Interval weights are defined by implementing the approach used by Sarkis (2000). The crisp sub-criteria weights obtained from ANP with the two stage LP approach proposed by Chandran et al. (2005) were varied with a dispersion of 25%. These weight intervals used as assurance region constraints in the super-efficiency DEA model in which the average values of the other projects were assigned to the missing values.

	1st Approach		2nd Approach			3rd Approach		4th Approach	
	Eff.	Rank	LB on Eff.	UB on Eff.	Rank	Eff.	Rank	Eff.	Rank
P1	0,045	**15**	0,042	0,045	**2nd. position**	0,334	**14**	0,016	**15**
P2	0,182	5	0,175	0,182	**1st. position**	0,324	**15**	0,073	9
P3	0,240	2	0,165	0,317		0,361	**13**	0,110	2
P4	0,058	**13**	0,052	0,064	**2nd. position**	0,421	**11**	0,049	**11**
P5	0,381	**1**	0,212	0,681	**1st. position**	0,466	7	0,132	**1**
P6	0,050	**14**	0,030	0,086	**2nd. position**	0,440	**10**	0,043	**14**
P7	0,129	**12**	0,061	0,457	**1st. position**	0,511	3	0,101	4
P8	0,150	**10**	0,000	0,698		0,461	8	0,046	**12**
P9	0,172	6	0,010	0,763		0,496	4	0,076	6
P10	0,144	**11**	0,030	0,314		0,411	**12**	0,076	7
P11	0,215	4	0,000	1,711		0,526	2	0,074	8
P12	0,168	7	0,084	0,381		0,483	5	0,102	3
P13	0,160	8	0,000	1,750		0,477	6	0,051	**10**
P14	0,156	9	0,000	1,413		0,457	9	0,045	**13**
P15	0,217	3	0,000	1,757		0,530	1	0,077	5

It is seen that, the ranking obtained from the first and fourth approaches are similar, whereas the ranking in the third approach is different from them. Obtaining a different ranking in the third approach is an expected result, since in this method the score of each project was calculated by taking directly a weighted sum of the sub-criteria values, whereas in the first and fourth approaches, DEA was used in which each project were allowed to appear in their best possible light. The second approach resulted in a partial ranking, in which the majority of the projects are in the first position and indifferent from each other, therefore it is not possible to make much comparison of the results obtained in this approach with the ranking obtained in the other approaches.

The efficiency values obtained from the fourth approach are lower than the efficiency values obtained in the first approach. Furthermore, the distances among the positions of the projects are smaller. The reason for obtaining lower efficiencies and smaller distances is the tightness of the bounds on weights in the fourth approach.

The weight intervals were presented in Table 13. Similar to the categorization made for the proposed model, the sub-criteria can also be categorized with respect to their relative importance according to these weight intervals. This categorization can be seen in Table 16.

Table 16 Categorization According to the Weight Intervals by Varying Crisp Weights

Sub-Criterion	**Lower Bound on Weight**	**Upper Bound on Weight**
S22	0.0024	0.0039
S10	0.0056	0.0093
S21	0.0058	0.0096
S11	0.0066	0.0110
S9	0.0083	0.0138

Table 16 Continued - Categorization According to the Weight Intervals by Varying Crisp Weights

S23	0.0086	0.0143
S1	0.0122	0.0204
S2	0.0132	0.0221
S8	0.0204	0.0339
S19	0.0210	0.0351
S25	0.0218	0.0364
S6	0.0243	0.0405
S20	0.0244	0.0407
S27	0.0293	0.0488
S7	0.0437	0.0729
S24	0.0607	0.1012
S17	0.0804	0.1340
S16	0.0978	0.1630

When Table 16 is investigated, it can be seen that this categorization is same with the categorization given in Table 9, which is for the weight intervals in the proposed model. Sub-criteria S10, S21 and S22 have the lowest importance and sub-criteria S16, S17 and S24 have the highest importance. It is also observed that the weight intervals are narrower in the fourth approach. As the weight intervals gets narrower, the range between the highest weight value of a given sub-criterion and the lowest weight value of another sub-criterion gets narrower, which decreases the discrimination among the projects. Therefore, this tightness of the bounds is the reason for obtaining lower efficiencies and smaller distances. If the weight intervals had been defined by varying the crisp weights with a higher dispersion than 25%, higher efficiency values and longer distances would have been obtained; however the dispersion should not be increased too much, by taking into account the remark of Sarkis (2000); as higher dispersions are given, the correlation of the results obtained from DEA with some MCDM methods decreases.

It is needed to emphasize that, since the weight intervals would change depending on the amount of dispersion, the amount of dispersion should be carefully decided in this approach. In the proposed method, the weight intervals are determined based on the judgments of a group of DM and will remain unchanged unless a change in the sub-criteria and/or the pairwise judgments is made, resulting in a more precise approach.

As it was previously mentioned in Section 6.4.2, when the ranking obtained from the first and fourth approaches are compared, it is seen that ranking is similar. There is a noticeable difference only for the rank of P7, which comes to the fourth position in the fourth approach, whereas it is in the twelfth position in the first approach.

It is also observed that, whereas P5 is the first in ranking with a noticeable difference in the first approach, this distance decreases in the fourth approach. Furthermore, in the fourth approach, P1 is noticeably in the lowermost position in the ranking, whereas the efficiency values of P1 and P6 are close in the first approach. The main reasons for P7 to come to a better position in the fourth approach are the decrease in the relative value of the upper bound of sub-criteria S6 and the decrease in the relative value of the upper bound of sub-criteria S2, in which P7 is in disadvantageous position with respect to most of the other projects. It should be mentioned that, the assurance region constraints on weight values should be taken into account for making these comparisons, rather than the weight values.

As it was previously mentioned in Section 6.4.1, when the ranking obtained from the first and third approaches are compared, it is seen that there are noticeable differences for the rank of P5, P3, P2 and P7.

The decrease in the relative weights of the sub-criteria S27 and S23 when compared to their upper bounds used in the first approach, in which P5 is in advantageous positions, are the main reasons for the descent in ranking of P5. It should be mentioned that, the assurance region constraints on weight values should be taken into account for making these comparisons, rather than the weight values. Similarly, the decrease in the relative weights of the sub-criteria S6 and S23 when compared to their upper bounds used in the first approach, in which P3 is in advantageous positions are the main reasons for the descent in ranking of P3. The reasons for P2 to fall to the last position are the decrease in the relative weights of the sub-criteria S6, S2 and S9 when compared to their upper bounds used in the first approach, in which P2 is in advantageous positions; and the increase in the relative weights of the sub-criteria S16, S19 and S20 when compared to their lower bounds used in the first approach, in which this project is in disadvantageous positions. Finally, the increase in the relative weights of the sub-criteria S16, S7 and S20 when compared to their upper bounds used in the first approach, in which P7 is in advantageous positions are the main reasons for the increase in ranking of P7.

It is seen that P1 is in the last position in the first and fourth approaches; the third from the bottom in the third approach and in the second position in the second approach. Similarly, P1 is in the second last position in the first and fourth approaches; the tenth in the third approach and in the second position in the second approach. P4 is also in the lowermost positions in the first, third and fourth approaches; and in the second position in the second approach. Therefore, it can be concluded that, P1, P4 and P6 stand in the lowermost positions in the ranking obtained in all four approaches.

6.6 Data to be Recorded within the Institute for Calculation of the Sub-Criteria Metrics

After the construction of the performance evaluation system proposed in this study, the necessary data related to these sub-criteria metrics will be recorded systematically and regularly by the designated personnel and it will take a moment to calculate the metric values.

Likewise, the data required for calculating the metric values of the twelve unconsidered sub-criteria in the case study will be systematically recorded after the construction of this performance evaluation system. The procedures for keeping record of these data are proposed as follows.

S3 - The Satisfaction of the Customer Regarding the Deliverables

The necessary data for this metric can be recorded by maintaining a list of the deliverables submitted to the customer. For each project, the list contains the information of submission date and the status (whether the deliverable is under inspection or the response time of the customer is obtained; if obtained, whether the deliverable is accepted or a change request is offered).

S4 - Average Response Time to Customer Change Requests

As it was previously explained, the proposed engineering changes are being documented by Engineering Change Proposals. All the information about the change requests, such as the description and the cause of the request; whether the customer or a project personnel offered the request; if the origin is institute personnel, whether the request is rejected or accepted; the responsible person who is in charge to perform the changes and the initiation and conclusion dates of the change request.

As it can be seen above, comprehensive data about the change requests are recorded by the Engineering Change Proposals. It would be possible to record the necessary data for this metric by making only a small modification in these forms, by the inclusion of the information about "expected conclusion time of a change request".

S5 - Average Response Time to Additional Customer Requests

The necessary data for this metric can be recorded by maintaining a list of the additional customer requests, for each project, which contains the information of notification date, the time limit given by the customer and the conclusion date.

S12 - Quality of the Subcontractors

As it was previously mentioned, a subcontractor management system is also being constructed in the Institute, in which the subcontractors will be graded according to some predefined evaluation criteria. The necessary data for this metric are going to be provided by the database which will be constructed within the context of the studies on this subcontractor management system.

S13 - Subcontractor Review Results

For this metric, the necessary data about the subcontractor reviews include the information of the dates of reviews; non-conformities identified in that reviews; the time limit given for correction of the non-conformities and the dates that the non-conformities are corrected. These data should be recorded for each project, but it should be entered to the database, rather than recording separately.

S14 - Subcontractor Quality Audit Results

For this metric, the necessary data about the subcontractor quality audits include the information of the dates of audits; non-conformities identified in those audits and the dates that the non-conformities are corrected. These data should be recorded for each project, but it should be entered to the database, rather than recording separately.

S15 - Acceptance Satisfaction of the Supplied Items

The necessary data for this metric can be obtained from the list of supplied items in each project, and the status (whether the item is under inspection, accepted or rejected). These data should be recorded for each project, but it should be entered to the database, rather than recording separately.

S18 - Deviation in Overseas Procurement Rate

The missing data that avoids the calculation of this metric is the budget planned to be allocated to overseas procurements. Therefore, this metric can be obtained by keeping the record of the prescribed overseas expenditures during the preparation of the project budgets.

S26 - Test Performance

In the Institute, the results of each test are recorded by Test Result Form, but there exists neither a list nor a database in which all the test results are summed up. The necessary data for this metric can be recorded by maintaining a list of the verification tests, for each project, which contains the information of test date and the status (whether the test is successful or unsuccessful).

S28 - Commercially off-the-Shelf Item Usage

The necessary data for this metric are the costs of items in the BOM. By calculating and recording these costs and by keeping record of the COTS items, this metric can be calculated. As it was mentioned previously, $COTSU_{max}$ value will be determined at the initial phase of the projects, during the costing process.

S29 - Common Item Usage among Projects

Similar to the above sub-criterion, the necessary data are the costs of items in the BOM. By calculating and recording these costs and by keeping record of the common items, this metric can be calculated. As it was mentioned previously, CIU_{max} value will be determined at the initial phase of the projects, during the costing process.

S30 - Standard Item Usage

This metric can be calculated by keeping the record of the unique items in the BOM. As it was mentioned previously, SIU_{min} and SIU_{max} values will be determined at the initial phase of the projects, during the costing process.

CHAPTER 7

CONCLUSION

7.1 Summary of the Study

In this study, a multiple criteria decision making approach was proposed in order to obtain a ranking of customer-based Research and Development projects being executed in TÜBİTAK-SAGE, with respect to their performances. The criteria and the sub-criteria that were determined for performance evaluation are interdependent to each other. In order to handle these interdependencies, ANP was used in determination of the sub-criteria weight intervals.

A questionnaire was conducted among the experts in the Institute for defining the importance and influences of the criteria/sub-criteria, and pairwise comparison matrices were formed as interval judgments. From these interval judgments, the sub-criteria weights were also determined as intervals and they were inserted as assurance region constraints in a super-efficiency DEA model, which was used to obtain project ranking.

Because of the nature of the problem, values of some sub-criteria might be missing for some projects. Taking this factor into consideration, the DEA model was extended to handle missing values. To handle missing values, two distinct approaches were used. In the first approach, the average value of the available values for other projects were assigned to the missing values and in the second approach, the missing values were replaced by interval estimations and efficiency scores were obtained as intervals rather than crisp values.

The proposed model was applied to a real case study on performance evaluation of the ongoing customer-based projects in the Institute at the end of year 2006. For comparison purposes, the case study described in Section 6.2 was also solved by two other approaches given in Sections 6.4.1 and 6.4.2 and the results were discussed.

7.2 Discussions on the Approach

In conventional ANP, the Unweighted Supermatrix is formed by using the local priorities that are obtained from crisp pairwise comparison matrices by using the principal right eigenvector method. Determination of the priorities of the sub-criteria required a group decision making process within the Institute and in group decision making problems, using interval pairwise comparison matrices instead of deriving crisp judgments from the group, provides a more realistic framework. In this study, the conventional ANP approach was extended to handle interval judgments, and also to generate interval weight estimates from interval pairwise comparison matrices. Application of ANP with interval judgments in a group decision making process, and the approach proposed for the generation of sub-criteria weight intervals are contributions to the literature.

The combination of two methods, ANP and DEA, provided a different approach for project performance evaluation.

By using ANP only in determining the weight intervals but not in the whole process, the number of pairwise comparisons needed was reduced by a considerable amount. The case study was implemented with 15 projects and 30 sub-criteria. Even under these conditions, a full ANP approach would yield a burden of multitudinous additional pairwise comparisons. By the year 2007, 21 customer-based projects are being executed in the Institute and the number of projects increases continuously year by year. When this increase is considered, with a greater number of projects, the number of pairwise comparisons will be considerably high and the full ANP method will become impractical.

Besides the advantage of reducing the number of pairwise comparisons, ranking the projects by using a DEA model provided a more flexible evaluation and gave the opportunity to evaluate each project in their best possible light. By using a super-efficiency model with the assurance region constraints obtained from the ANP model, the discriminatory power of DEA was increased. Most importantly, addition of assurance region constraints provided the inclusion of the priorities given to the sub-criteria into the DEA model.

In the super-efficiency method, the DMUs that have marginal values can be favored and assigned an excessively high ranking. During scaling of the sub-criteria metrics, values above or below some defined boundary values were assigned the best or worst values (0 or 100), which lead to the elimination of the marginal values. Therefore, this drawback of the super-efficiency method is prevented by the proposed model.

As it was also mentioned in discussion of the results, in the first DEA approach complete ranking can be obtained, whereas in the second approach, in which the efficiency values are obtained as intervals, partial ranking can be made. As it occurred in the case study, the efficiency intervals may be spanned such that very few conclusions can be made about the ranking. Therefore, the first approach is recommended to be applied in the Institute which provides more conclusive results with greater discriminating power.

It is needed to emphasize that the ease of use and the time efficiency of the method are two important factors in implementing the approach at the Institute. The project ranking is desired to be obtained frequently in the Institute such as in monthly periods. Unless a change is made in the criteria/sub-criteria and/or the pairwise judgments, the ANP part of the method will not be solved at each time, the bounds on weights will remain unchanged and will be constantly added to the DEA super-efficiency model. Only the DEA model will be solved in which the ranking can be obtained within a short span of time.

As the number of projects to be evaluated increases, the ANP part of the approach remains unchanged, an additional constraint would be added to the the DEA model (Model SDA, Model SDAI-U and Model SDAI-L) for each newly included project.

As the number of criteria or sub-criteria increases, the number of pairwise comparisons in the ANP part would change depending on the location of the criteria/sub-criteria in the model and also on the interdependency relations for the newly included criteria/sub-criteria. The number of assurance region constraints in the DEA model also increases with addition of new sub-criteria. Since LP is used, addition of new constraints would not result in any considerable increase the computational time of the model.

The proposed model is a flexible one, which allows alterations in the performance evaluation criteria/sub-criteria, such as inclusion of new criteria/sub-criteria, removal of undesirable criteria/sub-criteria and the changes in the pairwise comparison judgments.

It is also needed to be emphasized that, although the proposed method was developed for evaluation of the customer-based projects in TÜBİTAK-SAGE, it is a generalized model that can be adapted or extended for ranking projects in any organization. The criteria/sub-criteria determined in this study is peculiar to TÜBİTAK-SAGE, factors for evaluating project performance and their priorities will vary in each organization. The approach can be implemented in any organization by making the necessary changes in the criteria/sub-criteria and the pairwise comparison judgments.

7.3 Suggestions for Further Research Areas

Because of the nature of the problem considered in this study, the alternatives (projects) are independent from each other (the ongoing customer-based projects in the Institute are independent from each other). Therefore, the proposed approach does not cover interdependent alternatives. As a future study, the approach can be extended to handle interdependencies among the alternatives.

In this study, the constraints on the sub-criteria weights were determined by obtaining weight intervals from the judgments among the Institute. Further research may contain application of sensitivity analysis by changing the judgments in derivation of the sub-criteria weight intervals.

As a final suggestion, in the future, the model can be extended to consider the satisfaction of the subcontractors and the partners in evaluation of project performance, by including the sub-criterion “Satisfaction of Subcontractors” beneath criterion C5 - Subcontractor Management and by adding a new criterion “Satisfaction of Partners”.

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APPENDIX A

DEFINITIONS

Bill of Materials: A listing of all the subassemblies, intermediates, parts and raw materials that go into a parent assembly showing the quantity of each required to make an assembly (Wallace et al., 1987).

Configuration Item: Any hardware, software, or combination of both that satisfies an end use function and is designated for separate configuration management (MIL-HDBK-61A).

Commercially off-the-shelf (COTS): COTS means a product, such as an item, material, software, component, subsystem, or system, sold or traded to the general public in the course of normal business operations at prices based on established catalog or market prices. (http://podaac.jpl.nasa.gov/glossary/, 2006)

Engineering Change:

(1) A change to the current approved configuration documentation of a configuration item,
(2) Any alteration to a product or its released configuration documentation. (MIL-HDBK-61A)

Engineering Change Proposal: The documentation by which a proposed engineering change is described, justified, and submitted to the document change authority for approval (MIL-HDBK-61A).

According to MIL-STD-973, Engineering Change Proposals are classified into two types class I and class II.

Class I engineering changes are those required to:

a. Correct deficiencies
b. Add or modify interface or interoperability requirements
c. Make a significant and measurable effectiveness change in the operational capabilities or logistics supportability of the system or item
d. Effect substantial life cycle costs/savings
e. Prevent slippage in the approved production schedule

An engineering change which impacts none of the class I factors shall be classified as a class II engineering change.

Item: A nonspecific term used to denote any product, including systems, material, parts, subassemblies, sets, accessories, etc. (MIL-HDBK-61A).

Release: The designation that a document representation or software version is approved by the appropriate authority and is subject to configuration change management procedures. After a document or software is released, any revision will be performed after Engineering Change Proposal approval (MIL-HDBK-61A).

Work Breakdown Structure: A product-oriented family tree composed of hardware, software, services, data and facilities. A WBS displays and defines the product, or products, to be developed and/or produced. It relates the elements of work to be accomplished to each other and to the end product (MIL-HDBK-881).

