A METHODOLOGY FOR INTEGRATION OF ERGONOMICS AND TOTAL QUALITY MANAGEMENT FOR COMPANY STRATEGIES

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ABSTRACT

A METHODOLOGY FOR INTEGRATION OF ERGONOMICS AND TOTAL QUALITY MANAGEMENT FOR COMPANY STRATEGIES

Total Quality Management (TQM) and Ergonomics implementations in unison contribute to the sustainability of the company and promote sustainable strategy. TQM and Ergonomics approaches do have common goals, but also differ in some aspects. This study aimed to integrate these two approaches to achieve strategic company goals, mainly for manufacturing-based companies. In order to integrate these two approaches from a strategical point of view, firstly, critical success factors of TQM and Ergonomics were examined. Consequently, six main strategical objectives for companies and 25 factors of TQM and Ergonomics are determined to construct a hierarchical model. This model is solved by analytic hierarchy process (AHP) and fuzzy analytic hierarchy process (FAHP) methodologies. The data collected through a questionnaire from managers are analyzed to prioritize the critical success factors. Finally, the critical success factors of both approaches are then grouped to form four category and a conceptual model is suggested. Creating sustainable business is found to be the most important strategic objective, followed by profit maximization and company credibility and reputation increase, respectively. Business process category is found to be the most important category, followed by managerial issues and leadership and customers, respectively. Quality increase is found to be the most important factor, followed by productivity and efficiency and continuous improvement, respectively.

ÖZET

ERGONOMİ VE TOPLAM KALİTE YÖNETİMİNİN ŞİRKET STRATEJİLERİNE ENTEGRASYONUNU SAĞLAYAN BİR METODOLOJİ ÇALIŞMASI

Toplam kalite yönetimi (TKY) ve ergonominin birlikte uygulanması, şirketlerin varlıklarının devamlılığının sağlanmasına katkıda bulunur ve sürdürülebilir stratejiyi teşvik eder. Toplam kalite yönetimi ve ergonomi yaklaşımlarının bazı ortak amaçları vardır, aynı zamanda farklılaşan pek çok yönleri de bulunmaktadır. Bu çalışma, bünyesinde aktif üretim gerçekleştiren firmalarda stratejik şirket hedeflerine ulaşmak için bu iki yaklaşımı entegre etmeyi amaçlamıştır. Bu iki yaklaşımı stratejik bir bakış açısıyla bütünleştirmek için öncelikle toplam kalite yönetiminin ve ergonominin kritik başarı faktörleri araştırılmıştır. Şirketlere ait altı ana stratejik amaç ile TKY ve ergonomiye ait 25 faktör hiyerarşik bir model oluşturmak üzere belirlenmiştir. Bu model analitik hiyerarşi süreci ve bulanık analitik hiyerarşi süreci metotları ile çözümlenmiştir. Hedef kitlesi müdürler olan anket çalışması ile kritik başarı faktörleri önceliklendirilmiştir. Sonuç olarak, kritik başarı faktörleri 4 grup altında toplanmış ve kavramsal model oluşturulmuştur. Sürdürülebilir bir iş yaratmak en önemli stratejik amaç olarak belirlenmiştir, bu amacı önem sırasıyla maksimum karlılık amacı ve şirket bilinirliğinin ve saygınlığının artırılması amacı takip eder. İş süreçleri kategorisi en önemli kategori olarak belirlenmiştir, bu kategoriyi önem sırasıyla yönetimsel konular ve liderlik kategorisi ve müşteriler kategorisi takip eder. Kalite artışı en önemli faktör olarak belirlenmiştir, bu faktörü önem sırasıyla üretkenlik ve verimlilik faktörü ve sürekli iyileştirme ve geliştirme faktörü takip eder.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS/ABBREVIATIONS

AHP	Analytic Hierarchy Process
BP	Business Process
BSC	Balanced Scorecard
CI	Inconsistency Index
CR	Consistency Ratio
CUS	Customers
EMP	Employees
FAHP	Fuzzy Analytic Hierarchy Process
MCDM	Multi-Criteria Decision Making
MIL	Managerial Issues and Leadership
QA	Quality Assurance
QC	Quality Control
RI	Random Consistency Index
RQ1	Research Question 1
RQ2	Research Question 2
RQ3	Research Question 3
SLR	Systematic Literature Review
SO1	Profit Maximization
SO2	Market Share Increase
SO3	Company Credibility and Reputation Increase
SO4	Competitiveness Increase
SO5	Attracting and Maintaining Potential High Performer, Motivated and Skilled Employees
SO6	Creating Sustainable Business
SPE	Social and Physical Environment
TP	Third Parties
TQM	Total Quality Management

1. INTRODUCTION

A well-built strategy for continuous improvement in quality and better working condition creation for employees have become a necessity for a company to remain sustainable in a highly competitive business world. In recent years, many companies are going through organizational transformation in order to stay competitive in the market and to be able to meet ever-changing customer demands. Executives are facing increases in costs, competitive pricing and excessive demands from the stakeholders [4]. Formulating the right strategy, making the right decisions, prioritization for the right options for these demands is becoming more crucial than it was before.