APPENDIX B

SUB-CRITERIA METRICS AND SCALING

Table 17 Sub-Criteria Metrics and Scaling

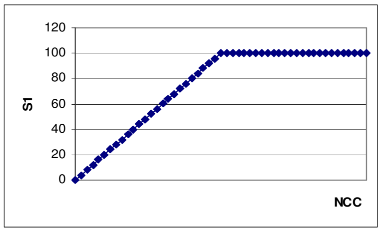
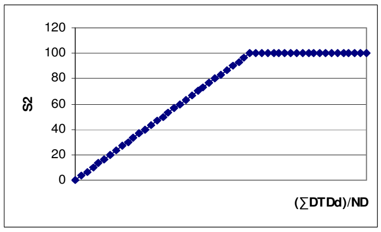
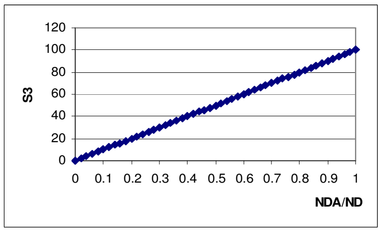
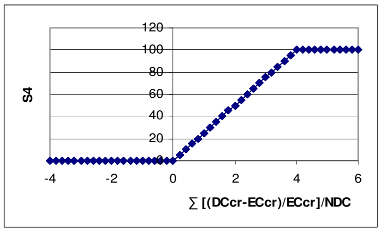
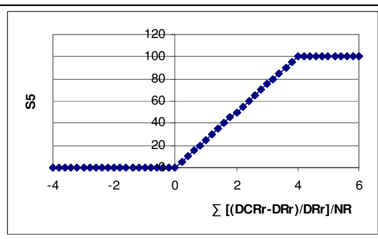
S1	NCC	Min.	
S2	$DD = \frac{\sum_{d=1}^{ND} DTD_d}{ND}$	Min.	
S3	$AS = \frac{NDA}{ND} \times 100$	Max.	
S4	$ART = \frac{\sum_{cr=1}^{NDC} \left(\frac{DC_{cr} - EC_{cr}}{EC_{cr}} \right)}{NDC}$	Min.	
S5	$ARTR = \frac{\sum_{r=1}^{NR} \left(\frac{DCR_r - DR_r}{DR_r} \right)}{NR}$	Min.	

Table 17 - Continued - Sub-Criteria Metrics and Scaling

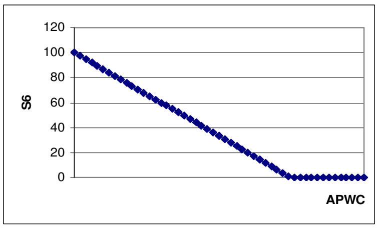
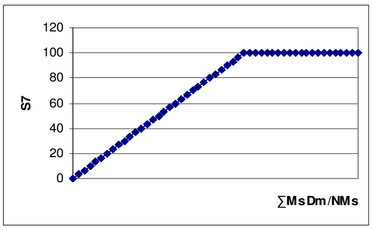
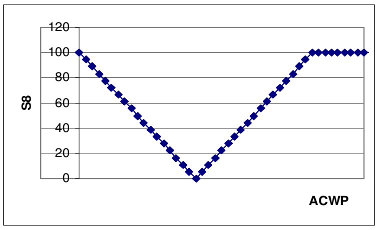
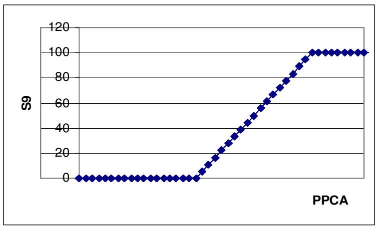
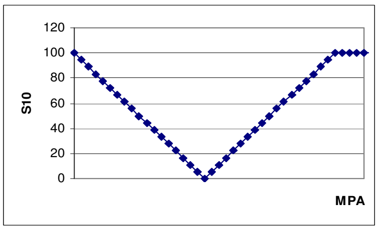
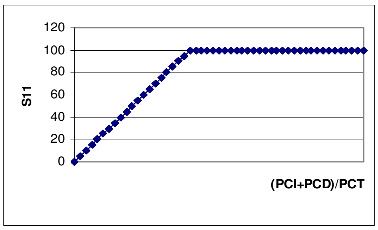
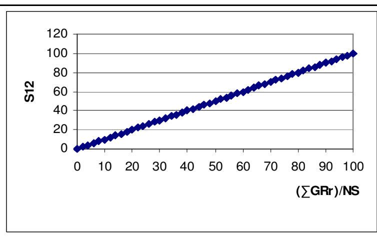
S6	$SD = PPWC - APWC$	Min.	
S7	$MsC = \dfrac{\sum_{m=1}^{NMs} MsD_m}{NMs}$	Min.	
S8	$PED = \left\lvert \dfrac{ACWP - BCWS}{BCWS} \times 100 \right\rvert$	Min.	
S9	$PPCD = \dfrac{PPCA - PPCP}{PPCP} \times 100$	Min.	
S10	$MPD = \left\lvert \dfrac{MPA - MPP}{MPP} \times 100 \right\rvert$	Min.	
S11	$TOR = \left(\dfrac{PCI + PCD}{PCT} \right) \times 100$	Min.	
S12	$QS = \dfrac{\sum_{s=1}^{NS} GR_s}{\text{NS}}$	Max.	

Table 17 - Continued - Sub-Criteria Metrics and Scaling

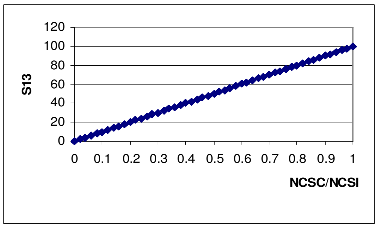
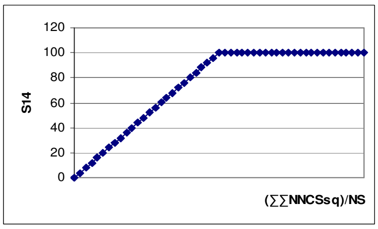
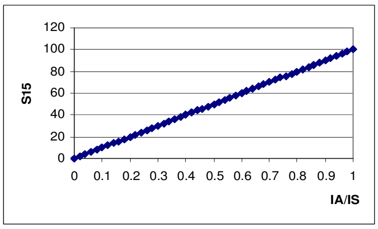
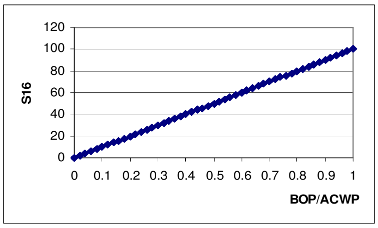
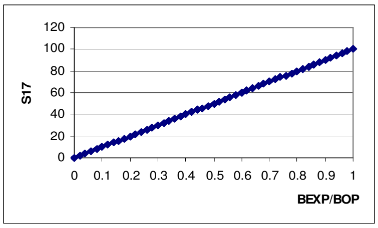
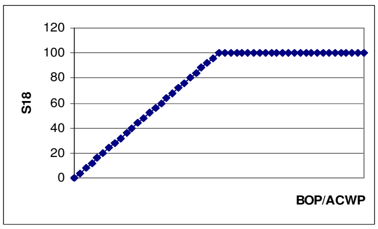
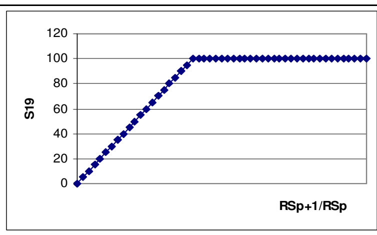
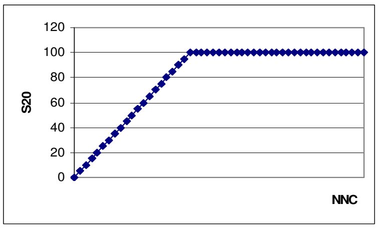
S13	$SRR = \frac{\text{NCSC}}{\text{NCSI}} \times 100$	Max.	
S14	$SQR = \frac{\sum_{s=1}^{NS} \sum_{q} NNCS_{sq}}{NS}$	Min.	
S15	$SAS = \frac{IA}{IS} \times 100$	Max.	
S16	$OPR = \frac{BOP}{ACWP} \times 100$	Min.	
S17	$EXPD = \frac{BEXP}{BOP} \times 100$	Min.	
S18	$OPRD = \frac{BOP}{ACWP} \Big/ \frac{BOPP}{BCWS}$	Min.	
S19	$RH = \frac{RS_{p+1}}{RS_{p}} \times 100$	Min.	

Table 17 - Continued - Sub-Criteria Metrics and Scaling

<table>
<tr><td>S20</td><td>NNC</td><td>Min.</td><td>
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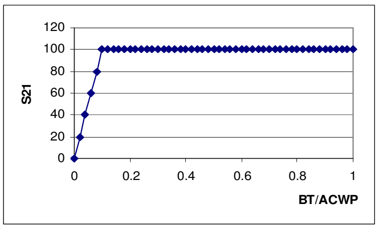
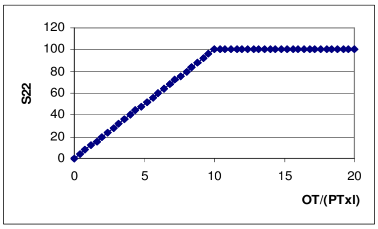
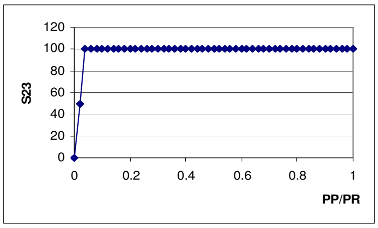
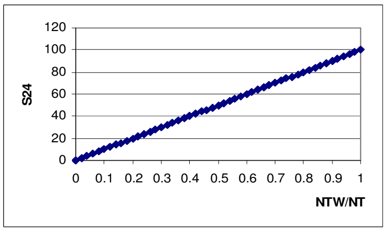
<tr><td>S21</td><td>$TRAIN = \frac{BT}{ACWP} \times 100$</td><td>Max.</td><td>
</td></tr>
<tr><td>S22</td><td>$OTR = \frac{OT}{PT}$</td><td>Min.</td><td>
</td></tr>
<tr><td>S23</td><td>$SP = \frac{PP}{PR} \times 100$</td><td>Max.</td><td>
</td></tr>
<tr><td>S24</td><td>$TECHPERF = \frac{NTW}{NT} \times 100$</td><td>Min.</td><td>
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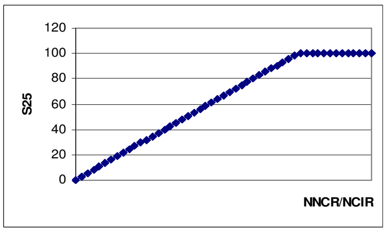
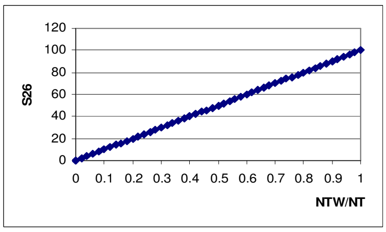
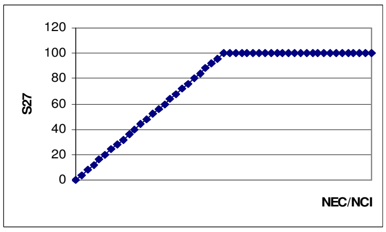
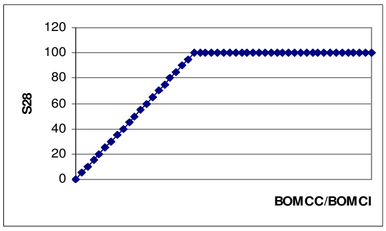
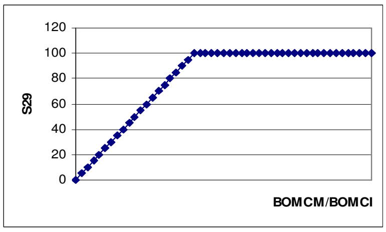
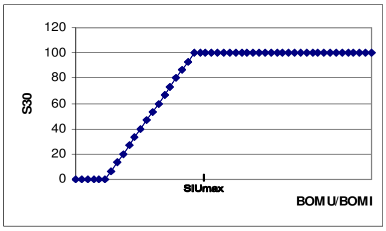
<tr><td>S25</td><td>$TECHREW = \frac{NNCR}{NCIR}$</td><td>Min.</td><td>
</td></tr>
<tr><td>S26</td><td>$TESTPERF = \frac{TS}{TT} \times 100$</td><td>Max.</td><td>
</td></tr>
</table>

Table 17 - Continued - Sub-Criteria Metrics and Scaling

S27	$ENGC = \dfrac{NEC}{NCI}$	Min.	
S28	$COTSU = \dfrac{BOMCC}{BOMCI} \times 100$	Max.	
S29	$CIU = \dfrac{BOMCCM}{BOMCI} \times 100$	Max.	
S30	$SIU = \dfrac{BOMU}{BOMI} \times 100$	Min.	

APPENDIX C

THE QUESTIONNAIRE ABOUT PROJECT PERFORMANCE EVALUATION CRITERIA

The questionnaire which consists of five parts is given in Table 19 - Table 23.

The scale that was used in evaluations is given in Table 18.

Table 18 The Scale Used in the Questionnaire

1	Eşit önemli
3	Biraz önemli
5	Fazla önemli
7	Çok fazla önemli
9	Aşırı derece önemli

Table 19 Questionnaire Part 1 - Pairwise Comparison of Criteria with respect to Project Performance

Proje Performansı üzerindeki etkileri açısından değerlendirildiğinde aşağıdaki iki kriterden hangisi diğerinden daha önemlidir ve kaç kat daha önemlidir?						
☐ C1- Müşteri Memnuniyeti	☐ C2- Zaman Kullanımı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C1- Müşteri Memnuniyeti	☐ C3- Mali Kaynak Kullanımı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C1- Müşteri Memnuniyeti	☐ C4- İnsan Kaynağı Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C1- Müşteri Memnuniyeti	☐ C5- Alt Yüklenici Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C1- Müşteri Memnuniyeti	☐ C6- Yurtdışına Bağımlılık	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C1- Müşteri Memnuniyeti	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C1- Müşteri Memnuniyeti	☐ C8- Kurum İçi Kalite Denetimi Sonuçları	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C1- Müşteri Memnuniyeti	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C1- Müşteri Memnuniyeti	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C1- Müşteri Memnuniyeti	☐ C11- Tasarımın Sadeliği	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C3- Mali Kaynak Kullanımı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C4- İnsan Kaynağı Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C5- Alt Yüklenici Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C6- Yurtdışına Bağımlılık	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C8- Kurum İçi Kalite Denetimi Sonuçları	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C11- Tasarımın Sadeliği	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C4- İnsan Kaynağı Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C5- Alt Yüklenici Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C6- Yurtdışına Bağımlılık	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C8- Kurum İçi Kalite Denetimi Sonuçları	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C11- Tasarımın Sadeliği	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Table 19 Continued - Questionnaire Part 1 - Pairwise Comparison of Criteria with respect to Project Performance

Proje Performansı üzerindeki etkileri açısından değerlendirildiğinde aşağıdaki iki kriterden hangisi diğerinden daha önemlidir ve kaç kat daha önemlidir?						
☐ C4- İnsan Kaynağı Yönetimi	☐ C5- Alt Yüklenici Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C4- İnsan Kaynağı Yönetimi	☐ C6- Yurtdışına Bağımlılık	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C4- İnsan Kaynağı Yönetimi	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C4- İnsan Kaynağı Yönetimi	☐ C8- Kurum İçi Kalite Denetimi Sonuçları	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C4- İnsan Kaynağı Yönetimi	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C4- İnsan Kaynağı Yönetimi	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C4- İnsan Kaynağı Yönetimi	☐ C11- Tasarımın Sadeliği	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C5- Alt Yüklenici Yönetimi	☐ C6- Yurtdışına Bağımlılık	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C5- Alt Yüklenici Yönetimi	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C5- Alt Yüklenici Yönetimi	☐ C8- Kurum İçi Kalite Denetimi Sonuçları	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C5- Alt Yüklenici Yönetimi	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C5- Alt Yüklenici Yönetimi	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C5- Alt Yüklenici Yönetimi	☐ C11- Tasarımın Sadeliği	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C6- Yurtdışına Bağımlılık	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C6- Yurtdışına Bağımlılık	☐ C8- Kurum İçi Kalite Denetimi Sonuçları	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C6- Yurtdışına Bağımlılık	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C6- Yurtdışına Bağımlılık	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C6- Yurtdışına Bağımlılık	☐ C11- Tasarımın Sadeliği	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C7- Risk Yönetimi	☐ C8- Kurum İçi Kalite Denetimi Sonuçları	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C7- Risk Yönetimi	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C7- Risk Yönetimi	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C7- Risk Yönetimi	☐ C11- Tasarımın Sadeliği	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Table 19 Continued - Questionnaire Part 1 - Pairwise Comparison of Criteria with respect to Project Performance

Proje Performansı üzerindeki etkileri açısından değerlendirildiğinde aşağıdaki iki kriterden hangisi diğerinden daha önemlidir ve kaç kat daha önemlidir?							
☐ C8- Kurum İçi Kalite Denetimi Sonuçları	☐ C9- Proje Personelinin Memnuniyeti		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C8- Kurum İçi Kalite Denetimi Sonuçları	☐ C10- Teknik Başarım		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C8- Kurum İçi Kalite Denetimi Sonuçları	☐ C11- Tasarımın Sadeliği		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C9- Proje Personelinin Memnuniyeti	☐ C10- Teknik Başarım		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C9- Proje Personelinin Memnuniyeti	☐ C11- Tasarımın Sadeliği		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C10- Teknik Başarım	☐ C11- Tasarımın Sadeliği		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Table 20 Questionnaire Part 2 - Pairwise Comparison for the Level of Influence of Criteria on Each Other

Aşağıdaki iki kriterden hangisi "Müşteri Memnuniyeti" kriterini daha çok etkiler ve kaç kat daha çok etkiler?						
☐ C2- Zaman Kullanımı	☐ C6- Yurtdışına Bağımlılık	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C6- Yurtdışına Bağımlılık	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
Aşağıdaki iki kriterden hangisi "Zaman Kullanımı" kriterini daha çok etkiler ve kaç kat daha çok etkiler?						
☐ C1- Müşteri Memnuniyeti	☐ C5- Alt Yüklenici Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C1- Müşteri Memnuniyeti	☐ C6- Yurtdışına Bağımlılık	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C1- Müşteri Memnuniyeti	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C1- Müşteri Memnuniyeti	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C5- Alt Yüklenici Yönetimi	☐ C6- Yurtdışına Bağımlılık	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C5- Alt Yüklenici Yönetimi	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C5- Alt Yüklenici Yönetimi	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C6- Yurtdışına Bağımlılık	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C6- Yurtdışına Bağımlılık	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C7 Risk Yönetimi	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Table 20 Continued - Questionnaire Part 2 - Pairwise Comparison for the Level of Influence of Criteria on Each Other

Aşağıdaki iki kriterden hangisi "Mali Kaynak Kullanımı" kriterini daha çok etkiler ve kaç kat daha çok etkiler?						
☐ C2- Zaman Kullanımı	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C7- Risk Yönetimi	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Aşağıdaki iki kriterden hangisi "İnsan Kaynağı Yönetimi" kriterini daha çok etkiler ve kaç kat daha çok etkiler?						
☐ C2- Zaman Kullanımı	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C9- Proje Personelinin Memnuniyeti	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Aşağıdaki iki kriterden hangisi "Risk Yönetimi" kriterini daha çok etkiler ve kaç kat daha çok etkiler?						
☐ C2- Zaman Kullanımı	☐ C3- Mali Kaynak Kullanımı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C4- İnsan Kaynağı Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C4- İnsan Kaynağı Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C4- İnsan Kaynağı Yönetimi	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Table 20 Continued - Questionnaire Part 2 - Pairwise Comparison for the Level of Influence of Criteria on Each Other

Aşağıdaki iki kriterden hangisi "Proje Personelinin Memnuniyeti" kriterini daha çok etkiler ve kaç kat daha çok etkiler?							
☐ C2- Zaman Kullanımı	☐ C3- Mali Kaynak Kullanımı		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C4- İnsan Kaynağı Yönetimi		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C10- Teknik Başarım		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C4- İnsan Kaynağı Yönetimi		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C10- Teknik Başarım		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C4- İnsan Kaynağı Yönetimi	☐ C10- Teknik Başarım		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Table 21 Questionnaire Part 3 - Pairwise Comparison of Sub-Criteria with respect to Criteria

"Müşteri Memnuniyeti" üzerindeki etkileri açısından değerlendirildiğinde aşağıdaki iki altkriterden hangisi diğerinden daha önemlidir ve kaç kat daha önemlidir?