In literature, there are many successful examples of a wide range of philosophies, total quality management (TQM) and ergonomics are two of these concepts that bring success. TQM is one of the widely accepted management philosophies that purposes continuous improvement in product and process quality, customer atonement while enhancing system effectiveness, system flexibility, and competitive power in responding customers expectations [5]. Recently, interest in TQM programs shows a decreasing trend because, in spite of the fact that successful results attained through TQM, expected breakthrough outcomes have not seen on sales profits and cost reductions [5]. Unfortunately not all the improvement projects lead the perfect results, unsuccessful program rates vary 60 between percent to 90 percent in literature [6]. TQM requires complementary approaches. Ergonomics is another topic that enhance system performance outputs. Integration of ergonomics with other disciplines working across boundaries involves a diversity of system interactions, therefore emphasizing the need for ergonomics to work with other disciplines. A cross-disciplinary approach can prefer for human factors problems with other disciplines to design whole systems, instead of pieces of the system. For ergonomics, there is a need for a wider approach and increased cooperation not only engineering disciplines but also social sciences such as economics, cultural factors, and politics [7]. Similarly, Hendrick claimed that ergonomics is often the most successful in concurrent application with TQM. The author pointed out the specific cases shown drastic improvements (over 70 percent) in time loss due to occu-

pational accidents. A higher level of personal satisfaction realized while quality targets are accomplished [8]. We believe different strengths reinforce the effectiveness of overall system performance. However, to obtain sustainable successful business results, a wider perspective is required. Thus a model that allows integrating total quality management and ergonomics into the business strategy can provide companies to obtain sustainable business strategy. In this thesis, we aimed a comprehensive study that merges two philosophies with a business strategy model.

Our thesis presents the results of a systematic literature review (SLR) that has been carried out to identify importance of TQM and ergonomics for a company from a strategic point of view and describe the critical success factors for each practices to determine crucial success factors for a company to improve its performance by combining TQM and ergonomics methodologies. The systematic literature review is performed by using different databases to answer our research questions. Based on the systematic literature review, critical success factors are identified for TQM and ergonomics and also common success factors for both ergonomics and TQM. The dependencies and interactions among of TQM and Ergonomics point of views are described and finally the combination of the critical success factors TQM and Ergonomics are discussed in detailed to constitute the hierarchical model.

This thesis is organized as follows: Section 1 provides brief information about TQM and Ergonomics approaches. Section 2 indicates the systematic literature review method which is used in this study and presents the results of the SLR, continues with the literature study of the concepts, by providing brief information about business strategy, TQM and Ergonomics; TQM and Ergonomics historical development and contributions to company strategies as a management tool. Section 3 gives rationale of the study and objectives. Section 4 clarifies the methodology used for our scientific research. Section 5 discusses the strategic map development. Additionally, identifies critical success factors for TQM and Ergonomics and the combination of these two points of views. Section 6 states how the hierarchical model was developed. Section 7 explains data gathering in detail. Section 8 includes two different method application to hierarchically order critical success factors. Additionally, a conceptual model sug-

gestion is given. To conclude, Section 9 presents the discussion and Section 10 states the overall results of this thesis and recommendations for future studies.

2. LITERATURE REVIEW

At first systematic literature review method is introduced. Then strategic objectives and balance score cards are explained briefly. Previous studies related to Ergonomics and TQM are examined afterwards. These concepts and historical developments and the main principles are reviewed, afterward critical success factors in literature are examined. Finally contributions to company strategy are summarized individually.

2.1. Systematic Literature Review Method

We carried out a systematic literature review (SLR). For this SLR, we used the technique proposed by Kitchenham and Charters [9]. In this study, we systematically identified and evaluated the critical success factors for the combination of TQM and ergonomics point of views in organizations. As a review protocol first of all, we defined three research questions by considering critical success factors of TQM and Ergonomics and defined the main objective of this study. We also identified the search strategy and search scope. For this stage, we decided for the time period of papers which we search for. We mostly used articles published in the last fifteen years, however, we also benefited from early publishing as they represent the origin or a generic publication related to our topic via manual search.

2.1.1. Research Questions

Research questions are crucial and must be very explicit for SLR study since research questions define the aim of the research therefore selecting the right questions results with more relevant findings. We aimed to get the best evidence by identifying explicit research questions.

The research questions are defined as follows:

- RQ1: What are the critical factors for successful ergonomics implementation?
- RQ2: What are the critical factors for successful TQM implementation?
- RQ3: Which factors are the most critical to build a model for a sustainable business strategy?

2.1.2. Search Strategy

To answer the research questions which are defined above, we have performed an extensive search of studies. Our search scope includes sources published between 2004 and 2019. We used the following databases and search engines: Google Scholar, Proquest, Science Direct and Academia. While determining research questions and keyword combinations, we also considered the listing of synonyms, abbreviations, and alternative spellings. In addition to the database searches, we also conducted manual searches by using the search strings. The manual searches were useful since we retrieved many studies which we could not find with an automatic search. Only published sources are used, unpublished studies are discarded. Chosen keywords can be seen in Table 2.1, any other words are not restricted or discarded from this search. Keywords are combined with each other, for example;
"Macroergonomics" AND "Critical Success Factors".

Table 2.1. Keyword Combinations for Literature Search Strategy

Macroergonomics
Ergonomics
Human Factors
Total Quality Management
Business Strategy
Critical Success Factors
Framework

2.1.3. Research Steps

To be able to answer three research questions, the study is completed through the steps indicated in Figure 2.1. Critical factors for adopting successful Ergonomics approach, critical factors for adopting successful TQM approach and critical success factors to build a model for a sustainable business strategy are examined by performing literature reviews and by developing model and by conducting survey.