☐ S1- Müşteri şikayeti	☐ S2- Teslimatlardaki gecikmeler (SAGE kaynaklı)		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S1- Müşteri şikayeti	☐ S3- Müşteriye teslim edilen kalemlerde müşterinin kabul memnuniyeti		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S1- Müşteri şikayeti	☐ S4- Müşteri tarafından talep edilen değişiklik isteklerinin gerçekleştirilme süresi		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S1- Müşteri şikayeti	☐ S5- Müşteri tarafından talep edilen ekstra isteklerin gerçekleştirilme süresi		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S2- Teslimatlardaki gecikmeler (SAGE kaynaklı)	☐ S3- Müşteriye teslim edilen kalemlerde müşterinin kabul memnuniyeti		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S2- Teslimatlardaki gecikmeler (SAGE kaynaklı)	☐ S4- Müşteri tarafından talep edilen değişiklik isteklerinin gerçekleştirilme süresi		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S2- Teslimatlardaki gecikmeler (SAGE kaynaklı)	☐ S5- Müşteri tarafından talep edilen ekstra isteklerin gerçekleştirilme süresi		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S3- Müşteriye teslim edilen kalemlerde müşterinin kabul memnuniyeti	☐ S4- Müşteri tarafından talep edilen değişiklik isteklerinin gerçekleştirilme süresi		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S3- Müşteriye teslim edilen kalemlerde müşterinin kabul memnuniyeti	☐ S5- Müşteri tarafından talep edilen ekstra isteklerin gerçekleştirilme süresi		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S4- Müşteri tarafından talep edilen değişiklik isteklerinin gerçekleştirilme süresi	☐ S5- Müşteri tarafından talep edilen ekstra isteklerin gerçekleştirilme süresi		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

"Zaman Kullanımı" üzerindeki etkileri açısından değerlendirildiğinde aşağıdaki iki altkriterden hangisi diğerinden daha önemlidir ve kaç kat daha önemlidir?

☐ S6- Zaman sapması	☐ S7- Kilometre taşlarının tamamlanma durumu		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

"Mali Kaynak Kullanımı" üzerindeki etkileri açısından değerlendirildiğinde aşağıdaki iki altkriterden hangisi diğerinden daha önemlidir ve kaç kat daha önemlidir?

☐ S8- Proje harcamalarında maliyet sapması	☐ S9- Proje personeli ücretlerinde maliyet sapması		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Table 21 Continued - Questionnaire Part 3 - Pairwise Comparison of Sub-Criteria with respect to Criteria

"İnsan Kaynağı Yönetimi" üzerindeki etkileri açısından değerlendirildiğinde aşağıdaki iki altkriterden hangisi diğerinden daha önemlidir ve kaç kat daha önemlidir?						
☐ S10- İnsan kaynağı sapması	☐ S11- Projedeki çalışanların devir oranı (turnover rate)	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

"Alt Yüklenici Yönetimi" üzerindeki etkileri açısından değerlendirildiğinde aşağıdaki iki altkriterden hangisi diğerinden daha önemlidir ve kaç kat daha önemlidir?						
☐ S12- Altyüklenicilerin niteliği	☐ S13- Altyüklenici gözden geçirme sonuçları	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S12- Altyüklenicilerin niteliği	☐ S14- Altyüklenici kalite denetimlerinde saptanan uygunsuzluk sayısı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S12- Altyüklenicilerin niteliği	☐ S15- Altyüklenicilerden tedarik edilen malın/hizmetin kabul memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S13- Altyüklenici gözden geçirme sonuçları	☐ S14- Altyüklenici kalite denetimlerinde saptanan uygunsuzluk sayısı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S13- Altyüklenici gözden geçirme sonuçları	☐ S15- Altyüklenicilerden tedarik edilen malın/hizmetin kabul memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S14- Altyüklenici kalite denetimlerinde saptanan uygunsuzluk sayısı	☐ S15- Altyüklenicilerden tedarik edilen malın/hizmetin kabul memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

"Yurtdışına Bağımlılık" üzerindeki etkileri açısından değerlendirildiğinde aşağıdaki iki altkriterden hangisi diğerinden daha önemlidir ve kaç kat daha önemlidir?						
☐ S16- Yurtdışı Satın Alma Tutarı	☐ S17- Export Lisans Bağımlılığı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S16- Yurtdışı Satın Alma Tutarı	☐ S18- Gerçekleşen/Planlanan dışabağımlılık oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S17- Export Lisans Bağımlılığı	☐ S18- Gerçekleşen/Planlanan dışabağımlılık oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Table 21 Continued - Questionnaire Part 3 - Pairwise Comparison of Sub-Criteria with respect to Criteria

"Proje Personelinin Memnuniyeti" üzerindeki etkileri açısından değerlendirildiğinde aşağıdaki iki altkriterden hangisi diğerinden daha önemlidir ve kaç kat daha önemlidir?						
☐ S21- Proje personelinin kendini geliştirmesine katkı	☐ S22- Fazla mesai oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S21- Proje personelinin kendini geliştirmesine katkı	☐ S23- Projeden personele dağıtılan hizmet geliri miktarı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S22- Fazla mesai oranı	☐ S23- Projeden personele dağıtılan hizmet geliri miktarı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
"Teknik Başarım" üzerindeki etkileri açısından değerlendirildiğinde aşağıdaki iki altkriterden hangisi diğerinden daha önemlidir ve kaç kat daha önemlidir?						
☐ S24- Teknik başarım kriterlerinin karşılanması	☐ S25- Teknik gözden geçirme sonuçları	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S24- Teknik başarım kriterlerinin karşılanması	☐ S26- Doğrulama testlerindeki başarım oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S24- Teknik başarım kriterlerinin karşılanması	☐ S27- Tasarımın olgunluğu	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S25- Teknik gözden geçirme sonuçları	☐ S26- Doğrulama testlerindeki başarım oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S25- Teknik gözden geçirme sonuçları	☐ S27- Tasarımın olgunluğu	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S26- Doğrulama testlerindeki başarım oranı	☐ S27- Tasarımın olgunluğu	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
"Tasarımın Sadeliği" üzerindeki etkileri açısından değerlendirildiğinde aşağıdaki iki altkriterden hangisi diğerinden daha önemlidir ve kaç kat daha önemlidir?						
☐ S28- Hazır ticari ürün (COTS) kullanımı	☐ S29- Projeler arası ortak ürün kullanımı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S28- Hazır ticari ürün (COTS) kullanımı	☐ S30- Standart ürün kullanımı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S29- Projeler arası ortak ürün kullanımı	☐ S30- Standart ürün kullanımı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Table 22 Questionnaire Part 4 - Pairwise Comparison for the Level of Influence of Sub-Criteria on Each Other

Aşağıdaki iki altkriterden hangisi "Müşteri şikayeti" altkriterini daha çok etkiler ve kaç kat daha çok etkiler?						
☐ S5- Müşteri tarafından talep edilen ekstra isteklerin gerçekleştirilme süresi	☐ S7- Kilometre taşlarının tamamlanma durumu	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S5- Müşteri tarafından talep edilen ekstra isteklerin gerçekleştirilme süresi	☐ S18- Gerçekleşen/Planlanan dışabağımlılık oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S5- Müşteri tarafından talep edilen ekstra isteklerin gerçekleştirilme süresi	☐ S26- Doğrulama testlerindeki başarım oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S7- Kilometre taşlarının tamamlanma durumu	☐ S18- Gerçekleşen/Planlanan dışabağımlılık oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S7- Kilometre taşlarının tamamlanma durumu	☐ S26- Doğrulama testlerindeki başarım oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S18- Gerçekleşen/Planlanan dışabağımlılık oranı	☐ S26- Doğrulama testlerindeki başarım oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Aşağıdaki iki altkriterden hangisi "Zaman sapması" altkriterini daha çok etkiler ve kaç kat daha çok etkiler?						
☐ S2- Teslimatlardaki gecikmeler (SAGE kaynaklı)	☐ S7- Kilometre taşlarının tamamlanma durumu	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S2- Teslimatlardaki gecikmeler (SAGE kaynaklı)	☐ S12- Altyüklenicilerin niteliği	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S2- Teslimatlardaki gecikmeler (SAGE kaynaklı)	☐ S15- Altyüklenicilerden tedarik edilen malın/hizmetin kabul memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S2- Teslimatlardaki gecikmeler (SAGE kaynaklı)	☐ S17- Export Lisans Bağımlılığı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S2- Teslimatlardaki gecikmeler (SAGE kaynaklı)	☐ S19- Risk ele alma	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S2- Teslimatlardaki gecikmeler (SAGE kaynaklı)	☐ S26- Doğrulama testlerindeki başarım oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S2- Teslimatlardaki gecikmeler (SAGE kaynaklı)	☐ S27- Tasarımın olgunluğu	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S7- Kilometre taşlarının tamamlanma durumu	☐ S12- Altyüklenicilerin niteliği	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Table 22 Continued - Questionnaire Part 4 - Pairwise Comparison for the Level of Influence of Sub-Criteria on Each Other

Aşağıdaki iki altkriterden hangisi "Zaman sapması" altkriterini daha çok etkiler ve kaç kat daha çok etkiler?						
☐ S7- Kilometre taşlarının tamamlanma durumu	☐ S15- Altyüklenicilerden tedarik edilen malın/hizmetin kabul memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S7- Kilometre taşlarının tamamlanma durumu	☐ S17- Export Lisans Bağımlılığı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S7- Kilometre taşlarının tamamlanma durumu	☐ S19- Risk ele alma	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S7- Kilometre taşlarının tamamlanma durumu	☐ S26- Doğrulama testlerindeki başarım oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S7- Kilometre taşlarının tamamlanma durumu	☐ S27- Tasarımın olgunluğu	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S12- Altyüklenicilerin niteliği	☐ S15- Altyüklenicilerden tedarik edilen malın/hizmetin kabul memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S12- Altyüklenicilerin niteliği	☐ S17- Export Lisans Bağımlılığı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S12- Altyüklenicilerin niteliği	☐ S19- Risk ele alma	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S12- Altyüklenicilerin niteliği	☐ S26- Doğrulama testlerindeki başarım oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S12- Altyüklenicilerin niteliği	☐ S27- Tasarımın olgunluğu	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S15- Altyüklenicilerden tedarik edilen malın/hizmetin kabul memnuniyeti	☐ S17- Export Lisans Bağımlılığı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S15- Altyüklenicilerden tedarik edilen malın/hizmetin kabul memnuniyeti	☐ S19- Risk ele alma	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S15- Altyüklenicilerden tedarik edilen malın/hizmetin kabul memnuniyeti	☐ S26- Doğrulama testlerindeki başarım oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S15- Altyüklenicilerden tedarik edilen malın/hizmetin kabul memnuniyeti	☐ S27- Tasarımın olgunluğu	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Table 22 Continued - Questionnaire Part 4 - Pairwise Comparison for the Level of Influence of Sub-Criteria on Each Other

Aşağıdaki iki altkriterden hangisi "Zaman sapması" altkriterini daha çok etkiler ve kaç kat daha çok etkiler?

☐ S17- Export Lisans Bağımlılığı	☐ S19- Risk ele alma	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S17- Export Lisans Bağımlılığı	☐ S26- Doğrulama testlerindeki başarım oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S17- Export Lisans Bağımlılığı	☐ S27- Tasarımın olgunluğu	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S19- Risk ele alma	☐ S26- Doğrulama testlerindeki başarım oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S19- Risk ele alma	☐ S27- Tasarımın olgunluğu	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S26- Doğrulama testlerindeki başarım oranı	☐ S27- Tasarımın olgunluğu	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Aşağıdaki iki altkriterden hangisi "Kilometre taşlarının tamamlanma durumu" altkriterini daha çok etkiler ve kaç kat daha çok etkiler?

☐ S2- Teslimatlardaki gecikmeler (SAGE kaynaklı)	☐ S12- Altyüklenicilerin niteliği	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S2- Teslimatlardaki gecikmeler (SAGE kaynaklı)	☐ S15- Altyüklenicilerden tedarik edilen malın/hizmetin kabul memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S2- Teslimatlardaki gecikmeler (SAGE kaynaklı)	☐ S17- Export Lisans Bağımlılığı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S2- Teslimatlardaki gecikmeler (SAGE kaynaklı)	☐ S19- Risk ele alma	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S2- Teslimatlardaki gecikmeler (SAGE kaynaklı)	☐ S26- Doğrulama testlerindeki başarım oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S2- Teslimatlardaki gecikmeler (SAGE kaynaklı)	☐ S27- Tasarımın olgunluğu	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Table 22 Continued - Questionnaire Part 4 - Pairwise Comparison for the Level of Influence of Sub-Criteria on Each Other

Aşağıdaki iki altkriterden hangisi "Kilometre taşlarının tamamlanma durumu" altkriterini daha çok etkiler ve kaç kat daha çok etkiler?								
☐ S12- Altyüklenicilerin niteliği	☐ S15- Altyüklenicilerden tedarik edilen malın/hizmetin kabul memnuniyeti		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S12- Altyüklenicilerin niteliği	☐ S17- Export Lisans Bağımlılığı		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S12- Altyüklenicilerin niteliği	☐ S19- Risk ele alma		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S12- Altyüklenicilerin niteliği	☐ S26- Doğrulama testlerindeki başarım oranı		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S12- Altyüklenicilerin niteliği	☐ S27- Tasarımın olgunluğu		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S15- Altyüklenicilerden tedarik edilen malın/hizmetin kabul memnuniyeti	☐ S17- Export Lisans Bağımlılığı		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S15- Altyüklenicilerden tedarik edilen malın/hizmetin kabul memnuniyeti	☐ S19- Risk ele alma		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S15- Altyüklenicilerden tedarik edilen malın/hizmetin kabul memnuniyeti	☐ S26- Doğrulama testlerindeki başarım oranı		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S15- Altyüklenicilerden tedarik edilen malın/hizmetin kabul memnuniyeti	☐ S27- Tasarımın olgunluğu		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S17- Export Lisans Bağımlılığı	☐ S19- Risk ele alma		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S17- Export Lisans Bağımlılığı	☐ S26- Doğrulama testlerindeki başarım oranı		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S17- Export Lisans Bağımlılığı	☐ S27- Tasarımın olgunluğu		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S19- Risk ele alma	☐ S26- Doğrulama testlerindeki başarım oranı		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S19- Risk ele alma	☐ S27- Tasarımın olgunluğu		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S26- Doğrulama testlerindeki başarım oranı	☐ S27- Tasarımın olgunluğu		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Table 22 Continued - Questionnaire Part 4 - Pairwise Comparison for the Level of Influence of Sub-Criteria on Each Other

Aşağıdaki iki altkriterden hangisi "Proje harcamalarında maliyet sapması" altkriterini daha çok etkiler ve kaç kat daha çok etkiler?						
☐ S19- Risk ele alma	☐ S26- Doğrulama testlerindeki başarım oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S19- Risk ele alma	☐ S27- Tasarımın olgunluğu	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S26- Doğrulama testlerindeki başarım oranı	☐ S27- Tasarımın olgunluğu	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Aşağıdaki iki altkriterden hangisi "Proje personeli ücretlerinde maliyet sapması" altkriterini daha çok etkiler ve kaç kat daha çok etkiler?						
☐ S7- Kilometre taşlarının tamamlanma durumu	☐ S8- Proje harcamalarında maliyet sapması	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Aşağıdaki iki altkriterden hangisi "İnsan kaynağı sapması" altkriterini daha çok etkiler ve kaç kat daha çok etkiler?						
☐ S7- Kilometre taşlarının tamamlanma durumu	☐ S11- Projedeki çalışanların devir oranı (turnover rate)	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S7- Kilometre taşlarının tamamlanma durumu	☐ S22- Fazla mesai oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S7- Kilometre taşlarının tamamlanma durumu	☐ S26- Doğrulama testlerindeki başarım oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S11- Projedeki çalışanların devir oranı (turnover rate)	☐ S22- Fazla mesai oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S11- Projedeki çalışanların devir oranı (turnover rate)	☐ S26- Doğrulama testlerindeki başarım oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S22- Fazla mesai oranı	☐ S26- Doğrulama testlerindeki başarım oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Table 22 Continued - Questionnaire Part 4 - Pairwise Comparison for the Level of Influence of Sub-Criteria on Each Other

Aşağıdaki iki altkriterden hangisi "Projedeki çalışanların devir oranı (turnover rate)" altkriterini daha çok etkiler ve kaç kat daha çok etkiler?						
☐ S21- Proje personelinin kendini geliştirmesine katkı	☐ S22- Fazla mesai oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S21- Proje personelinin kendini geliştirmesine katkı	☐ S23- Projeden personele dağıtılan hizmet geliri miktarı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S22- Fazla mesai oranı	☐ S23- Projeden personele dağıtılan hizmet geliri miktarı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
Aşağıdaki iki altkriterden hangisi "Altyüklenicilerin niteliği" altkriterini daha çok etkiler ve kaç kat daha çok etkiler?						
☐ S14- Altyüklenici kalite denetimlerinde saptanan uygunsuzluk sayısı	☐ S15- Altyüklenicilerden tedarik edilen malın/hizmetin kabul memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
Aşağıdaki iki altkriterden hangisi "Risk ele alma" altkriterini daha çok etkiler ve kaç kat daha çok etkiler?						
☐ S6- Zaman sapması	☐ S7- Kilometre taşlarının tamamlanma durumu	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S6- Zaman sapması	☐ S8- Proje harcamalarında maliyet sapması	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S6- Zaman sapması	☐ S9- Proje personeli ücretlerinde maliyet sapması	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S6- Zaman sapması	☐ S11- Projedeki çalışanların devir oranı (turnover rate)	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S6- Zaman sapması	☐ S24- Teknik başarım kriterlerinin karşılanması	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S6- Zaman sapması	☐ S26- Doğrulama testlerindeki başarım oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Table 22 Continued - Questionnaire Part 4 - Pairwise Comparison for the Level of Influence of Sub-Criteria on Each Other

Aşağıdaki iki altkriterden hangisi "Risk ele alma" altkriterini daha çok etkiler ve kaç kat daha çok etkiler?								
☐ S7- Kilometre taşlarının tamamlanma durumu	☐ S8- Proje harcamalarında maliyet sapması		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S7- Kilometre taşlarının tamamlanma durumu	☐ S9- Proje personeli ücretlerinde maliyet sapması		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S7- Kilometre taşlarının tamamlanma durumu	☐ S11- Projedeki çalışanların devir oranı (turnover rate)		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S7- Kilometre taşlarının tamamlanma durumu	☐ S24- Teknik başarım kriterlerinin karşılanması		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S7- Kilometre taşlarının tamamlanma durumu	☐ S26- Doğrulama testlerindeki başarım oranı		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S8- Proje harcamalarında maliyet sapması	☐ S9- Proje personeli ücretlerinde maliyet sapması		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S8- Proje harcamalarında maliyet sapması	☐ S11- Projedeki çalışanların devir oranı (turnover rate)		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S8- Proje harcamalarında maliyet sapması	☐ S24- Teknik başarım kriterlerinin karşılanması		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S8- Proje harcamalarında maliyet sapması	☐ S26- Doğrulama testlerindeki başarım oranı		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S9- Proje personeli ücretlerinde maliyet sapması	☐ S11- Projedeki çalışanların devir oranı (turnover rate)		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S9- Proje personeli ücretlerinde maliyet sapması	☐ S24- Teknik başarım kriterlerinin karşılanması		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S9- Proje personeli ücretlerinde maliyet sapması	☐ S26- Doğrulama testlerindeki başarım oranı		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S11- Projedeki çalışanların devir oranı (turnover rate)	☐ S24- Teknik başarım kriterlerinin karşılanması		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S11- Projedeki çalışanların devir oranı (turnover rate)	☐ S26- Doğrulama testlerindeki başarım oranı		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S24- Teknik başarım kriterlerinin karşılanması	☐ S26- Doğrulama testlerindeki başarım oranı		☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Table 22 Continued - Questionnaire Part 4 - Pairwise Comparison for the Level of Influence of Sub-Criteria on Each Other