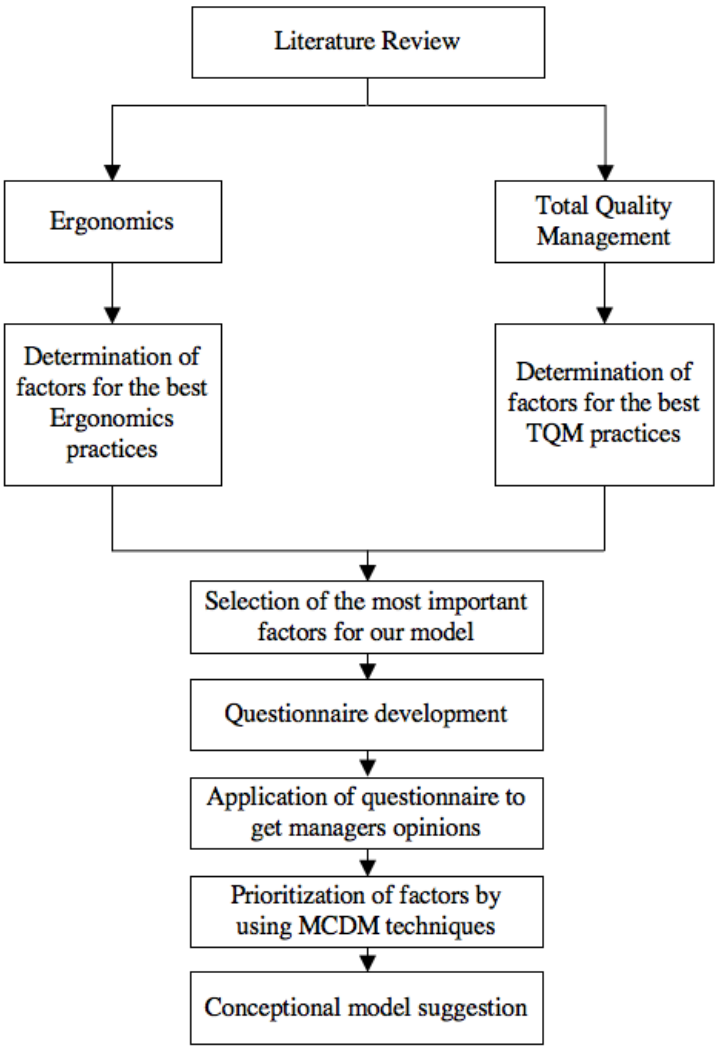

Figure 2.1. Flowchart of the Research Steps

To find the most critical factors of Ergonomics and TQM approaches, previous studies formed a basis. We performed a comprehensive systematic literature review,

then we combined all the critical factors to build a model for finding out the most critical factor. After building a model, a questionnaire is prepared to determine which factors have higher impact on the strategic goals of the company. For the questionnaire two different types of the multi-criteria decision-making (MCDM) methods are used. The Analytic Hierarchy Process (AHP) and the Fuzzy Analytic Hierarchy Process (FAHP) are among the most commonly used methods in the solution of decision-making problems. A hierarchy is designed which consist of all the factors. Data is obtained from upper and mid-level executives via questionnaire. Based on the results of the pairwise comparisons in questionnaire, critical success factors are hierarchically ordered. Factors deeply linked with strategic objectives of the companies have been used for a model suggestion.

2.2. Business Strategy Goals

2.2.1. Balanced Scorecard

Balanced Scorecard (BSC) is a tool, which is used for defining three basic functions of enterprises; communicating strategies, operating strategic management system and measuring the performance. Balanced Scorecard is a strategic performance management method that enables the company to realize its performance and strategy by spreading the targets balanced among four perspectives; financial, customer, internal business processes and learning and growth. It aims to build a corporate self-assessment system. BSC provides a general and understandable perspective for all units of the organization and employees. The strategy map details the vital elements for a company's strategy and the relationships between them in detail. The main purpose of the performance measurement is to improve the performance of the enterprise to increase efficiency and profitability.

Four dimension of balanced scorecard is explained below [10];

(i) Financial dimension consists of elements on how to be successful in order to ensure growth and profitability. Financial dimension presents the expectations of

business shareholders.

(ii) Customer dimension reveals how to increase the success of the target market in order to reach the vision of the enterprise.

(iii) Internal functioning dimension shows what business needs in order to satisfy the customers and shareholders in terms of design, production, delivery, and sales.

(iv) Learning and development dimension signifies what areas the enterprise should specialize in to satisfy the customers and shareholders. One of the most important input is employees' knowledge and skills, in other words, human capital.

The reason for explaining characteristics of the BSC is that we use BSC frame for the positioning of strategic objectives. It is important for us that strategic objectives are homogeneously distributed that provides an effective tool in creating a successful, sustainable strategy for a company. A comprehensive investigation of literature leads us to conclude six main strategic objectives [11,12]. Strategic goals, that are indicated as below, are explained in detail in Section 4.

Company Strategic Goals;

- Profit Maximization
- Company Credibility and Reputation Increase
- Market Share Increase
- Creating Sustainable Business
- Competitiveness Increase
- Attracting and Maintaining Highly Motivated and Skilled Employees

2.3. Ergonomics

2.3.1. Historical Background and Development of Ergonomics

As a word ergonomics has been derived from the combination of two Greek words: 'ergon' and 'nomos'. The prior word means work and latter means natural laws so ergonomics is working with natural laws [4]. European Productivity Agency is one of

the leading organizations in its field. After the foundation, one of the first action was conducting a study with the participation from different countries in an international platform to conceive an operational definition of ergonomics. Experts have been formed a new description of ergonomics in order to make it easier to comprehend as "fitting the job to the worker". This definition is widely accepted from many authorities from academicians, unions to labors and company owners [13]. Another name of ergonomics is human factors and both definitions are used within the scope of the thesis.

In early years, ergonomics was mostly performed at a micro level generally for the individuals, teams or subsystem levels. Based on analyses on detailed worker task observations, improper movements of tasks were eliminated by redesigning or arranging workplace according to human capabilities [14]. Ergonomists were also designing the process due to the human performance capabilities and limitations for matching proper human-task or machine-task processes. Within the technological improvements and increased human-machine interaction ergonomists used their professional knowledge for specific job design, right match of job-worker and then a well-judged person and machine interface [14]. Although micro level applications still maintaining their importance ergonomics has reached a more comprehensive perspective by successfully harmonizing work system both at macro and micro levels [15].

Ergonomics is the science that takes both forward human well-being and human performance via an optimum balance between human integration to system and system adaptation to human [16]. Ergonomics seeks to find the conditions for adapting the work to the human by investigating the unique qualities and abilities of human beings. Researches have been carried out on human characteristics and abilities, the movements of people during the work tasks or behavioral tendency are examined in the finest detail, and the objective is to make this person more capable of producing.

Ergonomics should be applied to organizations step-by-step. First, environmental design needs to be fit to human, then the right person selection who fits the environment or educating that person to fit system is only considered when the former is not possible. When the correct matching is achieved, employees are able to contribute more to

organizational performance [16].

As it is seen in the Figure 2.2 "fitting the job to the worker"concept is further developed and consists of reverse interaction and reciprocal relationship of system elements [14]. Organization as a human factor engineering element refers to organizational design such as tasks or activities, consideration of employee skills, employee needs, and human limits. Additionally, the usage of appropriate technology and the interaction with the other two elements to increase human productivity; to keep up with the pace of the machine, more production, more profit. With the introduction of automation in almost every department in current organizational systems, organizational designs and related managerial approaches to decision-making and control become more constrained in comparison to traditional non-automatized systems. Because of this progressively increasing automation, macroeconomic considerations such as management model has gained more importance, even prior to person-machine micro level design modules [14]. Any system that includes human and environment interaction is a potential topic of er-

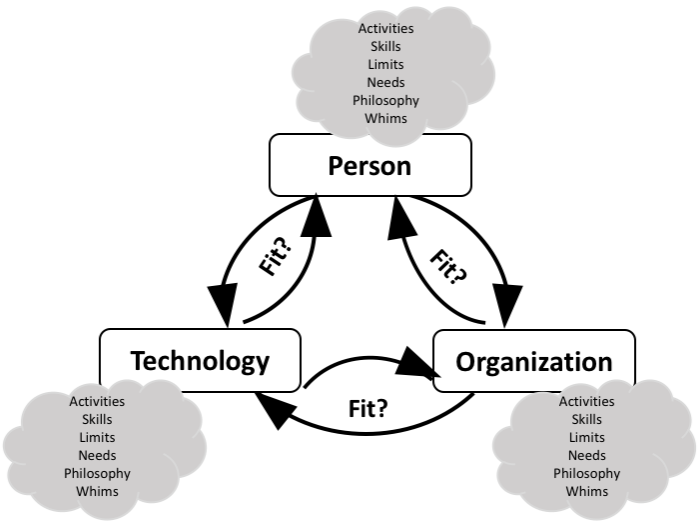

Figure 2.2. Human Factors in Three Ways Fit [11]

gonomics. Environment and system have referred to multiple implications. According to Dull *et al.* [16] "The environment is complex and consists of the physical environment (things), the organizational environment (how activities are organized and controlled), and the social environment (other people, culture). The system can be a work system

(where the human is a worker and the environment is the work environment) or a product system (where the human is a product user, the environment is the environment where the product is used). The focus of HFE is to jointly improve performance and well-being by designing the integrative whole better, and by integrating the human into the system better. This is done by fitting the environment to the human."

The system designed by human factor engineers can interpret more efficient systems, fewer quality deficiencies, healthy and satisfied employees. However, the potential of HFE remains under-exploited [16]. Managerial authorities within the organizations generally associate ergonomics with only health-related topics, most managers are not aware of the ergonomics contributions to organizational performance. This wrong perception caused by an insufficient number of human factors focused articles in the management magazines. Furthermore, in many countries ergonomics is perceived as a legal application which is forced by governments and authorities to ensure a safe and healthy workplace [17]. Ergonomics not only focus on human well being but also the level of output achieved through the system in which people work.

2.3.2. Critical Success Factors for Ergonomics

There have been made different studies which aim to find the important factors for successful ergonomics implementation. One of the leading names in the field of ergonomics Hendrick [8] compiled the factors that result in cost advantage via human factors engineering interventions. Real management commitment, true professional ergonomics leadership and expertise, participatory ergonomics, picking the 'low hanging fruit' first, and ergonomic improvements reduce work-related musculoskeletal disorders are important issues that enhance the productivity.

Carayon *et al.* [7] studied ergonomic work systems structural elements that effects working life quality, performance outputs and health and safety. Authors work system model includes the person in the middle of the system structure, organization, tasks, environment and technology, and tools in the field of health care. Factors under this five categories are education, skills and knowledge, motivation and needs,

physical characteristics, psychological characteristics, teamwork for the first element. Organization element includes coordination, collaboration and communication, organizational culture and safety culture, work schedules, social relationships supervisory and management style, performance evaluation, rewards, and incentives. Technology and tools include factors such as ergonomics characteristic, technological devices, and tools. Factors under the tasks element are tasks variety, demanded job, job content and skill utilization for a task and control of task and participation. The environment includes factors such as work station and layout design, lighting, humidity, noise, and temperature. Even though an employee is highly talented and well educated that does not guarantee the output quality of work. They highlighted these factors are supplementary for a work structure [7].

Karim *et al.* [18] aimed to decide performance indicators with the macroergonomics approach that has a principle of balancing between social and technical sides in a running system. Main attributes have been decided as an organization, human resources, tasks and activities, technology, physical environment, information systems. Authors applied Fuzzy Analytic Hierarchy Process methodology, 33 macroergonomics sub-attributes prioritizing resulted in 18 sub-attributes of macroergonomics and result in 21 key performance indicators.