Aşağıdaki iki altkriterden hangisi "Fazla mesai oranı" altkriterini daha çok etkiler ve kaç kat daha çok etkiler?						
☐ S7- Kilometre taşlarının tamamlanma durumu	☐ S10- İnsan kaynağı sapması	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S7- Kilometre taşlarının tamamlanma durumu	☐ S26- Doğrulama testlerindeki başarım oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ S10- İnsan kaynağı sapması	☐ S26- Doğrulama testlerindeki başarım oranı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Aşağıdaki iki altkriterden hangisi "Projeden personele dağıtılan hizmet geliri miktarı" altkriterini daha çok etkiler ve kaç kat daha çok etkiler?						
☐ S8- Proje harcamalarında maliyet sapması	☐ S9- Proje personeli ücretlerinde maliyet sapması	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Table 23 Questionnaire Part 5 - Pairwise Comparison for the Level of Influence of Sub-Criteria on Criteria (Feedback)

Aşağıdaki iki kriterden hangisi "Teslimatlardaki gecikmeler (SAGE kaynaklı)" altkriterinden daha çok etkilenir ve kaç kat daha çok etkilenir?						
☐ C1- Müşteri Memnuniyeti	☐ C2- Zaman Kullanımı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
Aşağıdaki iki kriterden hangisi "Zaman sapması" altkriterinden daha çok etkilenir ve kaç kat daha çok etkilenir?						
☐ C2- Zaman Kullanımı	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
Aşağıdaki iki kriterden hangisi "Kilometre taşlarının tamamlanma durumu" altkriterinden daha çok etkilenir ve kaç kat daha çok etkilenir?						
☐ C1- Müşteri Memnuniyeti	☐ C2- Zaman Kullanımı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C1- Müşteri Memnuniyeti	☐ C3- Mali Kaynak Kullanımı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C1- Müşteri Memnuniyeti	☐ C4- İnsan Kaynağı Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C1- Müşteri Memnuniyeti	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C1- Müşteri Memnuniyeti	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C3- Mali Kaynak Kullanımı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C4- İnsan Kaynağı Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C4- İnsan Kaynağı Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Table 23 Continued - Questionnaire Part 5 - Pairwise Comparison for the Level of Influence of Sub-Criteria on Criteria (Feedback)

Aşağıdaki iki kriterden hangisi "Kilometre taşlarının tamamlanma durumu" altkriterinden daha çok etkilenir ve kaç kat daha çok etkilenir?						
☐ C4- İnsan Kaynağı Yönetimi	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C4- İnsan Kaynağı Yönetimi	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C7- Risk Yönetimi	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
Aşağıdaki iki kriterden hangisi "Proje harcamalarında maliyet sapması" altkriterinden daha çok etkilenir ve kaç kat daha çok etkilenir?						
☐ C3- Mali Kaynak Kullanımı	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C7- Risk Yönetimi	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
Aşağıdaki iki kriterden hangisi "Proje personeli ücretlerinde maliyet sapması" altkriterinden daha çok etkilenir ve kaç kat daha çok etkilenir?						
☐ C3- Mali Kaynak Kullanımı	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C7- Risk Yönetimi	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
Aşağıdaki iki kriterden hangisi "İnsan kaynağı sapması" altkriterinden daha çok etkilenir ve kaç kat daha çok etkilenir?						
☐ C4- İnsan Kaynağı Yönetimi	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
Aşağıdaki iki kriterden hangisi "Projedeki çalışanların devir oranı (turnover rate)" altkriterinden daha çok etkilenir ve kaç kat daha çok etkilenir?						
☐ C4- İnsan Kaynağı Yönetimi	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Table 23 Continued - Questionnaire Part 5 - Pairwise Comparison for the Level of Influence of Sub-Criteria on Criteria (Feedback)

Aşağıdaki iki kriterden hangisi "Altyüklenicilerin niteliği" altkriterinden daha çok etkilenir ve kaç kat daha çok etkilenir?						
☐ C2- Zaman Kullanımı	☐ C5- Alt Yüklenici Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
Aşağıdaki iki kriterden hangisi "Altyüklenicilerden tedarik edilen malın/hizmetin kabul memnuniyeti" altkriterinden daha çok etkilenir ve kaç kat daha çok etkilenir?						
☐ C2- Zaman Kullanımı	☐ C5- Alt Yüklenici Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
Aşağıdaki iki kriterden hangisi "Export Lisans Bağımlılığı" altkriterinden daha çok etkilenir ve kaç kat daha çok etkilenir?						
☐ C2- Zaman Kullanımı	☐ C6- Yurtdışına Bağımlılık	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
Aşağıdaki iki kriterden hangisi "Gerçekleşen/Planlanan dışabağımlılık oranı" altkriterinden daha çok etkilenir ve kaç kat daha çok etkilenir?						
☐ C1- Müşteri Memnuniyeti	☐ C6- Yurtdışına Bağımlılık	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
Aşağıdaki iki kriterden hangisi "Risk ele alma" altkriterinden daha çok etkilenir ve kaç kat daha çok etkilenir?						
☐ C2- Zaman Kullanımı	☐ C3- Mali Kaynak Kullanımı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
Aşağıdaki iki kriterden hangisi "Proje personelinin kendini geliştirmesine katkı" altkriterinden daha çok etkilenir ve kaç kat daha çok etkilenir?						
☐ C4- İnsan Kaynağı Yönetimi	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Table 23 Continued - Questionnaire Part 5 - Pairwise Comparison for the Level of Influence of Sub-Criteria on Criteria (Feedback)

Aşağıdaki iki kriterden hangisi "Fazla mesai oranı" altkriterinden daha çok etkilenir ve kaç kat daha çok etkilenir?						
☐ C4- İnsan Kaynağı Yönetimi	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
Aşağıdaki iki kriterden hangisi "Projeden personele dağıtılan hizmet geliri miktarı" altkriterinden daha çok etkilenir ve kaç kat daha çok etkilenir?						
☐ C4- İnsan Kaynağı Yönetimi	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
Aşağıdaki iki kriterden hangisi "Teknik başarım kriterlerinin karşılanması" altkriterinden daha çok etkilenir ve kaç kat daha çok etkilenir?						
☐ C7- Risk Yönetimi	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
Aşağıdaki iki kriterden hangisi "Doğrulama testlerindeki başarım oranı" altkriterinden daha çok etkilenir ve kaç kat daha çok etkilenir?						
☐ C1- Müşteri Memnuniyeti	☐ C2- Zaman Kullanımı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C1- Müşteri Memnuniyeti	☐ C3- Mali Kaynak Kullanımı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C1- Müşteri Memnuniyeti	☐ C4- İnsan Kaynağı Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C1- Müşteri Memnuniyeti	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C1- Müşteri Memnuniyeti	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C1- Müşteri Memnuniyeti	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C3- Mali Kaynak Kullanımı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C4- İnsan Kaynağı Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

Table 23 Continued - Questionnaire Part 5 - Pairwise Comparison for the Level of Influence of Sub-Criteria on Criteria (Feedback)

Aşağıdaki iki kriterden hangisi "Doğrulama testlerindeki başarım oranı" altkriterinden daha çok etkilenir ve kaç kat daha çok etkilenir?						
☐ C2- Zaman Kullanımı	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C4- İnsan Kaynağı Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C4- İnsan Kaynağı Yönetimi	☐ C7- Risk Yönetimi	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C4- İnsan Kaynağı Yönetimi	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C4- İnsan Kaynağı Yönetimi	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C7- Risk Yönetimi	☐ C9- Proje Personelinin Memnuniyeti	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C7- Risk Yönetimi	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C9- Proje Personelinin Memnuniyeti	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
Aşağıdaki iki kriterden hangisi "Tasarımın olgunluğu" altkriterinden daha çok etkilenir ve kaç kat daha çok etkilenir?						
☐ C2- Zaman Kullanımı	☐ C3- Mali Kaynak Kullanımı	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C2- Zaman Kullanımı	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ C3- Mali Kaynak Kullanımı	☐ C10- Teknik Başarım	☐ 1	☐ 3	☐ 5	☐ 7	☐ 9

APPENDIX D

SUPERMATRICES

The cluster matrix, which is formed by assigning equal importance and influence to all the clusters, is given in Figure 12.

	1 GOAL	2 CRITERIA	3 SUB-CRITERIA
GOAL	0	0	0
CRITERIA	1	0.5	0.5
SUB-CRITERIA	0	0.5	0.5

Figure 12 Cluster Matrix

The Unweighted Supermatrix, constructed by using the crisp priorities derived from the interval pairwise comparison matrices by using the two stage linear programming approach proposed by Chandran et al. (2005), is given in Figure 13.

The Weighted Supermatrix and the Limit Supermatrix derived from this Unweighted Supermatrix are given in Figure 14 and Figure 15.

The Unweighted Supermatrix, constructed by using the priorities derived from the lower bounds of the pairwise comparison judgments by using the eigenvector method, is given in Figure 16, and the corresponding Weighted Supermatrix and Limit Supermatrix are given in Figure 17 and Figure 18, respectively.

The Unweighted Supermatrix, constructed by using the priorities derived from the upper bounds of the pairwise comparison judgments by using the eigenvector method, is given in Figure 19, and the corresponding Weighted Supermatrix Limit Supermatrix are given in Figure 20 and, Figure 21 respectively.

		1 GOAL	2 CRITERIA											3 SUB-CRITERIA																													
		PP	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**	**S15**	**S16**	**S17**	**S18**	**S19**	**S20**	**S21**	**S22**	**S23**	**S24**	**S25**	**S26**	**S27**	**S28**	**S29**	**S30**
1 GOAL	**PP**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 CRITERIA	**C1**	0.2062	0	0.0927	0	0	0	0	0	0	0	0	0	1	0.2500	1	1	1	0	0.2799	0	0	0	0	0	0	0	0	0	0	0.4365	0	0	0	0	0	0	0	0.2269	0	0	0	0
	C2	0.1299	0.2824	0	0.3035	0.3622	0	0	0.3227	0	0.1255	0	0	0	0.7500	0	0	0	0.8210	0.2799	0	0	0	0	0.3090	0	0	0.4365	0	0.4365	0	0.2566	0	0	0	0	0	0	0.2130	0.3514	0	0	0
	C3	0.0887	0	0	0	0	0	0	0.1862	0	0.2174	0	0	0	0	0	0	0	0	0.1251	0.6859	0.5099	0	0	0	0	0	0	0	0	0	0.2163	0	0	0	0	0	0	0.2001	0.2266	0	0	0
	C4	0.0687	0	0	0	0	0	0	0.1007	0	0.3765	0	0	0	0	0	0	0	0	0.1251	0	0	0.6341	0.7949	0	0	0	0	0	0	0	0	0	0.1791	0.5000	0.1446	0	0	0.0585	0	0	0	0
	C5	0.0491	0	0.2451	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6910	1	1	0.5635	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C6	0.1006	0.1375	0.2785	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.5635	0.5635	0	0	0	0	0	0	0	0	0	0	0	0
	C7	0.0450	0	0.1053	0.1775	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1790	0.0932	0.1372	0.1698	0	0.2051	0	0	0	0	0	0	0	0.5271	0	0	0	0	0.1446	0	0.0755	0	0	0	0
	C8	0.0336	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	C9	0.0780	0	0	0	0.3325	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0968	0.1770	0.3202	0.3659	0	0	0	0	0	0	0	0	0	0	0.8209	0.5000	0.8554	0	0	0.0710	0	0	0	0
	C10	0.1743	0.5801	0.2785	0.5190	0.3053	0	0	0.3904	0	0.2806	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8554	1	0.1549	0.4220	0	0	0
	C11	0.0260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
3 SUB-CRITERIA	**S1**	0	0.3401	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S2	0	0.1520	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1771	0.2570	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S3	0	0.2323	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S4	0	0.1622	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S5	0	0.1133	0	0	0	0	0	0	0	0	0	0	0.2281	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S6	0	0	0.3957	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0989	0	0	0	0	0	0	0	0	0	0	0
	S7	0	0	0.6043	0	0	0	0	0	0	0	0	0	0.2698	0	0	0	0	0.1562	0	0	0.5731	0.2198	0	0	0	0	0	0	0	0	0.1246	0	0	0.3514	0	0	0	0	0	0	0	0
	S8	0	0	0	0.7257	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4269	0	0	0	0	0	0	0	0	0	0.1246	0	0	0	0.5000	0	0	0	0	0	0	0
	S9	0	0	0	0.2743	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0415	0	0	0	0.5000	0	0	0	0	0	0	0
	S10	0	0	0	0	0.5000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2266	0	0	0	0	0	0	0	0
	S11	0	0	0	0	0.5000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2601	0	0	0	0	0	0	0	0	0.0536	0	0	0	0	0	0	0	0	0	0	0
	S12	0	0	0	0	0	0.4548	0	0	0	0	0	0	0	0	0	0	0	0.0354	0.0786	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S13	0	0	0	0	0	0.1173	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S14	0	0	0	0	0	0.1173	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2743	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S15	0	0	0	0	0	0.3106	0	0	0	0	0	0	0	0	0	0	0	0.0590	0.0817	0	0	0	0	0.7257	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S16	0	0	0	0	0	0	0.2163	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
	S17	0	0	0	0	0	0	0.4764	0	0	0	0	0	0	0	0	0	0	0.2095	0.1830	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S18	0	0	0	0	0	0	0.3073	0	0	0	0	0	0.0899	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S19	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0.0698	0.0609	0.1949	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S20	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S21	0	0	0	0	0	0	0	0	0	0.3880	0	0	0	0	0	0	0	0	0	0	0	0	0.2553	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S22	0	0	0	0	0	0	0	0	0	0.0974	0	0	0	0	0	0	0	0	0	0	0	0.2601	0.1243	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S23	0	0	0	0	0	0	0	0	0	0.5146	0	0	0	0	0	0	0	0	0	0	0	0	0.6204	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S24	0	0	0	0	0	0	0	0	0	0	0.4456	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2785	0	0	0	0	0	0	0	0	0	0	0
	S25	0	0	0	0	0	0	0	0	0	0	0.1684	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S26	0	0	0	0	0	0	0	0	0	0	0.2175	0	0.4122	0	0	0	0	0.1771	0.2084	0.4945	0	0.2601	0	0	0	0	0	0	0	0	0.2785	0	0	0.4220	0	1	0	0	1	0	0	0
	S27	0	0	0	0	0	0	0	0	0	0	0.1684	0	0	0	0	0	0	0.1160	0.1303	0.3105	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S28	0	0	0	0	0	0	0	0	0	0	0	0.3178	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S29	0	0	0	0	0	0	0	0	0	0	0	0.4649	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S30	0	0	0	0	0	0	0	0	0	0	0	0.2173	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 13 Unweighted Supermatrix 1 - Constructed by Using the Crisp Priorities Derived From the Interval Pairwise Comparison Matrices

		1 GOAL	2 CRITERIA											3 SUB-CRITERIA																													
		PP	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30
1 GOAL	PP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 CRITERIA	C1	0.2062	0	0.0463	0	0	0	0	0	0	0	0	0	0.5	0.2500	1	0.5	1	0	0.1399	0	0	0	0	0	0	0	0	0	0	0.2182	0	0	0	0	0	0	0	0.2269	0	0	0	0
	C2	0.1299	0.1412	0	0.1517	0.1811	0	0	0.1613	0	0.0628	0	0	0	0.7500	0	0	0	0.4105	0.1399	0	0	0	0	0.1545	0	0	0.4365	0	0.2182	0	0.1283	0	0	0	0	0	0	0.2130	0.1757	0	0	0
	C3	0.0887	0	0	0	0	0	0	0.0931	0	0.1087	0	0	0	0	0	0	0	0	0.0626	0.3429	0.2550	0	0	0	0	0	0	0	0	0	0.1082	0	0	0	0	0	0	0.2001	0.1133	0	0	0
	C4	0.0687	0	0	0	0	0	0	0.0503	0	0.1883	0	0	0	0	0	0	0	0	0.0626	0	0	0.3171	0.3975	0	0	0	0	0	0	0	0	0	0.1791	0.2500	0.0723	0	0	0.0585	0	0	0	0
	C5	0.0491	0	0.1225	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3455	1	1	0.5635	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C6	0.1006	0.0688	0.1393	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.2818	0.2818	0	0	0	0	0	0	0	0	0	0	0	0
	C7	0.0450	0	0.0526	0.0888	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0895	0.0466	0.0686	0.0849	0	0.1025	0	0	0	0	0	0	0	0.2635	0	0	0	0	0.0723	0	0.0755	0	0	0	0
	C8	0.0336	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	C9	0.0780	0	0	0	0.1662	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0484	0.0885	0.1601	0.1829	0	0	0	0	0	0	0	0	0	0	0.8209	0.2500	0.4277	0	0	0.0710	0	0	0	0
	C10	0.1743	0.2900	0.1393	0.2595	0.1527	0	0	0.1952	0	0.1403	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4277	1	0.1549	0.2110	0	0	0
	C11	0.0260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
3 SUB-CRITERIA	S1	0	0.1701	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S2	0	0.0760	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0885	0.1285	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S3	0	0.1162	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S4	0	0.0811	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S5	0	0.0566	0	0	0	0	0	0	0	0	0	0	0.1141	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S6	0	0	0.1979	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0494	0	0	0	0	0	0	0	0	0	0	0
	S7	0	0	0.3021	0	0	0	0	0	0	0	0	0	0.1349	0	0	0	0	0.0781	0	0	0.2865	0.1099	0	0	0	0	0	0	0	0	0.0623	0	0	0.1757	0	0	0	0	0	0	0	0
	S8	0	0	0	0.3628	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2135	0	0	0	0	0	0	0	0	0	0.0623	0	0	0	0.2500	0	0	0	0	0	0	0
	S9	0	0	0	0.1372	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0208	0	0	0	0.2500	0	0	0	0	0	0	0
	S10	0	0	0	0	0.2500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1133	0	0	0	0	0	0	0	0
	S11	0	0	0	0	0.2500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1300	0	0	0	0	0	0	0	0	0.0268	0	0	0	0	0	0	0	0	0	0	0
	S12	0	0	0	0	0	0.4548	0	0	0	0	0	0	0	0	0	0	0	0.0177	0.0393	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S13	0	0	0	0	0	0.1173	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S14	0	0	0	0	0	0.1173	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1372	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S15	0	0	0	0	0	0.3106	0	0	0	0	0	0	0	0	0	0	0	0.0295	0.0409	0	0	0	0	0.3628	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S16	0	0	0	0	0	0	0.2163	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0
	S17	0	0	0	0	0	0	0.4764	0	0	0	0	0	0	0	0	0	0	0.1047	0.0915	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S18	0	0	0	0	0	0	0.3073	0	0	0	0	0	0.0449	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S19	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0.0349	0.0305	0.0975	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S20	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S21	0	0	0	0	0	0	0	0	0	0.1940	0	0	0	0	0	0	0	0	0	0	0	0	0.1276	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S22	0	0	0	0	0	0	0	0	0	0.0487	0	0	0	0	0	0	0	0	0	0	0	0.1300	0.0622	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S23	0	0	0	0	0	0	0	0	0	0.2573	0	0	0	0	0	0	0	0	0	0	0	0	0.3102	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S24	0	0	0	0	0	0	0	0	0	0	0.4456	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1392	0	0	0	0	0	0	0	0	0	0	0
	S25	0	0	0	0	0	0	0	0	0	0	0.1684	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S26	0	0	0	0	0	0	0	0	0	0	0.2175	0	0.2061	0	0	0	0	0.0885	0.1042	0.2473	0	0.1300	0	0	0	0	0	0	0	0	0.1392	0	0	0.2110	0	0.5	0	0	0.5	0	0	0
	S27	0	0	0	0	0	0	0	0	0	0	0.1684	0	0	0	0	0	0	0.0580	0.0652	0.1553	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S28	0	0	0	0	0	0	0	0	0	0	0	0.3178	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S29	0	0	0	0	0	0	0	0	0	0	0	0.4649	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S30	0	0	0	0	0	0	0	0	0	0	0	0.2173	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 14 Weighted Supermatrix 1

		1 GOAL	2 CRITERIA										
		PP	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
1 GOAL	PP	0	0	0	0	0	0	0	0	0	0	0	0
2 CRITERIA	C1	0.0496	0.0527	0.0527	0.0528	0.0528	0.0526	0.0526	0.0528	0	0.0528	0.0528	0
	C2	0.0809	0.0860	0.0859	0.0861	0.0862	0.0862	0.0852	0.0861	0	0.0862	0.0861	0
	C3	0.0287	0.0305	0.0304	0.0307	0.0307	0.0305	0.0298	0.0306	0	0.0307	0.0307	0
	C4	0.0146	0.0155	0.0155	0.0156	0.0156	0.0155	0.0151	0.0156	0	0.0156	0.0156	0
	C5	0.0429	0.0456	0.0456	0.0458	0.0458	0.0464	0.0445	0.0457	0	0.0458	0.0458	0
	C6	0.1069	0.1137	0.1142	0.1128	0.1126	0.1132	0.1188	0.1129	0	0.1124	0.1126	0
	C7	0.0232	0.0247	0.0246	0.0248	0.0248	0.0247	0.0242	0.0248	0	0.0249	0.0248	0
	C8	0.0336	0	0	0	0	0	0	0	0	0	0	0
	C9	0.0174	0.0185	0.0184	0.0186	0.0186	0.0185	0.018	0.0186	0	0.0187	0.0186	0
	C10	0.0893	0.0950	0.0947	0.0953	0.0954	0.0948	0.0932	0.0953	0	0.0955	0.0954	0
	C11	0.0260	0	0	0	0	0	0	0	0	0	0	0
3 SUB-CRITERIA	S1	0.008434	0.0090	0.009	0.009	0.009	0.0089	0.0089	0.009	0	0.009	0.009	0
	S2	0.009123	0.0097	0.0097	0.0097	0.0097	0.0097	0.0096	0.0097	0	0.0097	0.0097	0
	S3	0.007772	0.0083	0.0083	0.0083	0.0083	0.0082	0.0082	0.0083	0	0.0083	0.0083	0
	S4	0.004023	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0	0.0043	0.0043	0
	S5	0.003771	0.0040	0.004	0.004	0.004	0.004	0.004	0.004	0	0.004	0.004	0
	S6	0.016719	0.0178	0.0178	0.0178	0.0178	0.0178	0.0176	0.0178	0	0.0178	0.0178	0
	S7	0.03013	0.032	0.0320	0.0321	0.0321	0.0321	0.0317	0.0321	0	0.0321	0.0321	0
	S8	0.014019	0.0149	0.0149	0.0150	0.015	0.0149	0.0145	0.015	0	0.015	0.015	0
	S9	0.005714	0.0061	0.0061	0.0061	0.0061	0.0061	0.0059	0.0061	0	0.0061	0.0061	0
	S10	0.003837	0.0041	0.0041	0.0041	0.0041	0.0041	0.004	0.0041	0	0.0041	0.0041	0
	S11	0.00454	0.0048	0.0048	0.0049	0.0049	0.0048	0.0047	0.0049	0	0.0049	0.0049	0
	S12	0.020997	0.0223	0.0223	0.0224	0.0224	0.0227	0.0218	0.0224	0	0.0224	0.0224	0
	S13	0.005035	0.0053	0.0054	0.0054	0.0054	0.0055	0.0052	0.0054	0	0.0054	0.0054	0
	S14	0.007916	0.0084	0.0084	0.0084	0.0085	0.0086	0.0082	0.0084	0	0.0085	0.0084	0
	S15	0.022674	0.0241	0.0241	0.0242	0.0242	0.0246	0.0235	0.0242	0	0.0242	0.0242	0
	S16	0.067366	0.0717	0.072	0.071	0.0709	0.0713	0.0752	0.0711	0	0.0707	0.0709	0
	S17	0.055402	0.0589	0.0592	0.0585	0.0584	0.0587	0.0615	0.0585	0	0.0583	0.0584	0
	S18	0.033207	0.0353	0.0355	0.035	0.0349	0.0351	0.0370	0.0351	0	0.0349	0.035	0
	S19	0.014494	0.0154	0.0154	0.0155	0.0155	0.0154	0.0151	0.0155	0	0.0155	0.0155	0
	S20	0	0	0	0	0	0	0	0	1	0	0	0
	S21	0.003961	0.0042	0.0042	0.0042	0.0042	0.0042	0.0041	0.0042	0	0.0042	0.0042	0
	S22	0.00163	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0	0.0017	0.0017	0
	S23	0.005893	0.0063	0.0062	0.0063	0.0063	0.0062	0.0061	0.0063	0	0.0063	0.0063	0
	S24	0.041838	0.0445	0.0444	0.0447	0.0447	0.0444	0.0436	0.0446	0	0.0447	0.0447	0
	S25	0.015052	0.016	0.016	0.0161	0.0161	0.016	0.0157	0.0161	0	0.0161	0.0161	0
	S26	0.063137	0.0671	0.0669	0.0674	0.0675	0.067	0.0657	0.0674	0	0.0675	0.0675	0
	S27	0.020163	0.0214	0.0214	0.0215	0.0215	0.0214	0.021	0.0215	0	0.0216	0.0215	0
	S28	0	0	0	0	0	0	0	0	0	0	0	0.3178
	S29	0	0	0	0	0	0	0	0	0	0	0	0.4649
	S30	0	0	0	0	0	0	0	0	0	0	0	0.2173

	3 SUB-CRITERIA														
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
PP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C1	0.0527	0.0527	0.0527	0.0527	0.0527	0.0527	0.0527	0.0528	0.0528	0.0528	0.0528	0.0526	0.0526	0.0526	0.0526
C2	0.086	0.0859	0.086	0.086	0.086	0.0859	0.0860	0.0861	0.0861	0.0862	0.0862	0.0861	0.0862	0.0862	0.0861
C3	0.0305	0.0305	0.0305	0.0306	0.0305	0.0304	0.0305	0.0307	0.0307	0.0307	0.0307	0.0305	0.0305	0.0305	0.0305
C4	0.0155	0.0155	0.0155	0.0155	0.0155	0.0155	0.0155	0.0156	0.0156	0.0156	0.0156	0.0155	0.0155	0.0155	0.0155
C5	0.0456	0.0456	0.0456	0.0456	0.0456	0.0456	0.0456	0.0458	0.0458	0.0458	0.0458	0.0463	0.0465	0.0465	0.0461
C6	0.1137	0.114	0.1136	0.1136	0.1136	0.1142	0.1138	0.1127	0.1128	0.1125	0.1123	0.1133	0.113	0.113	0.1135
C7	0.0247	0.0247	0.0247	0.0247	0.0247	0.0247	0.0247	0.0248	0.0248	0.0248	0.0249	0.0247	0.0247	0.0247	0.0247
C8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C9	0.0185	0.0185	0.0185	0.0185	0.0185	0.0185	0.0185	0.0186	0.0186	0.0187	0.0187	0.0185	0.0185	0.0185	0.0185
C10	0.095	0.0948	0.095	0.095	0.095	0.0948	0.0949	0.0953	0.0953	0.0954	0.0955	0.0948	0.0948	0.0948	0.0948
C11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S1	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.0089	0.0089	0.0089	0.009
S2	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097
S3	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0082	0.0082	0.0082	0.0082
S4	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043
S5	0.0040	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
S6	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178
S7	0.0320	0.032	0.032	0.032	0.032	0.0320	0.032	0.0321	0.0321	0.0321	0.0321	0.0321	0.0321	0.0321	0.0321
S8	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.0149	0.015	0.0150	0.015	0.015	0.0149	0.0149	0.0149	0.0149
S9	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061
S10	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041
S11	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0049	0.0049	0.0049	0.0049	0.0048	0.0048	0.0048	0.0048
S12	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0224	0.0224	0.0224	0.0224	0.0227	0.0228	0.0228	0.0226
S13	0.0053	0.0054	0.0053	0.0053	0.0053	0.0053	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054	0.0055	0.0055	0.0054
S14	0.0084	0.0084	0.0084	0.0084	0.0084	0.0084	0.0084	0.0084	0.0084	0.0085	0.0085	0.0086	0.0086	0.0086	0.0085
S15	0.0241	0.0241	0.0241	0.0241	0.0241	0.0241	0.0241	0.0242	0.0242	0.0242	0.0242	0.0245	0.0246	0.0246	0.0244
S16	0.0716	0.0719	0.0716	0.0716	0.0716	0.072	0.0717	0.071	0.071	0.0708	0.0707	0.0714	0.0712	0.0712	0.0715
S17	0.0589	0.0591	0.0589	0.0589	0.0589	0.0592	0.0590	0.0584	0.0585	0.0583	0.0582	0.0587	0.0586	0.0586	0.0588
S18	0.0353	0.0354	0.0353	0.0353	0.0353	0.0355	0.0353	0.035	0.035	0.0349	0.0349	0.0352	0.0351	0.0351	0.0353
S19	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0155	0.0155	0.0155	0.0155	0.0154	0.0154	0.0154	0.0154
S20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S21	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0043	0.0042	0.0042	0.0042	0.0042
S22	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0018	0.0017	0.0017	0.0017	0.0017
S23	0.0063	0.0062	0.0063	0.0063	0.0063	0.0062	0.0063	0.0063	0.0063	0.0063	0.0063	0.0062	0.0062	0.0062	0.0062
S24	0.0445	0.0444	0.0445	0.0445	0.0445	0.0444	0.0445	0.0447	0.0447	0.0447	0.0448	0.0444	0.0444	0.0444	0.0444
S25	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.0161	0.0161	0.0161	0.0161	0.016	0.016	0.016	0.016
S26	0.0671	0.067	0.0672	0.0672	0.0672	0.0670	0.0671	0.0674	0.0674	0.0675	0.0676	0.067	0.067	0.067	0.067
S27	0.0214	0.0214	0.0215	0.0215	0.0215	0.0214	0.0214	0.0215	0.0215	0.0215	0.0216	0.0214	0.0214	0.0214	0.0214
S28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30
PP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C1	0.0526	0.0526	0.0526	0.0528	0	0.0528	0.0528	0.0528	0.0528	0.0528	0.0528	0.0528	0	0	0
C2	0.0851	0.0853	0.0853	0.0861	0	0.0862	0.0861	0.0862	0.0861	0.0862	0.0861	0.0861	0	0	0
C3	0.0297	0.0298	0.0299	0.0306	0	0.0308	0.0307	0.0307	0.0307	0.0307	0.0306	0.0306	0	0	0
C4	0.0151	0.0152	0.0152	0.0156	0	0.0157	0.0156	0.0156	0.0156	0.0156	0.0156	0.0156	0	0	0
C5	0.0444	0.0447	0.0446	0.0457	0	0.0458	0.0458	0.0458	0.0458	0.0458	0.0457	0.0457	0	0	0
C6	0.1192	0.1183	0.1182	0.113	0	0.1122	0.1127	0.1124	0.1127	0.1124	0.1131	0.113	0	0	0
C7	0.0242	0.0243	0.0243	0.0248	0	0.0249	0.0248	0.0249	0.0248	0.0249	0.0248	0.0248	0	0	0
C8	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
C9	0.018	0.018	0.0181	0.0186	0	0.0187	0.0186	0.0187	0.0186	0.0187	0.0186	0.0186	0	0	0
C10	0.0931	0.0934	0.0934	0.0952	0	0.0955	0.0954	0.0955	0.0954	0.0955	0.0952	0.0952	0	0	0
C11	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
S1	0.0089	0.0089	0.0089	0.009	0	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0	0	0
S2	0.0096	0.0096	0.0096	0.0097	0	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0	0	0
S3	0.0082	0.0082	0.0082	0.0083	0	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0	0	0
S4	0.0043	0.0043	0.0043	0.0043	0	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0	0	0
S5	0.004	0.004	0.004	0.004	0	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0	0	0
S6	0.0176	0.0176	0.0176	0.0178	0	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0	0	0
S7	0.0316	0.0317	0.0317	0.0321	0	0.0322	0.0321	0.0321	0.0321	0.0321	0.0321	0.0321	0	0	0
S8	0.0145	0.0145	0.0145	0.0150	0	0.015	0.015	0.0150	0.015	0.015	0.015	0.015	0	0	0
S9	0.0059	0.0059	0.0059	0.0061	0	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061	0	0	0
S10	0.004	0.004	0.004	0.0041	0	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0	0	0
S11	0.0047	0.0047	0.0047	0.0048	0	0.0049	0.0049	0.0049	0.0049	0.0049	0.0048	0.0048	0	0	0
S12	0.0217	0.0218	0.0218	0.0224	0	0.0224	0.0224	0.0224	0.0224	0.0224	0.0224	0.0224	0	0	0
S13	0.0052	0.0052	0.0052	0.0054	0	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054	0	0	0
S14	0.0082	0.0082	0.0082	0.0084	0	0.0085	0.0084	0.0085	0.0084	0.0085	0.0084	0.0084	0	0	0
S15	0.0234	0.0236	0.0236	0.0242	0	0.0242	0.0242	0.0242	0.0242	0.0242	0.0242	0.0242	0	0	0
S16	0.0755	0.0748	0.0748	0.0712	0	0.0706	0.0709	0.0707	0.071	0.0707	0.0712	0.0712	0	0	0
S17	0.0617	0.0612	0.0612	0.0586	0	0.0582	0.0584	0.0583	0.0584	0.0583	0.0586	0.0586	0	0	0
S18	0.0371	0.0369	0.0368	0.0351	0	0.0348	0.035	0.0349	0.035	0.0349	0.0351	0.0351	0	0	0
S19	0.015	0.0151	0.0151	0.0155	0	0.0155	0.0155	0.0155	0.0155	0.0155	0.0155	0.0155	0	0	0
S20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S21	0.0041	0.0041	0.0041	0.0042	0	0.0043	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0	0	0
S22	0.0017	0.0017	0.0017	0.0017	0	0.0018	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0	0	0
S23	0.0061	0.0061	0.0061	0.0063	0	0.0063	0.0063	0.0063	0.0063	0.0063	0.0063	0.0063	0	0	0
S24	0.0435	0.0437	0.0437	0.0446	0	0.0448	0.0447	0.0447	0.0447	0.0447	0.0446	0.0446	0	0	0
S25	0.0157	0.0157	0.0157	0.0161	0	0.0161	0.0161	0.0161	0.0161	0.0161	0.016	0.0161	0	0	0
S26	0.0656	0.0658	0.0659	0.0673	0	0.0676	0.0674	0.0675	0.0674	0.0675	0.0673	0.0673	0	0	0
S27	0.021	0.021	0.0211	0.0215	0	0.0216	0.0215	0.0216	0.0215	0.0216	0.0215	0.0215	0	0	0
S28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 15 Limit Supermatrix 1

		1 GOAL	2 CRITERIA											3 SUB-CRITERIA																													
		PP	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30
1 GOAL	PP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 CRITERIA	C1	0.0815	0	0.0331	0	0	0	0	0	0	0	0	0	1	0.2500	1	1	1	0	0.1555	0	0	0	0	0	0	0	0	0	0	0.1667	0	0	0	0	0	0	0	0.1072	0	0	0	0
	C2	0.0518	0.1429	0	0.1429	0.1203	0	0	0.1250	0	0.0585	0	0	0	0.7500	0	0	0	0.7500	0.1703	0	0	0	0	0.1667	0	0	0.1667	0	0.1667	0	0.1022	0	0	0	0	0	0	0.1185	0.1022	0	0	0
	C3	0.0391	0	0	0	0	0	0	0.1250	0	0.1339	0	0	0	0	0	0	0	0	0.0952	0.4545	0.1680	0	0	0	0	0	0	0	0	0	0.2114	0	0	0	0	0	0	0.1359	0.2114	0	0	0
	C4	0.0525	0	0	0	0	0	0	0.1250	0	0.2814	0	0	0	0	0	0	0	0	0.1321	0	0	0.2500	0.7500	0	0	0	0	0	0	0	0	0	0.1250	0.2500	0.1250	0	0	0.0324	0	0	0	0
	C5	0.0332	0	0.1139	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8333	1	1	0.8333	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C6	0.1038	0.1429	0.2244	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.8333	0.8333	0	0	0	0	0	0	0	0	0	0	0	0
	C7	0.0417	0	0.1376	0.1429	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2500	0.1076	0.0909	0.0807	0	0.2500	0	0	0	0	0	0	0	0.6864	0	0	0	0	0.1250	0	0.0788	0	0	0	0
	C8	0.0426	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	C9	0.1749	0	0	0	0.2824	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3393	0.4545	0.7513	0.7500	0	0	0	0	0	0	0	0	0	0	0.8750	0.7500	0.8750	0	0	0.1191	0	0	0	0
	C10	0.2838	0.7143	0.4909	0.7143	0.5973	0	0	0.6250	0	0.5261	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8750	1	0.4081	0.6864	0	0	0
	C11	0.0950	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
3 SUB-CRITERIA	S1	0	0.1471	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S2	0	0.0664	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0512	0.0906	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S3	0	0.2103	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S4	0	0.2841	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S5	0	0.2921	0	0	0	0	0	0	0	0	0	0	0.0399	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S6	0	0	0.1250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0261	0	0	0	0	0	0	0	0	0	0	0
	S7	0	0	0.8750	0	0	0	0	0	0	0	0	0	0.2016	0	0	0	0	0.0745	0	0	0.1667	0.0562	0	0	0	0	0	0	0	0	0.0642	0	0	0.1022	0	0	0	0	0	0	0	0
	S8	0	0	0	0.5000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8333	0	0	0	0	0	0	0	0	0	0.0927	0	0	0	0.1667	0	0	0	0	0	0	0
	S9	0	0	0	0.5000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0457	0	0	0	0.8333	0	0	0	0	0	0	0
	S10	0	0	0	0	0.1667	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2114	0	0	0	0	0	0	0	0
	S11	0	0	0	0	0.8333	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1587	0	0	0	0	0	0	0	0	0.0941	0	0	0	0	0	0	0	0	0	0	0
	S12	0	0	0	0	0	0.1986	0	0	0	0	0	0	0	0	0	0	0	0.0303	0.0276	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S13	0	0	0	0	0	0.0731	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S14	0	0	0	0	0	0.1202	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S15	0	0	0	0	0	0.6081	0	0	0	0	0	0	0	0	0	0	0	0.0541	0.0544	0	0	0	0	0.8750	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S16	0	0	0	0	0	0	0.0660	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
	S17	0	0	0	0	0	0	0.3112	0	0	0	0	0	0	0	0	0	0	0.1741	0.1660	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S18	0	0	0	0	0	0	0.6228	0	0	0	0	0	0.1146	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S19	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0.1016	0.0707	0.0660	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S20	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S21	0	0	0	0	0	0	0	0	0	0.1680	0	0	0	0	0	0	0	0	0	0	0	0	0.1111	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S22	0	0	0	0	0	0	0	0	0	0.0807	0	0	0	0	0	0	0	0	0	0	0	0.2519	0.1111	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S23	0	0	0	0	0	0	0	0	0	0.7513	0	0	0	0	0	0	0	0	0	0	0	0	0.7778	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S24	0	0	0	0	0	0	0	0	0	0	0.2293	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3021	0	0	0	0	0	0	0	0	0	0	0
	S25	0	0	0	0	0	0	0	0	0	0	0.1284	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S26	0	0	0	0	0	0	0	0	0	0	0.2668	0	0.6439	0	0	0	0	0.2108	0.2576	0.3112	0	0.5332	0	0	0	0	0	0	0	0	0.3752	0	0	0.6864	0	1	0	0	1	0	0	0
	S27	0	0	0	0	0	0	0	0	0	0	0.3755	0	0	0	0	0	0	0.3035	0.3330	0.6228	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S28	0	0	0	0	0	0	0	0	0	0	0	0.0782	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S29	0	0	0	0	0	0	0	0	0	0	0	0.4865	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S30	0	0	0	0	0	0	0	0	0	0	0	0.4353	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 16 Unweighted Supermatrix 2 - Constructed by Using the Priorities Derived From the Lower Bounds of the Pairwise Comparison Judgments