Erensal and Albayrak [19] examine the factors for an excellent macroergonomics adaptation and to determine the most advantageous management style. Physical conditions, organizational conditions, leadership, participation, culture, employee, and employee attitudes are indicated as critical factors for macroergonomics adoption.

Fitzgerald *et al.* [20] emphasized that a safe and healthy environment can be obtained via ergonomic applications. They indicated ten key factors as follows; training and competence, staffing, organizational change, safety critical communications, ergonomic design, fatigue and shift work, organizational culture, managing human failures and maintenance, inspection and testing, human failures management and procedures.

Vargas *et al.* [21], specified macroergonomics factors for manufacturing systems as following; education knowledge and skills, physical characteristics, psychological characteristics, motivation and needs, teamwork, coordination, collaboration and communication, organizational culture and safety culture,work schedules, social relationships, supervision and management styles, performance evaluation, rewards, and incentives task variety,job content, challenges, and use of skills, autonomy, job control, and participation, work demands, information technology, advanced manufacturing technology, human resources characteristics in technology and tool usage.

2.3.3. Ergonomics Contributions to Strategic Objectives

Dul and Neumann [17] claimed that human factors can be more adopted by managers and absorbed by the organization when ergonomics has a straight effect on strategy. That will be easier if the way of ergonomics communication manner shows similarity with organizational speaking. If managers are not aware of the ergonomic improvements that contribute directly to the strategy, health and safety improvement actions takes longer time to apply. When ergonomics is implemented to the organizational strategy there would be definitely development in ergonomics application since it is a part of strategy especially managers will prioritize and that will lead to better system performance.

Ergonomics is not a strategy by itself, it is a contributor and a significant feature while setting up the strategy and execution [17]. Two ergonomics factors; organizational culture and communication have straight positive impact on customers and indirectly impact on the manufacturing operations and the development of the organization itself. Those analyses might bring new know-how and target oriented information to the company in order to increase companies' competitiveness [15]. Communicating the care about ergonomics might be appreciated especially by customers.

Ergonomics contributes not only to company targets but also the employees in terms of their safety, health, gladness, and performance. That leads the organization to find better solutions against faced troubles and decrease the number of discontinuity of

employees in order to raise customer satisfaction and devotion by increasing efficiency and rivalry of the system [21]. This provides a company to attract and maintain talented employees.

Although longer time periods are needed, engagement of communities and people in the organization is recommended by ergonomics. Nevertheless, the integration of ergonomics to company strategies and targets is an encouraging method to have a stable expansion for companies with low social costs coming from the work-related sickness [17]. In the long run that significantly contributes to the rate of profit.

Table 2.2 shows the factors critical for successful implementations of ergonomics from previous studies.

Table 2.2. Critical Success Factors for Ergonomics

FACTORS	**Ref [15]**	**Ref [7]**	**Ref [8]**	**Ref [19]**	**Ref [20]**	**Ref [22]**
Management Commitment and Involvement		X	X	X	X	
Organizational Design	X	X			X	
Long-term View and Strategic Planning		X			X	
Performance Evaluation and Rewarding	X					
Motivation and Needs	X	X	X	X		
Training, Education and Skills	X	X			X	X
Employee Involvement	X		X			
Teamwork	X	X				
Organizational Culture	X	X		X	X	
Maintaining Employee Well-Being	X	X	X		X	X
Use of Technology	X	X		X		X
Work Place Design	X	X				X
Government and Unions Involvement						X
Productivity and Efficiency			X		X	
Continuous Improvement			X			
Data Driven		X				

2.4. Total Quality Management

2.4.1. Historical Background and Development of Total Quality Management

The total quality management philosophy originated from operational inspection activities. Dale [1] explains the evolution of TQM in four stages shown in Figure 2.3.

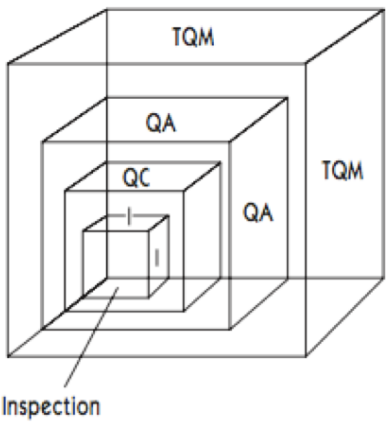

Figure 2.3. Evolution of TQM [1]

The first stage is inspection activities which includes finding the sources of non-conformance, takes the corrective actions. The second stage is quality control which includes basic quality planning and data usage, self-inspection. The third stage is quality assurance where advance planning and quality systems are introduced. Additionally, statistical process control and failure mode effect analysis and quality cost methods have been used. Afterwards, current TQM method was formed. Paradigm has shifted from blame allocation and compliance to specification to empowering people and continuous improvement [1]. The concept named as TQM became well-known in the 1990s by courtesy of positive effects on customer satisfaction and performance of corporations [23]. Fotopoulos [24] highlighted the main difference between TQM and previously developed models as "The evaluation of the organizational performance with respect to customer satisfaction, employee satisfaction, the protection of the natural and social environment and finally the internal and external business results".

Increase in the number of globally formed organizations rises competition even in the international platform and the requirement of better quality to satisfy customers prepare a suitable ambient to come up TQM philosophy [25]. TQM is a systematic approach that everybody associated within the company is involved in continuous improvement to meet customers quality needs and expectation to provide customer satisfaction with the management committee.

There are a few people who move forward TQM with their contributions, can be mentioned as quality gurus. Crosby is one of the guru, he asserted when the high quality obtains, costs reduce and consequently profitability increases. He claimed that quality means conformance to requirements, it is important to do it right the first time because the quality is not an appraisal, performance standard should be zero defects and measurement is the cost of quality [1]. Another guru W. Edwards Deming claimed that productivity and competitiveness can be achieved through maintaining good quality by eliminating variation. He highlighted the major cost of quality as defective products in the hands end users. He summarized his approach in 14 clauses. Moreover, Deming's plan-do-check-act principles aimed at continuous improvement. Juran's description of quality is "fitness for use". Juran's trilogy is another contribution to TQM that includes quality planning, quality control, and quality improvement [1].

2.4.2. Critical Success Factors for Total Quality Management

Dale [1] indicated that, the key elements of TQM are; commitment and leadership of the chief executive officer, planning and organization, tools and techniques are used, education and training, involvement, teamwork, measurement and feedback. Dale [1] also ensures that the culture is conducive for continuous improvement and a key element of TQM.

Nicholas *et al.* [26] presented the critical success factor of TQM in five categories. Each category includes a varying number of factors. Customer orientation, a well-built strategy, vision of the company and long-term focus are stated as critical success factors under planning. Leadership, senior management involvement, lower manage-

ment involvement, attitudes and communication, change acceptance and communication are stated under leadership and management involvement category. Teamwork, cross-functional effort, responsibilities and infrastructure, employee commitment are stated under involvement-commitment and responsibility category. Lastly, goals and plans, time and resource allocation and measuring, monitoring and review are stated as critical success factors under the goals and plans category.

Talib *et al.* [27] analyzed nine critical factors responsible for TQM to build a model to reach business excellence and increase business agility to ever-changing conditions in the market. The model consists of top-management commitment, customer focus, training and education, continuous improvement and innovation, supplier management, employee involvement, quality information, and performance measurement, benchmarking, employee encouragement as significant points that need to be considered. Top management commitment factor is the most critical factor while quality information and performance factor have the lowest degree of importance.

Tseng *et al.* [28] identified core strategic concepts of TQM as strategic planning, effective leadership, customer focus, people management, and process management. Data collected for the empirical study with the participation of employees who has the power of strategic decisions from different business units. Leadership effectiveness has found the highest priority in TQM strategy. To achieve effective leadership sub-factors are required such as flatten the organization, organizational development, continuous improvement, organizational change for best practices, employee participation, and environmental protection.

Anil *et al.* [5] compiled TQM practices for smooth TQM integration to the company and defeat possible obstacles in integration to build a model which can be empirically tested for future studies. Comprehensive search on related literature the model used 18 factors out of 30 factors. These factors include continuous improvement, supplier, customers, employees, quality, benchmarking product and processes can be mention as main headings of topics. Sub-factors are listed as continuous improvement, supplier quality management, customer focus, employees involvement, employees em-

powerment, education and training, strategic management, SPC usage, quality information analysis, quality assurance, quality citizenship, quality culture, benchmarking, process and product design, process management, product innovation and knowledge management.

Fotopoulos *et al.* [24] studied how TQM factors affect performance output of a corporation at the same time the authors evaluated how factors affect each other. In the study, factors are indicated as the quality practices of the top management, employee involvement in the quality management system, customer focus, process and data quality management and quality tools and techniques implementation. Their broadly viewed study has been concluded as management of process and data quality and workers commitment are two main practices influence the degree of quality. These practices are directly affected by high-level management attitudes and indirectly effected the use of specific quality tools.

2.4.3. Total Quality Management Contributions to Strategic Objectives

TQM assists to accomplish strategic goals and positively accelerates an organization's financial and market performance, stock management and quality performance. TQM integration to company results in a change in organizational culture, fulfilling clients expectations, never-ending improvements are promising a superior place in market and productivity in the long run [29]. The empirical study concludes TQM companies outperformed non-TQM implemented companies. Authors also mentioned that decrements in workforce turnover is one of the performance indicators and expected results for appropriate implementation.

Prajogo *et al.* [30] studied the relationship between TQM and corporate strategy. Data obtained through the questionnaire with the participation of a total of 194 employees from middle management and senior management have resulted that TQM has a strong relation with a differentiation strategy. TQM has a role in organizational performance in terms of product quality, product and process innovations, authors also added especially for innovations, implementing only TQM is not enough, it should be

supported by other resources to accomplish strategical targets. Differentiation strategy uses the focus of offering innovative products that competitors do not have. In an intense competition environment, it is logical to focus on both quality and innovation to take a step ahead from the rivals. Another remark of authors is integrating TQM to business environment prevent customer loss, inspection costs, rework cost which is comparatively high than producing cost of high-quality products [30].

Similarly, Porter [31] indicates if an enterprise differentiate by fulfilling customer expectations in a different way than the competitors with its differentiation strategy, due to the prestige of products customers willing to pay higher amounts. Quality is a good point for differentiation. Moreover, quality brings in customer loyalty and leads to decrements in prices sensitiveness. This is strategically important for a decent reputation.

Barclay *et al.* [32] hypothesized quality as a strategic intent and quality as a strategic advantage through TQM in American firms. The authors indicate that to achieve sustainable business implementing TQM plays a crucial role since interactivity of high-quality outputs with a competitive advantage no matter the type of company either profit-making or non-profit making organizations. The rise in the net income, the portion that owned in the market, the atonement of workforce and customers can be accomplished by integrating TQM to the business environment.

Table 2.3 shows the factors critical for successful implementations of TQM in previous studies. Table 2.4 shows the factors critical for successful implementations of ergonomics and TQM in previous studies.