		1 GOAL	2 CRITERIA											3 SUB-CRITERIA																													
		PP	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30
1 GOAL	PP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 CRITERIA	C1	0.0815	0	0.0166	0	0	0	0	0	0	0	0	0	0.5	0.2500	1	0.5	1	0	0.0778	0	0	0	0	0	0	0	0	0	0	0.0833	0	0	0	0	0	0	0	0.1072	0	0	0	0
	C2	0.0518	0.0714	0	0.0714	0.0601	0	0	0.0625	0	0.0293	0	0	0	0.7500	0	0	0	0.3750	0.0852	0	0	0	0	0.0833	0	0	0.1667	0	0.0833	0	0.0511	0	0	0	0	0	0	0.1185	0.0511	0	0	0
	C3	0.0391	0	0	0	0	0	0	0.0625	0	0.0670	0	0	0	0	0	0	0	0	0.0476	0.2273	0.0840	0	0	0	0	0	0	0	0	0	0.1057	0	0	0	0	0	0	0.1359	0.1057	0	0	0
	C4	0.0525	0	0	0	0	0	0	0.0625	0	0.1407	0	0	0	0	0	0	0	0	0.0660	0	0	0.1250	0.3750	0	0	0	0	0	0	0	0	0	0.1250	0.1250	0.0625	0	0	0.0324	0	0	0	0
	C5	0.0332	0	0.0570	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4167	1	1	0.8333	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C6	0.1038	0.0714	0.1122	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.4167	0.4167	0	0	0	0	0	0	0	0	0	0	0	0
	C7	0.0417	0	0.0688	0.0714	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1250	0.0538	0.0455	0.0403	0	0.1250	0	0	0	0	0	0	0	0.3432	0	0	0	0	0.0625	0	0.0788	0	0	0	0
	C8	0.0426	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	C9	0.1749	0	0	0	0.1412	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1697	0.2273	0.3757	0.3750	0	0	0	0	0	0	0	0	0	0	0.8750	0.3750	0.4375	0	0	0.1191	0	0	0	0
	C10	0.2838	0.3571	0.2454	0.3571	0.2987	0	0	0.3125	0	0.2631	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4375	1	0.4081	0.3432	0	0	0
	C11	0.0950	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
3 SUB-CRITERIA	S1	0	0.0736	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S2	0	0.0332	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0256	0.0453	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S3	0	0.1051	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S4	0	0.1421	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S5	0	0.1460	0	0	0	0	0	0	0	0	0	0	0.0200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S6	0	0	0.0625	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0130	0	0	0	0	0	0	0	0	0	0	0
	S7	0	0	0.4375	0	0	0	0	0	0	0	0	0	0.1008	0	0	0	0	0.0372	0	0	0.0833	0.0281	0	0	0	0	0	0	0	0	0.0321	0	0	0.0511	0	0	0	0	0	0	0	0
	S8	0	0	0	0.2500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4167	0	0	0	0	0	0	0	0	0	0.0464	0	0	0	0.0833	0	0	0	0	0	0	0
	S9	0	0	0	0.2500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0228	0	0	0	0.4167	0	0	0	0	0	0	0
	S10	0	0	0	0	0.0833	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1057	0	0	0	0	0	0	0	0
	S11	0	0	0	0	0.4167	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0794	0	0	0	0	0	0	0	0	0.0471	0	0	0	0	0	0	0	0	0	0	0
	S12	0	0	0	0	0	0.1986	0	0	0	0	0	0	0	0	0	0	0	0.0151	0.0138	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S13	0	0	0	0	0	0.0731	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S14	0	0	0	0	0	0.1202	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0625	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S15	0	0	0	0	0	0.6081	0	0	0	0	0	0	0	0	0	0	0	0.0270	0.0272	0	0	0	0	0.4375	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S16	0	0	0	0	0	0	0.0660	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0
	S17	0	0	0	0	0	0	0.3112	0	0	0	0	0	0	0	0	0	0	0.0871	0.0830	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S18	0	0	0	0	0	0	0.6228	0	0	0	0	0	0.0573	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S19	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0.0508	0.0353	0.0330	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S20	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S21	0	0	0	0	0	0	0	0	0	0.0840	0	0	0	0	0	0	0	0	0	0	0	0	0.0556	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S22	0	0	0	0	0	0	0	0	0	0.0403	0	0	0	0	0	0	0	0	0	0	0	0.1260	0.0556	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S23	0	0	0	0	0	0	0	0	0	0.3757	0	0	0	0	0	0	0	0	0	0	0	0	0.3889	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S24	0	0	0	0	0	0	0	0	0	0	0.2293	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1510	0	0	0	0	0	0	0	0	0	0	0
	S25	0	0	0	0	0	0	0	0	0	0	0.1284	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S26	0	0	0	0	0	0	0	0	0	0	0.2668	0	0.3220	0	0	0	0	0.1054	0.1288	0.1556	0	0.2666	0	0	0	0	0	0	0	0	0.1876	0	0	0.3432	0	0.5	0	0	0.5	0	0	0
	S27	0	0	0	0	0	0	0	0	0	0	0.3755	0	0	0	0	0	0	0.1517	0.1665	0.3114	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S28	0	0	0	0	0	0	0	0	0	0	0	0.0782	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S29	0	0	0	0	0	0	0	0	0	0	0	0.4865	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S30	0	0	0	0	0	0	0	0	0	0	0	0.4353	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 17 Weighted Supermatrix 2

		1 GOAL	2 CRITERIA										
		PP	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
1 GOAL	PP	0	0	0	0	0	0	0	0	0	0	0	0
2 CRITERIA	C1	0.0291	0.0337	0.0337	0.0337	0.0337	0.0331	0.0341	0.0337	0	0.0337	0.0337	0
	C2	0.0303	0.0351	0.0351	0.0356	0.0356	0.0358	0.0328	0.0355	0	0.0356	0.0356	0
	C3	0.0295	0.0342	0.034	0.0349	0.0349	0.0339	0.0304	0.0348	0	0.0350	0.0349	0
	C4	0.0149	0.0173	0.0172	0.0176	0.0177	0.0172	0.0153	0.0176	0	0.0177	0.0176	0
	C5	0.0177	0.0203	0.0207	0.0207	0.0208	0.027	0.0175	0.0207	0	0.0208	0.0207	0
	C6	0.0843	0.0984	0.0989	0.093	0.0925	0.0942	0.1271	0.0932	0	0.0924	0.0931	0
	C7	0.0209	0.0242	0.0241	0.0247	0.0247	0.0241	0.0217	0.0247	0	0.0248	0.0247	0
	C8	0.0000	0	0	0	0	0	0	0	1	0	0	0
	C9	0.0362	0.0419	0.0417	0.0428	0.0429	0.0416	0.0371	0.0428	0	0.0429	0.0428	0
	C10	0.1409	0.1632	0.1626	0.1662	0.1665	0.162	0.1472	0.1661	0	0.1666	0.1662	0
	C11	0.0000	0	0	0	0	0	0	0	0	0	0	1
3 SUB-CRITERIA	S1	0.002137	0.0025	0.0025	0.0025	0.0025	0.0024	0.0025	0.0025	0	0.0025	0.0025	0
	S2	0.00171	0.0020	0.002	0.002	0.002	0.002	0.0019	0.002	0	0.002	0.002	0
	S3	0.005118	0.0059	0.0059	0.0059	0.0059	0.0058	0.006	0.0059	0	0.0059	0.0059	0
	S4	0.004127	0.0048	0.0048	0.0048	0.0048	0.0047	0.0048	0.0048	0	0.0048	0.0048	0
	S5	0.004286	0.0050	0.005	0.005	0.005	0.0049	0.005	0.005	0	0.005	0.005	0
	S6	0.002049	0.0024	0.0024	0.0024	0.0024	0.0024	0.0022	0.0024	0	0.0024	0.0024	0
	S7	0.015295	0.0177	0.0177	0.0179	0.018	0.018	0.0164	0.0179	0	0.018	0.0179	0
	S8	0.0153	0.0177	0.0176	0.0181	0.0181	0.0176	0.0156	0.0181	0	0.0182	0.0181	0
	S9	0.014438	0.0167	0.0166	0.0171	0.0171	0.0166	0.0147	0.0171	0	0.0171	0.0171	0
	S10	0.001458	0.0017	0.0017	0.0017	0.0017	0.0017	0.0015	0.0017	0	0.0017	0.0017	0
	S11	0.00688	0.008	0.0079	0.0081	0.0082	0.0079	0.007	0.0081	0	0.0082	0.0081	0
	S12	0.003766	0.0043	0.0044	0.0044	0.0044	0.0057	0.0037	0.0044	0	0.0044	0.0044	0
	S13	0.001297	0.0015	0.0015	0.0015	0.0015	0.0020	0.0013	0.0015	0	0.0015	0.0015	0
	S14	0.002368	0.0027	0.0028	0.0028	0.0028	0.0037	0.0023	0.0028	0	0.0028	0.0028	0
	S15	0.012908	0.0148	0.0151	0.0151	0.0151	0.0198	0.0127	0.0151	0	0.0151	0.0151	0
	S16	0.045548	0.0532	0.0535	0.0501	0.0499	0.0508	0.0695	0.0503	0	0.0498	0.0502	0
	S17	0.027631	0.0322	0.0324	0.0305	0.0304	0.0309	0.0414	0.0306	0	0.0303	0.0306	0
	S18	0.052511	0.0613	0.0617	0.0578	0.0575	0.0586	0.0799	0.058	0	0.0574	0.0579	0
	S19	0.011615	0.0134	0.0134	0.0137	0.0137	0.0134	0.012	0.0137	0	0.0138	0.0137	0
	S20	0.042636	0	0	0	0	0	0	0	0	0	0	0
	S21	0.003424	0.004	0.0039	0.0041	0.0041	0.0039	0.0035	0.004	0	0.0041	0.0041	0
	S22	0.002028	0.0023	0.0023	0.0024	0.0024	0.0023	0.0021	0.0024	0	0.0024	0.0024	0
	S23	0.016283	0.0188	0.0188	0.0193	0.0193	0.0187	0.0166	0.0193	0	0.0193	0.0193	0
	S24	0.034096	0.0395	0.0393	0.0402	0.0403	0.0392	0.0354	0.0402	0	0.0403	0.0402	0
	S25	0.018103	0.021	0.0209	0.0214	0.0214	0.0208	0.0188	0.0213	0	0.0214	0.0214	0
	S26	0.093521	0.1083	0.1079	0.1104	0.1106	0.1075	0.0971	0.1103	0	0.1107	0.1104	0
	S27	0.06058	0.0701	0.0699	0.0715	0.0716	0.0697	0.063	0.0714	0	0.0717	0.0715	0
	S28	0.007428	0	0	0	0	0	0	0	0	0	0	0.0000
	S29	0.046228	0	0	0	0	0	0	0	0	0	0	0.0000
	S30	0.04136	0	0	0	0	0	0	0	0	0	0	0.0000

		3 SUB-CRITERIA													
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
1 GOAL	PP	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 CRITERIA	C1	0.0337	0.0337	0.0337	0.0337	0.0337	0.0337	0.0337	0.0337	0.0337	0.0337	0.0336	0.0332	0.0331	0.0331
	C2	0.0351	0.0351	0.0351	0.0351	0.0351	0.0351	0.0353	0.0356	0.0356	0.0356	0.0356	0.0358	0.0359	0.0359
	C3	0.0342	0.0341	0.0342	0.0342	0.0342	0.0341	0.0343	0.0349	0.0349	0.0349	0.035	0.0339	0.0339	0.0339
	C4	0.0173	0.0172	0.0173	0.0173	0.0173	0.0172	0.0173	0.0176	0.0177	0.0177	0.0177	0.0172	0.0172	0.0172
	C5	0.0203	0.0206	0.0203	0.0203	0.0203	0.0207	0.0207	0.0207	0.0207	0.0207	0.0208	0.0266	0.0274	0.0274
	C6	0.0982	0.0987	0.0982	0.0981	0.0982	0.0985	0.0969	0.0928	0.0927	0.0926	0.0921	0.0945	0.0939	0.0939
	C7	0.0242	0.0242	0.0242	0.0242	0.0242	0.0242	0.0243	0.0247	0.0247	0.0247	0.0248	0.0241	0.0241	0.0241
	C8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C9	0.0419	0.0418	0.0419	0.0419	0.0419	0.0418	0.0421	0.0428	0.0429	0.0429	0.043	0.0416	0.0416	0.0416
	C10	0.1633	0.1628	0.1633	0.1634	0.1633	0.1628	0.1639	0.1663	0.1664	0.1665	0.1668	0.1621	0.162	0.162
	C11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 SUB-CRITERIA	S1	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0024	0.0024	0.0024
	S2	0.002	0.002	0.002	0.002	0.002	0.0020	0.0020	0.002	0.002	0.002	0.002	0.002	0.002	0.002
	S3	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059	0.0058	0.0058	0.0058
	S4	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0047	0.0047	0.0047
	S5	0.0050	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0049	0.0049	0.0049
	S6	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024
	S7	0.0177	0.0177	0.0177	0.0177	0.0177	0.0177	0.0178	0.018	0.0180	0.0180	0.018	0.018	0.018	0.018
	S8	0.0177	0.0177	0.0177	0.0177	0.0177	0.0177	0.0178	0.0181	0.0181	0.0181	0.0182	0.0176	0.0176	0.0176
	S9	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0168	0.0171	0.0171	0.0171	0.0172	0.0166	0.0166	0.0166
	S10	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
	S11	0.008	0.0079	0.008	0.008	0.008	0.0079	0.008	0.0081	0.0082	0.0082	0.0082	0.0079	0.0079	0.0079
	S12	0.0043	0.0044	0.0043	0.0043	0.0043	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0056	0.0058	0.0058
	S13	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.002	0.002	0.002
	S14	0.0027	0.0028	0.0027	0.0027	0.0027	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0036	0.0037	0.0037
	S15	0.0148	0.015	0.0148	0.0148	0.0148	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	0.0195	0.0201	0.0201
	S16	0.0531	0.0533	0.0531	0.053	0.0531	0.0533	0.0523	0.05	0.0499	0.0499	0.0496	0.051	0.0506	0.0506
	S17	0.0322	0.0323	0.0322	0.0322	0.0322	0.0323	0.0318	0.0305	0.0304	0.0304	0.0302	0.031	0.0308	0.0308
	S18	0.0612	0.0615	0.0612	0.0611	0.0612	0.0614	0.0603	0.0577	0.0576	0.0576	0.0572	0.0588	0.0584	0.0584
	S19	0.0135	0.0134	0.0135	0.0135	0.0135	0.0134	0.0135	0.0137	0.0137	0.0137	0.0138	0.0134	0.0134	0.0134
	S20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S21	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.0041	0.0041	0.0041	0.0041	0.0039	0.0039	0.0039
	S22	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0024	0.0024	0.0024	0.0024	0.0024	0.0023	0.0023	0.0023
	S23	0.0189	0.0188	0.0189	0.0189	0.0189	0.0188	0.0189	0.0193	0.0193	0.0193	0.0194	0.0187	0.0187	0.0187
	S24	0.0395	0.0394	0.0395	0.0395	0.0395	0.0394	0.0397	0.0403	0.0403	0.0403	0.0404	0.0392	0.0392	0.0392
	S25	0.021	0.0209	0.021	0.021	0.021	0.0209	0.0211	0.0214	0.0214	0.0214	0.0214	0.0208	0.0208	0.0208
	S26	0.1083	0.108	0.1084	0.1084	0.1084	0.1080	0.1088	0.1105	0.1105	0.1106	0.1108	0.1075	0.1075	0.1075
	S27	0.0702	0.07	0.0702	0.0702	0.0702	0.0700	0.0705	0.0715	0.0716	0.0716	0.0717	0.0697	0.0696	0.0696
	S28	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S29	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S30	0	0	0	0	0	0	0	0	0	0	0	0	0	0

		3 SUB-CRITERIA															
		S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30
1 GOAL	PP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 CRITERIA	C1	0.0332	0.0341	0.0341	0.0341	0.0337	0	0.0336	0.0337	0.0337	0.0337	0.0337	0.0337	0.0337	0	0	0
	C2	0.0358	0.0327	0.0328	0.0328	0.0355	0	0.0356	0.0356	0.0356	0.0355	0.0356	0.0355	0.0355	0	0	0
	C3	0.0339	0.0303	0.0305	0.0305	0.0348	0	0.035	0.0349	0.035	0.0349	0.0349	0.0347	0.0348	0	0	0
	C4	0.0172	0.0152	0.0153	0.0154	0.0176	0	0.0177	0.0176	0.0177	0.0176	0.0177	0.0176	0.0176	0	0	0
	C5	0.0263	0.0175	0.0177	0.0176	0.0207	0	0.0208	0.0207	0.0208	0.0207	0.0207	0.0207	0.0207	0	0	0
	C6	0.0947	0.128	0.1261	0.1260	0.0934	0	0.092	0.0928	0.0922	0.0932	0.0928	0.0939	0.0935	0	0	0
	C7	0.0241	0.0216	0.0218	0.0218	0.0247	0	0.0248	0.0247	0.0248	0.0247	0.0247	0.0246	0.0246	0	0	0
	C8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C9	0.0416	0.0369	0.0372	0.0372	0.0427	0	0.0430	0.0428	0.0430	0.0428	0.0429	0.0426	0.0427	0	0	0
	C10	0.1621	0.1467	0.1477	0.1478	0.166	0	0.1668	0.1663	0.1667	0.1661	0.1664	0.1657	0.1659	0	0	0
	C11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 SUB-CRITERIA	S1	0.0024	0.0025	0.0025	0.0025	0.0025	0	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0	0	0
	S2	0.002	0.0019	0.0019	0.0019	0.002	0	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0	0	0
	S3	0.0058	0.006	0.006	0.006	0.0059	0	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059	0	0	0
	S4	0.0047	0.0048	0.0048	0.0048	0.0048	0	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0	0	0
	S5	0.0049	0.005	0.005	0.005	0.005	0	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0	0	0
	S6	0.0024	0.0022	0.0022	0.0022	0.0024	0	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0	0	0
	S7	0.018	0.0163	0.0164	0.0164	0.0179	0	0.018	0.0180	0.018	0.0179	0.018	0.0179	0.0179	0	0	0
	S8	0.0176	0.0155	0.0157	0.0157	0.0181	0	0.0182	0.0181	0.0182	0.0181	0.0181	0.018	0.0181	0	0	0
	S9	0.0166	0.0147	0.0148	0.0148	0.0171	0	0.0172	0.0171	0.0172	0.0171	0.0171	0.017	0.0171	0	0	0
	S10	0.0017	0.0015	0.0015	0.0015	0.0017	0	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0	0	0
	S11	0.0079	0.007	0.007	0.0071	0.0081	0	0.0082	0.0081	0.0082	0.0081	0.0082	0.0081	0.0081	0	0	0
	S12	0.0056	0.0037	0.0038	0.0037	0.0044	0	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0	0	0
	S13	0.0019	0.0013	0.0013	0.0013	0.0015	0	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0	0	0
	S14	0.0036	0.0023	0.0023	0.0023	0.0028	0	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0	0	0
	S15	0.0193	0.0127	0.0128	0.0128	0.0151	0	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	0	0	0
	S16	0.0511	0.0701	0.069	0.0689	0.0504	0	0.0496	0.05	0.0497	0.0502	0.05	0.0507	0.0504	0	0	0
	S17	0.0311	0.0417	0.0411	0.0411	0.0307	0	0.0302	0.0305	0.0303	0.0306	0.0305	0.0308	0.0307	0	0	0
	S18	0.0589	0.0805	0.0792	0.0792	0.0581	0	0.0572	0.0577	0.0573	0.058	0.0577	0.0584	0.0582	0	0	0
	S19	0.0134	0.0119	0.012	0.012	0.0137	0	0.0138	0.0137	0.0138	0.0137	0.0137	0.0137	0.0137	0	0	0
	S20	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	S21	0.0039	0.0035	0.0035	0.0035	0.004	0	0.0041	0.0041	0.0041	0.0041	0.0041	0.004	0.004	0	0	0
	S22	0.0023	0.0021	0.0021	0.0021	0.0024	0	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0	0	0
	S23	0.0187	0.0165	0.0167	0.0167	0.0192	0	0.0194	0.0193	0.0193	0.0193	0.0193	0.0192	0.0192	0	0	0
	S24	0.0392	0.0353	0.0356	0.0356	0.0402	0	0.0404	0.0403	0.0404	0.0402	0.0403	0.0401	0.0402	0	0	0
	S25	0.0208	0.0188	0.0189	0.0189	0.0213	0	0.0214	0.0214	0.0214	0.0214	0.0214	0.0213	0.0213	0	0	0
	S26	0.1075	0.0967	0.0974	0.0975	0.1102	0	0.1108	0.1105	0.1108	0.1103	0.1105	0.11	0.1102	0	0	0
	S27	0.0697	0.0627	0.0632	0.0632	0.0714	0	0.0718	0.0715	0.0717	0.0715	0.0716	0.0713	0.0714	0	0	0
	S28	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0782	0.0782	0.0782
	S29	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4865	0.4865	0.4865
	S30	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4353	0.4353	0.4353