Table 2.3. Critical Success Factors For TQM

FACTORS	**Ref [26]**	**Ref [5]**	**Ref [28]**	**Ref [29]**	**Ref [24]**	**Ref [33]**	**Ref [34]**
Management Commitment and Involvement	X	X	X		X	X	X
Organizational Design	X	X	X				
Long-term View and Strategic Planning	X	X	X		X	X	
Performance Evaluation and Rewarding	X	X					
Empowerment			X				X
Motivation and Needs							X
Training, Education and Skills			X				
Employee Involvement	X		X	X	X	X	
Teamwork	X						
Organizational Culture	X	X	X	X			
Maintaining Employee Well-Being			X	X		X	X
Use of Technology	X						X
Supplier Involvement		X	X				
Government and Unions Involvement						X	
Recognizing Customer Demand	X	X	X		X		
Quick Response to Customers	X	X	X		X		
Initiatives about Customer Feedback	X	X	X	X	X	X	X
Productivity and Efficiency	X	X	X	X		X	
Innovation			X			X	X
Waste Elimination				X			
Continuous Improvement			X				
Quality Increase		X	X			X	X
Cost Reduction				X			X
Data Driven	X	X		X	X		

Table 2.4. Critical Success Factors For TQM and Ergonomic

FACTORS	Ref [15]	Ref [7]	Ref [8]	Ref [19]	Ref [20]	Ref [22]	Ref [26]	Ref [5]	Ref [28]	Ref [29]	Ref [24]	Ref [33]	Ref [34]
Management Commitment and Involvement		X	X	X	X		X	X	X		X	X	X
Organizational Design	X	X			X		X	X	X				
Long-term View and Strategic Planning		X			X		X	X	X		X	X	
Performance Evaluation and Rewarding	X						X	X					
Empowerment									X				X
Motivation and Needs	X	X	X	X									X
Training, Education and Skills	X	X			X	X			X				
Employee Involvement	X		X				X		X	X	X	X	
Teamwork	X	X					X						
Organizational Culture	X	X		X	X		X	X	X	X			
Maintaining Employee Well-Being	X	X	X		X	X			X	X		X	X
Use of Technology	X	X		X		X	X						X
Work Place Design	X	X				X							

Table 2.4. Critical Success Factors For TQM and Ergonomic (cont.).

FACTORS	Ref [15]	Ref [7]	Ref [8]	Ref [19]	Ref [20]	Ref [22]	Ref [26]	Ref [5]	Ref [28]	Ref [29]	Ref [24]	Ref [33]	Ref [34]
Supplier Involvement								X	X				
Government and Unions Involvement						X						X	
Recognizing Customer Demand							X	X	X		X		
Quick Response to Customers							X	X	X		X		
Initiatives about Customer Feedback							X	X	X	X	X	X	X
Productivity and Efficiency			X		X		X	X	X	X		X	
Innovation									X			X	X
Waste Elimination										X			
Continuous Improvement			X						X				
Quality Increase								X	X			X	X
Cost Reduction										X			X
Data Driven		X					X	X		X	X		

3. RATIONALE AND OBJECTIVES OF THE STUDY

3.1. Rationale of the Study

The rationale for conducting this thesis is the need to investigate the opportunity for simultaneous strategic benefits to overall performance and sustainability of TQM and ergonomics. Even though there are great improvements in quality and ergonomics interventions, there are still many gaps in implementing these studies to business to create a system that works flawlessly [16]. The literature review leads us to conclude ergonomics and total quality management have many mutual benefits on organizational components from employees to customers. Some topics such as managerial issues and leadership, employees, social and physical environment, third parties involvement requirement, customer orientation and improvements in various business processes found as common components.

There are many studies in ergonomics, most of them investigate microergonomics issues and the effects on mostly one function or performance output, not an overall strategical perspective. Similarly for the TQM concept, we find few studies that consist of both ergonomics and total quality management however, they mentioned ergonomics at the micro level. Furthermore, there exists some studies that involved TQM and strategy implementation and few studies that involved in ergonomics and strategy however previously these three concepts have not merged. This study combines the mentioned concepts that will minimize inefficient activities and utilize all resources by prioritizing the common factors for a strong strategy that maintains organizational sustainability. Our study differentiates from previous studies that the investigation of TQM and ergonomics at macro level from a strategical perspective is not examined before.

This study will contribute a better understanding of ergonomics and TQM contribution to the company from a strategic perspective. As a result of the reciprocal integration of ergonomics and overlapping factors some targets such as profit maximiza-

tion and stakeholder satisfaction which includes shareholders, customers, employees, governmental authorities and regularity bodies can be accomplished. This study is in the fields of ergonomics, TQM and business strategy that aims to systematize, generalize the theoretical and practical knowledge to build a guide in the managerial area.

3.2. Objectives

This thesis study builds mainly on two objectives which are indicated below;

(i) Determining the most critical factors for companies for building a business strategy in terms of ergonomics and total quality management to accomplish simultaneous improvement within the organization.
(ii) Developing a strategic decision-making guide for companies in terms of simultaneous application of TQM and ergonomics.

To achieve the first objective, research question one (RQ1) and research question two (RQ2) are investigated. To achieve the second objective, research question three (RQ3) is investigated (see 2.1.1).

4. RESEARCH METHODOLOGY

4.1. Multi-Criteria Decision Making Methods

Decision-making can be defined as the decision maker analyzing a problem by choosing, sorting or classifying among the available options. Throughout their lives, people have to make choices. Choosing the most appropriate one of the alternatives can be interpreted as the decision making. In other words, decision-making is the act of choosing the most appropriate and the most effective one by evaluating the results of available solutions separately.