Figure 18 Limit Supermatrix 2

		1 GOAL	2 CRITERIA											3 SUB-CRITERIA																													
		PP	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**	**S15**	**S16**	**S17**	**S18**	**S19**	**S20**	**S21**	**S22**	**S23**	**S24**	**S25**	**S26**	**S27**	**S28**	**S29**	**S30**
1 GOAL	**PP**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 CRITERIA	**C1**	0.3202	0	0.2252	0	0	0	0	0	0	0	0	0	1	0.7500	1	1	1	0	0.3657	0	0	0	0	0	0	0	0	0	0	0.7500	0	0	0	0	0	0	0	0.3504	0	0	0	0
	C2	0.1602	0.4796	0	0.5007	0.6584	0	0	0.5386	0	0.2510	0	0	0	0.2500	0	0	0	0.8750	0.2951	0	0	0	0	0.5000	0	0	0.7500	0	0.7500	0	0.5007	0	0	0	0	0	0	0.2213	0.7143	0	0	0
	C3	0.1341	0	0	0	0	0	0	0.2402	0	0.3096	0	0	0	0	0	0	0	0	0.1428	0.7231	0.7233	0	0	0	0	0	0	0	0	0	0.1890	0	0	0	0	0	0	0.1909	0.1429	0	0	0
	C4	0.0935	0	0	0	0	0	0	0.0628	0	0.3386	0	0	0	0	0	0	0	0	0.1005	0	0	0.9000	0.8333	0	0	0	0	0	0	0	0	0	0.2500	0.7500	0.1667	0	0	0.0747	0	0	0	0
	C5	0.0561	0	0.3617	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5000	1	1	0.2500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C6	0.0671	0.1150	0.2412	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.2500	0.2500	0	0	0	0	0	0	0	0	0	0	0	0
	C7	0.0361	0	0.0567	0.1890	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1250	0.0691	0.2157	0.2059	0	0.1667	0	0	0	0	0	0	0	0.3102	0	0	0	0	0.1667	0	0.0650	0	0	0	0
	C8	0.0276	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	C9	0.0315	0	0	0	0.2529	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0268	0.0612	0.0708	0.1000	0	0	0	0	0	0	0	0	0	0	0.7500	0.2500	0.8333	0	0	0.0526	0	0	0	0
	C10	0.0625	0.4055	0.1153	0.3102	0.0887	0	0	0.1584	0	0.1008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8333	1	0.0453	0.1429	0	0	0
	C11	0.0112	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
3 SUB-CRITERIA	**S1**	0	0.4923	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S2	0	0.2459	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3416	0.4626	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S3	0	0.1629	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S4	0	0.0677	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S5	0	0.0311	0	0	0	0	0	0	0	0	0	0	0.5896	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S6	0	0	0.7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2915	0	0	0	0	0	0	0	0	0	0	0
	S7	0	0	0.2500	0	0	0	0	0	0	0	0	0	0.1893	0	0	0	0	0.2097	0	0	0.9000	0.4992	0	0	0	0	0	0	0	0	0.2172	0	0	0.7143	0	0	0	0	0	0	0	0
	S8	0	0	0	0.8750	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1000	0	0	0	0	0	0	0	0	0	0.1165	0	0	0	0.8333	0	0	0	0	0	0	0
	S9	0	0	0	0.1250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0441	0	0	0	0.1667	0	0	0	0	0	0	0
	S10	0	0	0	0	0.8333	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1429	0	0	0	0	0	0	0	0
	S11	0	0	0	0	0.1667	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2819	0	0	0	0	0	0	0	0	0.0288	0	0	0	0	0	0	0	0	0	0	0
	S12	0	0	0	0	0	0.6308	0	0	0	0	0	0	0	0	0	0	0	0.0649	0.1237	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S13	0	0	0	0	0	0.1562	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S14	0	0	0	0	0	0.0976	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S15	0	0	0	0	0	0.1154	0	0	0	0	0	0	0	0	0	0	0	0.0683	0.0976	0	0	0	0	0.5000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S16	0	0	0	0	0	0	0.4545	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
	S17	0	0	0	0	0	0	0.4545	0	0	0	0	0	0	0	0	0	0	0.1406	0.1475	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S18	0	0	0	0	0	0	0.0909	0	0	0	0	0	0.0674	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S19	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0.0527	0.0402	0.3893	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S20	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S21	0	0	0	0	0	0	0	0	0	0.6687	0	0	0	0	0	0	0	0	0	0	0	0	0.4796	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S22	0	0	0	0	0	0	0	0	0	0.0882	0	0	0	0	0	0	0	0	0	0	0	0.1612	0.1150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S23	0	0	0	0	0	0	0	0	0	0.2431	0	0	0	0	0	0	0	0	0	0	0	0	0.4055	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S24	0	0	0	0	0	0	0	0	0	0	0.6527	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2007	0	0	0	0	0	0	0	0	0	0	0
	S25	0	0	0	0	0	0	0	0	0	0	0.1488	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S26	0	0	0	0	0	0	0	0	0	0	0.1488	0	0.1536	0	0	0	0	0.0983	0.1021	0.5105	0	0.0577	0	0	0	0	0	0	0	0	0.1013	0	0	0.1429	0	1	0	0	1	0	0	0
	S27	0	0	0	0	0	0	0	0	0	0	0.0498	0	0	0	0	0	0	0.0240	0.0263	0.1001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S28	0	0	0	0	0	0	0	0	0	0	0	0.6751	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S29	0	0	0	0	0	0	0	0	0	0	0	0.2595	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S30	0	0	0	0	0	0	0	0	0	0	0	0.0654	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 19 Unweighted Supermatrix 3 - Constructed by Using the Priorities Derived From the Upper Bounds of the Pairwise Comparison Judgments

		1 GOAL	2 CRITERIA											3 SUB-CRITERIA																													
		PP	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**	**S15**	**S16**	**S17**	**S18**	**S19**	**S20**	**S21**	**S22**	**S23**	**S24**	**S25**	**S26**	**S27**	**S28**	**S29**	**S30**
1 GOAL	**PP**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 CRITERIA	**C1**	0.3202	0	0.1126	0	0	0	0	0	0	0	0	0	0.5	0.7500	1	0.5	1	0	0.1828	0	0	0	0	0	0	0	0	0	0	0.3750	0	0	0	0	0	0	0	0.3504	0	0	0	0
	C2	0.1602	0.2398	0	0.2504	0.3292	0	0	0.2693	0	0.1255	0	0	0	0.2500	0	0	0	0.4375	0.1476	0	0	0	0	0.2500	0	0	0.7500	0	0.3750	0	0.2504	0	0	0	0	0	0	0.2213	0.3571	0	0	0
	C3	0.1341	0	0	0	0	0	0	0.1201	0	0.1548	0	0	0	0	0	0	0	0	0.0714	0.3615	0.3616	0	0	0	0	0	0	0	0	0	0.0945	0	0	0	0	0	0	0.1909	0.0714	0	0	0
	C4	0.0935	0	0	0	0	0	0	0.0314	0	0.1693	0	0	0	0	0	0	0	0	0.0503	0	0	0.4500	0.4167	0	0	0	0	0	0	0	0	0	0.2500	0.3750	0.0833	0	0	0.0747	0	0	0	0
	C5	0.0561	0	0.1809	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2500	1	1	0.2500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C6	0.0671	0.0575	0.1206	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.1250	0.1250	0	0	0	0	0	0	0	0	0	0	0	0
	C7	0.0361	0	0.0283	0.0945	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0625	0.0345	0.1079	0.1029	0	0.0833	0	0	0	0	0	0	0	0.1551	0	0	0	0	0.0833	0	0.0650	0	0	0	0
	C8	0.0276	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	C9	0.0315	0	0	0	0.1264	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0134	0.0306	0.0354	0.0500	0	0	0	0	0	0	0	0	0	0	0.7500	0.1250	0.4167	0	0	0.0526	0	0	0	0
	C10	0.0625	0.2027	0.0576	0.1551	0.0443	0	0	0.0792	0	0.0504	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4167	1	0.0453	0.0714	0	0	0
	C11	0.0112	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
3 SUB-CRITERIA	**S1**	0	0.2462	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S2	0	0.1230	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1708	0.2313	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S3	0	0.0814	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S4	0	0.0339	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S5	0	0.0156	0	0	0	0	0	0	0	0	0	0	0.2948	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S6	0	0	0.3750	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1457	0	0	0	0	0	0	0	0	0	0	0
	S7	0	0	0.1250	0	0	0	0	0	0	0	0	0	0.0947	0	0	0	0	0.1048	0	0	0.4500	0.2496	0	0	0	0	0	0	0	0	0.1086	0	0	0.3571	0	0	0	0	0	0	0	0
	S8	0	0	0	0.4375	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0500	0	0	0	0	0	0	0	0	0	0.0582	0	0	0	0.4167	0	0	0	0	0	0	0
	S9	0	0	0	0.0625	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0221	0	0	0	0.0833	0	0	0	0	0	0	0
	S10	0	0	0	0	0.4167	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0714	0	0	0	0	0	0	0	0
	S11	0	0	0	0	0.0833	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1410	0	0	0	0	0	0	0	0	0.0144	0	0	0	0	0	0	0	0	0	0	0
	S12	0	0	0	0	0	0.6308	0	0	0	0	0	0	0	0	0	0	0	0.0324	0.0618	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S13	0	0	0	0	0	0.1562	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S14	0	0	0	0	0	0.0976	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S15	0	0	0	0	0	0.1154	0	0	0	0	0	0	0	0	0	0	0	0.0342	0.0488	0	0	0	0	0.2500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S16	0	0	0	0	0	0	0.4545	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0
	S17	0	0	0	0	0	0	0.4545	0	0	0	0	0	0	0	0	0	0	0.0703	0.0737	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S18	0	0	0	0	0	0	0.0909	0	0	0	0	0	0.0337	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S19	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0.0264	0.0201	0.1947	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S20	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S21	0	0	0	0	0	0	0	0	0	0.3343	0	0	0	0	0	0	0	0	0	0	0	0	0.2398	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S22	0	0	0	0	0	0	0	0	0	0.0441	0	0	0	0	0	0	0	0	0	0	0	0.0806	0.0575	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S23	0	0	0	0	0	0	0	0	0	0.1216	0	0	0	0	0	0	0	0	0	0	0	0	0.2027	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S24	0	0	0	0	0	0	0	0	0	0	0.6527	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1003	0	0	0	0	0	0	0	0	0	0	0
	S25	0	0	0	0	0	0	0	0	0	0	0.1488	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S26	0	0	0	0	0	0	0	0	0	0	0.1488	0	0.0768	0	0	0	0	0.0491	0.0511	0.2553	0	0.0289	0	0	0	0	0	0	0	0	0.0506	0	0	0.0714	0	0.5	0	0	0.5	0	0	0
	S27	0	0	0	0	0	0	0	0	0	0	0.0498	0	0	0	0	0	0	0.0120	0.0132	0.0501	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S28	0	0	0	0	0	0	0	0	0	0	0	0.6751	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S29	0	0	0	0	0	0	0	0	0	0	0	0.2595	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S30	0	0	0	0	0	0	0	0	0	0	0	0.0654	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 20 Weighted Supermatrix 3

		1 GOAL	2 CRITERIA											3 SUB-CRITERIA													
		PP	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**
1 GOAL	**PP**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 CRITERIA	**C1**	0.0770	0.080123656	0.0800	0.08	0.08	0.08	0.079	0.08	0	0.08	0.08	0	0.08	0.0801	0.08	0.08	0.08	0.08	0.0801	0.08	0.08	0.08	0.08	0.08	0.08	0.08
	C2	0.1214	0.1263	0.126	0.1263	0.1263	0.126	0.126	0.1263	0	0.1264	0.126	0	0.126	0.1263	0.126	0.126	0.126	0.1262	0.1263	0.126	0.126	0.126	0.126	0.1264	0.126	0.126
	C3	0.0162	0.016890052	0.017	0.017	0.017	0.017	0.017	0.0169	0	0.0169	0.017	0	0.017	0.017	0.017	0.017	0.017	0.017	0.0169	0.0169	0.0169	0.017	0.017	0.017	0.017	0.017
	C4	0.0085	0.008812976	0.009	0.009	0.009	0.009	0.009	0.0088	0	0.0088	0.009	0	0.009	0.009	0.009	0.009	0.009	0.009	0.0088	0.009	0.009	0.0088	0.0089	0.009	0.009	0.009
	C5	0.0673	0.070026366	0.0700	0.07	0.07	0.071	0.069	0.07	0	0.07	0.07	0	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.0704	0.071	0.071
	C6	0.1100	0.1145	0.1148	0.114	0.114	0.114	0.118	0.114	0	0.114	0.114	0	0.114	0.114	0.114	0.114	0.114	0.115	0.115	0.114	0.114	0.114	0.114	0.114	0.114	0.114
	C7	0.0169	0.017578742	0.0175	0.0176	0.018	0.018	0.017	0.018	0	0.018	0.018	0	0.018	0.018	0.018	0.018	0.018	0.0176	0.0176	0.0176	0.0176	0.018	0.0176	0.018	0.018	0.018
	C8	0.0000	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C9	0.0059	0.006191834	0.006	0.006	0.0062	0.006	0.006	0.006	0	0.006	0.006	0	0.006	0.006	0.006	0.006	0.006	0.006	0.0062	0.0062	0.0062	0.0062	0.006	0.006	0.006	0.006
	C10	0.0509	0.0530	0.0529	0.0531	0.0531	0.053	0.052	0.0530	0	0.0531	0.053	0	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053
	C11	0.0000	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 SUB-CRITERIA	**S1**	0.0189607	0.0197	0.02	0.02	0.02	0.02	0.02	0.02	0	0.02	0.02	0	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	S2	0.0233086	0.0243	0.024	0.024	0.024	0.024	0.024	0.024	0	0.024	0.024	0	0.024	0.024	0.024	0.024	0.024	0.0242	0.0242	0.024	0.024	0.024	0.024	0.024	0.024	0.024
	S3	0.0075786	0.0079	0.008	0.008	0.008	0.008	0.008	0.008	0	0.008	0.008	0	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
	S4	0.00260895	0.0027	0.003	0.003	0.003	0.003	0.003	0.003	0	0.003	0.003	0	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
	S5	0.0067907	0.0071	0.007	0.007	0.007	0.007	0.007	0.007	0	0.007	0.007	0	0.0071	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
	S6	0.04724036	0.049144853	0.0491	0.049	0.049	0.049	0.049	0.049	0	0.049	0.049	0	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049
	S7	0.02493502	0.025942001	0.0259	0.026	0.026	0.026	0.026	0.026	0	0.026	0.026	0	0.0259	0.026	0.026	0.026	0.026	0.0259	0.026	0.026	0.0260	0.0260	0.026	0.026	0.026	0.026
	S8	0.00827953	0.008617068	0.009	0.0086	0.009	0.009	0.008	0.009	0	0.009	0.009	0	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.0086	0.009	0.009	0.009	0.009	0.009
	S9	0.00135949	0.001414896	0.001	0.0014	0.001	0.001	0.001	0.001	0	0.001	0.001	0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	S10	0.00357572	0.003721978	0.004	0.004	0.0037	0.004	0.004	0.004	0	0.004	0.004	0	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
	S11	0.0013805	0.001436972	0.001	0.001	0.0014	0.001	0.001	0.001	0	0.001	0.001	0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0014	0.001	0.001	0.001	0.001
	S12	0.04556537	0.047377155	0.047	0.047	0.047	0.0477	0.047	0.047	0	0.048	0.047	0	0.047	0.047	0.047	0.047	0.047	0.0474	0.0474	0.047	0.047	0.047	0.048	0.048	0.048	0.048
	S13	0.01052066	0.01093854	0.011	0.011	0.011	0.0110	0.011	0.011	0	0.011	0.011	0	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
	S14	0.0179677	0.018680547	0.019	0.019	0.019	0.0188	0.018	0.019	0	0.019	0.019	0	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.0188	0.019	0.019
	S15	0.02200179	0.022876624	0.023	0.023	0.023	0.0231	0.023	0.023	0	0.023	0.023	0	0.023	0.023	0.023	0.023	0.023	0.0229	0.0229	0.023	0.023	0.023	0.023	0.0230	0.023	0.023
	S16	0.08283095	0.086189065	0.086	0.086	0.086	0.086	0.0891	0.086	0	0.086	0.086	0	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.085	0.085
	S17	0.05513363	0.057367749	0.058	0.057	0.057	0.057	0.0591	0.057	0	0.057	0.057	0	0.057	0.057	0.057	0.057	0.057	0.0575	0.0574	0.057	0.057	0.057	0.057	0.057	0.057	0.057
	S18	0.01063416	0.011065287	0.011	0.011	0.011	0.011	0.0114	0.011	0	0.011	0.011	0	0.0111	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
	S19	0.01180927	0.012288476	0.012	0.012	0.012	0.012	0.012	0.012	0	0.012	0.012	0	0.012	0.012	0.012	0.012	0.012	0.0123	0.0123	0.0123	0.012	0.012	0.012	0.012	0.012	0.012
	S20	0.02760102	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S21	0.00232179	0.00241701	0.002	0.002	0.002	0.002	0.002	0.002	0	0.0024	0.002	0	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.0024	0.002	0.002	0.002
	S22	0.00063038	0.000656233	7E-04	7E-04	7E-04	7E-04	6E-04	7E-04	0	0.0007	7E-04	0	7E-04	7E-04	7E-04	7E-04	7E-04	7E-04	7E-04	7E-04	7E-04	0.0007	0.0007	7E-04	7E-04	7E-04
	S23	0.00100379	0.001044953	0.001	0.001	0.001	0.001	0.001	0.001	0	0.0011	0.001	0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0011	0.001	0.001	0.001
	S24	0.03444341	0.035843162	0.036	0.036	0.036	0.036	0.035	0.036	0	0.036	0.0360	0	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
	S25	0.00758212	0.007890259	0.008	0.008	0.008	0.008	0.008	0.008	0	0.008	0.0079	0	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
	S26	0.03465096	0.03605921	0.036	0.036	0.036	0.036	0.035	0.036	0	0.036	0.0362	0	0.0361	0.036	0.036	0.036	0.036	0.0360	0.0360	0.0361	0.036	0.0361	0.036	0.036	0.036	0.036
	S27	0.00384705	0.004003213	0.004	0.004	0.004	0.004	0.004	0.004	0	0.004	0.0040	0	0.004	0.004	0.004	0.004	0.004	0.0040	0.0040	0.0040	0.004	0.004	0.004	0.004	0.004	0.004
	S28	0.00756979	0	0	0	0	0	0	0	0	0	0	0.0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S29	0.00290933	0	0	0	0	0	0	0	0	0	0	0.0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S30	0.00073372	0	0	0	0	0	0	0	0	0	0	0.0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0

		3 SUB-CRITERIA (cont.)															
		S15	**S16**	**S17**	**S18**	**S19**	**S20**	**S21**	**S22**	**S23**	**S24**	**S25**	**S26**	**S27**	**S28**	**S29**	**S30**
1 GOAL	**PP**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 CRITERIA	**C1**	0.08	0.079	0.08	0.0796	0.08	0	0.08	0.08	0.08	0.08	0.08	0.0802	0.08	0	0	0
	C2	0.1263	0.126	0.1258	0.126	0.1263	0	0.126	0.126	0.126	0.126	0.126	0.1263	0.1263	0	0	0
	C3	0.017	0.017	0.017	0.017	0.0169	0	0.017	0.017	0.017	0.017	0.017	0.0169	0.0169	0	0	0
	C4	0.009	0.009	0.009	0.009	0.009	0	0.0089	0.0088	0.0089	0.009	0.009	0.0088	0.009	0	0	0
	C5	0.0702	0.069	0.069	0.069	0.07	0	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0	0	0
	C6	0.114	0.118	0.1171	0.1170	0.114	0	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0	0	0
	C7	0.018	0.017	0.017	0.017	0.0176	0	0.018	0.018	0.018	0.0176	0.018	0.0176	0.018	0	0	0
	C8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C9	0.006	0.006	0.006	0.006	0.006	0	0.0062	0.0062	0.0062	0.006	0.006	0.0062	0.006	0	0	0
	C10	0.053	0.052	0.052	0.052	0.053	0	0.053	0.053	0.053	0.0531	0.053	0.0530	0.0530	0	0	0
	C11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 SUB-CRITERIA	**S1**	0.02	0.02	0.02	0.02	0.02	0	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0	0	0
	S2	0.024	0.024	0.024	0.024	0.024	0	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0	0	0
	S3	0.008	0.008	0.008	0.008	0.008	0	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0	0	0
	S4	0.003	0.003	0.003	0.003	0.003	0	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0	0	0
	S5	0.007	0.007	0.007	0.007	0.007	0	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0	0	0
	S6	0.049	0.049	0.049	0.049	0.0492	0	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0	0	0
	S7	0.026	0.026	0.026	0.026	0.0260	0	0.026	0.0260	0.026	0.026	0.026	0.026	0.026	0	0	0
	S8	0.009	0.008	0.008	0.008	0.0086	0	0.009	0.009	0.0087	0.009	0.009	0.009	0.009	0	0	0
	S9	0.001	0.001	0.001	0.001	0.0014	0	0.001	0.001	0.0014	0.001	0.001	0.001	0.001	0	0	0
	S10	0.004	0.004	0.004	0.004	0.004	0	0.004	0.0037	0.004	0.004	0.004	0.004	0.004	0	0	0
	S11	0.001	0.001	0.001	0.001	0.0014	0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0	0	0
	S12	0.048	0.047	0.047	0.047	0.047	0	0.048	0.047	0.048	0.047	0.048	0.047	0.047	0	0	0
	S13	0.011	0.011	0.011	0.011	0.011	0	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0	0	0
	S14	0.019	0.018	0.018	0.018	0.019	0	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0	0	0
	S15	0.023	0.023	0.023	0.023	0.023	0	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0	0	0
	S16	0.086	0.089	0.088	0.088	0.086	0	0.086	0.086	0.086	0.086	0.085	0.086	0.086	0	0	0
	S17	0.057	0.059	0.059	0.059	0.057	0	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0	0	0
	S18	0.011	0.011	0.011	0.011	0.011	0	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0	0	0
	S19	0.012	0.012	0.012	0.012	0.012	0	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0	0	0
	S20	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	S21	0.002	0.002	0.002	0.002	0.002	0	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0	0	0
	S22	7E-04	6E-04	6E-04	6E-04	7E-04	0	7E-04	7E-04	7E-04	7E-04	7E-04	7E-04	7E-04	0	0	0
	S23	0.001	0.001	0.001	0.001	0.001	0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0	0	0
	S24	0.036	0.035	0.035	0.035	0.0359	0	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0	0	0
	S25	0.008	0.008	0.008	0.008	0.008	0	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0	0	0
	S26	0.036	0.035	0.036	0.036	0.0361	0	0.036	0.0361	0.036	0.036	0.036	0.036	0.036	0	0	0
	S27	0.004	0.004	0.004	0.004	0.004	0	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0	0	0
	S28	0	0	0	0	0	0	0	0	0	0	0	0	0	0.675	0.675	0.675
	S29	0	0	0	0	0	0	0	0	0	0	0	0	0	0.259	0.259	0.259
	S30	0	0	0	0	0	0	0	0	0	0	0	0	0	0.065	0.065	0.065

Figure 21 Limit Supermatrix 3

APPENDIX E

SUB-CRITERIA VALUES OF THE PROJECTS

The sub-criteria values of the projects used in the case study are presented in Table 24 - Table 28.

Table 24 Sub-Criteria Values of the Projects in the Case Study

		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
Max. S.C.	S21	3,82	34,41	100,00	82,79	34,02	65,06	100,00	0,00	20,95	73,28	0,00	100,00	0,00	0,00	0,00
	S23	21,83	100,00	100,00	0,00	100,00	0,00	0,00	-	-	-	-	16,59	-	-	-
Minimizing Sub-Criteria	S1	32,50	20,83	16,67	0,00	50,00	0,00	0,00	0,00	0,00	50,00	0,00	0,00	0,00	0,00	0,00
	S2	100,00	5,95	100,00	100,00	100,00	100,00	100,00	100,00	0,00	0,00	0,00	90,30	-	73,33	0,00
	S6	18,00	9,00	5,00	41,41	19,05	15,00	32,89	8,00	3,23	14,74	5,88	30,00	10,53	71,43	2,00
	S7	100,00	100,00	100,00	100,00	100,00	100,00	0,00	100,00	7,78	84,44	0,00	60,00	-	-	0,00
	S8	59,93	47,75	75,34	57,81	55,07	50,05	58,09	17,71	60,91	63,56	100,00	66,69	90,25	100,00	100,00
	S9	0,00	0,44	53,24	0,00	0,00	40,89	6,48	-	-	0,00	-	0,00	-	-	0,00
	S10	53,69	41,63	39,50	8,69	21,36	23,50	7,04	31,44	36,39	10,26	31,43	18,04	32,04	12,64	33,81
	S11	21,77	15,63	88,89	16,79	0,00	33,33	75,00	22,50	23,33	44,00	21,43	22,22	12,50	0,00	0,00
	S16	8,96	51,47	45,43	19,90	2,26	0,00	0,30	8,35	17,31	30,63	0,00	0,00	1,39	0,00	0,00
	S17	75,37	63,70	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	S19	95,00	100,00	-	96,91	-	-	-	-	-	100,00	-	-	-	-	-
	S20	87,50	100,00	100,00	25,00	0,00	50,00	0,00	0,00	50,00	50,00	0,00	0,00	0,00	0,00	0,00
	S22	25,78	17,96	12,93	20,33	4,53	39,83	6,73	8,65	2,44	9,70	1,35	8,17	4,17	0,56	17,00
	S24	20,00	10,00	-	14,29	-	-	-	-	-	-	-	-	-	-	-
	S25	9,33	44,67	-	-	-	-	-	-	-	100,00	-	-	-	-	-
	S27	55,67	46,87	61,11	-	33,33	-	-	-	-	-	-	-	-	-	-

Table 25 Sub-Criteria Values of the Projects When Average Values of the Other Projects Are Assigned to Missing Values

		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
Max. S.C.	S21	3,82	34,41	100,00	82,79	34,02	65,06	100,00	0,00	20,95	73,28	0,00	100,00	0,00	0,00	0,00
	S23	21,83	100,00	100,00	0,00	100,00	0,00	0,00	42,30	42,30	42,30	42,30	16,59	42,30	42,30	42,30
Minimizing Sub-Criteria	S1	32,50	20,83	16,67	0,00	50,00	0,00	0,00	0,00	0,00	50,00	0,00	0,00	0,00	0,00	0,00
	S2	100,00	5,95	100,00	100,00	100,00	100,00	100,00	100,00	0,00	0,00	0,00	90,30	62,11	73,33	0,00
	S6	18,00	9,00	5,00	41,41	19,05	15,00	32,89	8,00	3,23	14,74	5,88	30,00	10,53	71,43	2,00
	S7	100,00	100,00	100,00	100,00	100,00	100,00	0,00	100,00	7,78	84,44	0,00	60,00	65,56	65,56	0,00
	S8	59,93	47,75	75,34	57,81	55,07	50,05	58,09	17,71	60,91	63,56	100,00	66,69	90,25	100,00	100,00
	S9	0,00	0,44	53,24	0,00	0,00	40,89	6,48	10,11	10,11	0,00	10,11	0,00	10,11	10,11	0,00
	S10	53,69	41,63	39,50	8,69	21,36	23,50	7,04	31,44	36,39	10,26	31,43	18,04	32,04	12,64	33,81
	S11	21,77	15,63	88,89	16,79	0,00	33,33	75,00	22,50	23,33	44,00	21,43	22,22	12,50	0,00	0,00
	S16	8,96	51,47	45,43	19,90	2,26	0,00	0,30	8,35	17,31	30,63	0,00	0,00	1,39	0,00	0,00
	S17	75,37	63,70	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	S19	95,00	100,00	97,98	96,91	97,98	97,98	97,98	97,98	97,98	100,00	97,98	97,98	97,98	97,98	97,98
	S20	87,50	100,00	100,00	25,00	0,00	50,00	0,00	0,00	50,00	50,00	0,00	0,00	0,00	0,00	0,00
	S22	25,78	17,96	12,93	20,33	4,53	39,83	6,73	8,65	2,44	9,70	1,35	8,17	4,17	0,56	17,00
	S24	20,00	10,00	14,76	14,29	14,76	14,76	14,76	14,76	14,76	14,76	14,76	14,76	14,76	14,76	14,76
	S25	9,33	44,67	51,33	51,33	51,33	51,33	51,33	51,33	51,33	100,00	51,33	51,33	51,33	51,33	51,33
	S27	55,67	46,87	61,11	49,25	33,33	49,25	49,25	49,25	49,25	49,25	49,25	49,25	49,25	49,25	49,25

Table 26 Lower Bounds Used for the Sub-Criteria Values of the Projects in Interval DEA Approach

		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
Max. S.C.	S21-L	3,82	34,41	100,00	82,79	34,02	65,06	100,00	0,00	20,95	73,28	0,00	100,00	0,00	0,00	0,00
	S23-L	21,83	100,00	100,00	0,00	100,00	0,00	0,00	0,00	0,00	0,00	0,00	16,59	0,00	0,00	0,00
Minimizing Sub-Criteria	S1-L	32,50	20,83	16,67	0,00	50,00	0,00	0,00	0,00	0,00	50,00	0,00	0,00	0,00	0,00	0,00
	S2-L	100,00	5,95	100,00	100,00	100,00	100,00	100,00	100,00	0,00	0,00	0,00	90,30	0,00	73,33	0,00
	S6-L	18,00	9,00	5,00	41,41	19,05	15,00	32,89	8,00	3,23	14,74	5,88	30,00	10,53	71,43	2,00
	S7-L	100,00	100,00	100,00	100,00	100,00	100,00	0,00	100,00	7,78	84,44	0,00	60,00	0,00	0,00	0,00
	S8-L	59,93	47,75	75,34	57,81	55,07	50,05	58,09	17,71	60,91	63,56	100,00	66,69	90,25	100,00	100,00
	S9-L	0,00	0,44	53,24	0,00	0,00	40,89	6,48	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	S10-L	53,69	41,63	39,50	8,69	21,36	23,50	7,04	31,44	36,39	10,26	31,43	18,04	32,04	12,64	33,81
	S11-L	21,77	15,63	88,89	16,79	0,00	33,33	75,00	22,50	23,33	44,00	21,43	22,22	12,50	0,00	0,00
	S16-L	8,96	51,47	45,43	19,90	2,26	0,00	0,30	8,35	17,31	30,63	0,00	0,00	1,39	0,00	0,00
	S17-L	75,37	63,70	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	S19-L	95,00	100,00	0,00	96,91	0,00	0,00	0,00	0,00	0,00	100,00	0,00	0,00	0,00	0,00	0,00
	S20-L	87,50	100,00	100,00	25,00	0,00	50,00	0,00	0,00	50,00	50,00	0,00	0,00	0,00	0,00	0,00
	S22-L	25,78	17,96	12,93	20,33	4,53	39,83	6,73	8,65	2,44	9,70	1,35	8,17	4,17	0,56	17,00
	S24-L	20,00	10,00	0,00	14,29	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	S25-L	9,33	44,67	0,00	0,00	0,00	0,00	0,00	0,00	0,00	100,00	0,00	0,00	0,00	0,00	0,00
	S27-L	55,67	46,87	61,11	0,00	33,33	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Table 27 Upper Bounds Used for the Sub-Criteria Values of the Projects in Interval DEA Approach

		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
Max. S.C.	S21-U	3,82	34,41	100,00	82,79	34,02	65,06	100,00	0,00	20,95	73,28	0,00	100,00	0,00	0,00	0,00
	S23-U	21,83	100,00	100,00	0,00	100,00	0,00	0,00	100,00	100,00	100,00	100,00	16,59	100,00	100,00	100,00
Minimizing Sub-Criteria	S1-U	32,50	20,83	16,67	0,00	50,00	0,00	0,00	0,00	0,00	50,00	0,00	0,00	0,00	0,00	0,00
	S2-U	100,00	5,95	100,00	100,00	100,00	100,00	100,00	100,00	0,00	0,00	0,00	90,30	100,00	73,33	0,00
	S6-U	18,00	9,00	5,00	41,41	19,05	15,00	32,89	8,00	3,23	14,74	5,88	30,00	10,53	71,43	2,00
	S7-U	100,00	100,00	100,00	100,00	100,00	100,00	0,00	100,00	7,78	84,44	0,00	60,00	100,00	100,00	0,00
	S8-U	59,93	47,75	75,34	57,81	55,07	50,05	58,09	17,71	60,91	63,56	100,00	66,69	90,25	100,00	100,00
	S9-U	0,00	0,44	53,24	0,00	0,00	40,89	6,48	100,00	100,00	0,00	100,00	0,00	100,00	100,00	0,00
	S10-U	53,69	41,63	39,50	8,69	21,36	23,50	7,04	31,44	36,39	10,26	31,43	18,04	32,04	12,64	33,81
	S11-U	21,77	15,63	88,89	16,79	0,00	33,33	75,00	22,50	23,33	44,00	21,43	22,22	12,50	0,00	0,00
	S16-U	8,96	51,47	45,43	19,90	2,26	0,00	0,30	8,35	17,31	30,63	0,00	0,00	1,39	0,00	0,00
	S17-U	75,37	63,70	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	S19-U	95,00	100,00	100,00	96,91	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00
	S20-U	87,50	100,00	100,00	25,00	0,00	50,00	0,00	0,00	50,00	50,00	0,00	0,00	0,00	0,00	0,00
	S22-U	25,78	17,96	12,93	20,33	4,53	39,83	6,73	8,65	2,44	9,70	1,35	8,17	4,17	0,56	17,00
	S24-U	20,00	10,00	100,00	14,29	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00
	S25-U	9,33	44,67	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00
	S27-U	55,67	46,87	61,11	100,00	33,33	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

Table 28 Sub-Criteria Values of the Projects Used in Weighted Sum Approach

		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
Max. S.C.	y21	3,82	34,41	100,00	82,79	34,02	65,06	100,00	0,00	20,95	73,28	0,00	100,00	0,00	0,00	0,00
	y23	21,83	100,00	100,00	0,00	100,00	0,00	0,00	42,30	42,30	42,30	42,30	16,59	42,30	42,30	42,30
Minimizing Sub-Criteria	x1	67,50	79,17	83,33	100,00	50,00	100,00	100,00	100,00	100,00	50,00	100,00	100,00	100,00	100,00	100,00
	x2	0,00	94,05	0,00	0,00	0,00	0,00	0,00	0,00	100,00	100,00	100,00	9,70	37,89	26,67	100,00
	x6	82,00	91,00	95,00	58,59	80,95	85,00	67,11	92,00	96,77	85,26	94,12	70,00	89,47	28,57	98,00
	x7	0,00	0,00	0,00	0,00	0,00	0,00	100,00	0,00	92,22	15,56	100,00	40,00	34,44	34,44	100,00
	x8	40,07	52,25	24,66	42,19	44,93	49,95	41,91	82,29	39,09	36,44	0,00	33,31	9,75	0,00	0,00
	x9	100,00	99,56	46,76	100,00	100,00	59,11	93,52	89,89	89,89	100,00	89,89	100,00	89,89	89,89	100,00
	x10	46,31	58,37	60,50	91,31	78,64	76,50	92,96	68,56	63,61	89,74	68,57	81,96	67,96	87,36	66,19
	x11	78,23	84,37	11,11	83,21	100,00	66,67	25,00	77,50	76,67	56,00	78,57	77,78	87,50	100,00	100,00
	x16	91,04	48,53	54,57	80,10	97,74	100,00	99,70	91,65	82,69	69,37	100,00	100,00	98,61	100,00	100,00
	x17	24,63	36,30	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00
	x19	5,00	0,00	2,02	3,09	2,02	2,02	2,02	2,02	2,02	0,00	2,02	2,02	2,02	2,02	2,02
	x20	12,50	0,00	0,00	75,00	100,00	50,00	100,00	100,00	50,00	50,00	100,00	100,00	100,00	100,00	100,00
	x22	74,22	82,04	87,07	79,67	95,47	60,17	93,27	91,35	97,56	90,30	98,65	91,83	95,83	99,44	83,00
	x24	80,00	90,00	85,24	85,71	85,24	85,24	85,24	85,24	85,24	85,24	85,24	85,24	85,24	85,24	85,24
	x25	90,67	55,33	48,67	48,67	48,67	48,67	48,67	48,67	48,67	0,00	48,67	48,67	48,67	48,67	48,67
	x27	44,33	53,13	38,89	50,75	66,67	50,75	50,75	50,75	50,75	50,75	50,75	50,75	50,75	50,75	50,75