In the decision-making process, the decision maker must obtain the data accurately and consistently. It is easier to decide on a single constraint and a single purpose; however, when more than one constraint is activated, the solution of these problems can be even more difficult. Multi-Criteria Decision-Making (MCDM) techniques play a significant role as tools to help individuals or groups to choose the right one among alternatives in situations where there are at least two decision criteria [35].

It is possible to perform multiple-criteria decision making by using different decision-making techniques. Hybrid Fuzzy Multi-Criteria Decision-Making, Hybrid Multi-Criteria Decision-Making, Analytic Hierarchy Process, Fuzzy Analytic Hierarchy Process, Fuzzy TOPSIS, TOPSIS Analytic Network Process, Fuzzy Analytic Network Process and PROMETHEE are frequently used MCDM tools in the field of science, engineering, technology, and management [36]. For our study, we preferred two of the most frequently used methodologies; Analytic Hierarchy Process and Fuzzy Analytic Hierarchy Process methodologies.

4.1.1. AHP Method

Thomas Saaty is accepted as one of the pioneers of this method with his works in 1970's. AHP is a method based on hierarchical relationship of elements and comparison

of alternatives. It is the estimation method that helps to make decisions by obtaining percentage distributions of alternatives. AHP provides a decision maker to have a systematic approach that is quite good to organize their thoughts. In the case of complex decisions, it is almost impossible to take all factors into account. AHP enables to think systematically for complex and difficult decisions. In other words, AHP method is a quantitative method for ordering and selecting the factors in decision making problem according to multiple alternatives. Through the AHP Method, the decision-making action can be cast into a numerical result by determining the relative relationships of the factors that cannot be counted with each other. Additionally, AHP enables group participation in decision making or problem solving. AHP methodology is introduced step by step by Saaty [37] as follows.

The structure of a hierarchical system needs to be identified as the first step of AHP application.

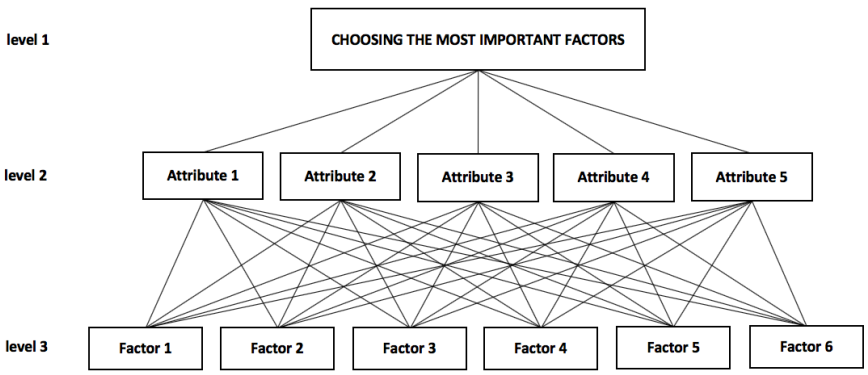

Figure 4.1. Hierarchical Structure Example for AHP

Visual representation of a simple model is given in Figure 4.1. The hierarchical structure example aims to determine the order of importance of the factors. The main goal is located at the top of the hierarchy; attributes are located at the second level and factors are located at the third level. AHP hierarchy is highly flexible, priority weights of all elements are related to each other and the change in any one is immediately reflected on the result.

In order to determine general weights, the superiority between the elements should be determined at each level of the hierarchy. The maximum number of elements at one level is indicated as nine. If the limit is exceeded, the problems regarding reliability of assessment emerges [38].

Table 4.1. Nine-Point Pairwise Comparison Scale [2]

Importance Level	**Definition**	**Explanation**
1	Equally Important	Items contribute equally to the purpose
3	Slightly More Important	One option is slightly more preferred than the other
5	More Important	One option is preferred more than the other
7	Strongly More Important	One option is strongly more preferred than the other
9	Absolutely Important	One option is definitely preferred, leaving no room for doubt
2-4-6-8	Intermediate-Values	When a preference cannot be made between two severity levels, the appropriate values are selected.
Reciprocals		If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i

The second step is conducting preference analysis. In AHP method, elements are evaluated at each hierarchical level by pairwise comparisons with a nine-point scale in Table 4.1 suggested by Saaty. Factors are compared according to their degree of importance and assessments are generally based on experience and expertise. This preference analysis is started from the top level and analysis ends at the lowest hierarchical level. At each hierarchical level, the higher level is taking as reference for comparisons [37].

The ranking procedure proceeds as:

- If two elements are considered to contribute equally to the purpose, it is expressed as equal importance and corresponds to the value 1.

- If one option is slightly more preferred than the other, it is expressed as slightly more important and corresponds to the value 3;
- If one option is chosen more favorably than the other, it is expressed as more important and corresponds to 5;
- If one option is preferred more strongly than the other, it is expressed as strongly more important and corresponds to 7;
- The highest degree of importance is expressed as definitely more important corresponds to a value of 9;
- When a preference cannot be selected among indicated numbers above, the appropriate values can selected from 2,4,6 or 8.

If an hierarchical level consist of n elements, to obtain comparison a matrix $n(n-1)/2$ times pairwise comparisons should be performed according to Table 4.1. Based on ranking of the inter-factor comparison, a square matrix is obtained. Property 4.1 demonstrates a matrix where n is the number of elements in comparison at one cluster. Since diagonals refer the factor comparison itself, diagonal components of comparison matrices are always equal to one: $a_{ii} = 1$ as indicated in Property 4.2.

Pairwise comparisons are performed based on the assumption that how relatively valuable of the i^{th} element in the row than the j^{th} element in the column: a_{ij}. Property 4.3 demonstrates it is assumed that the comparison of the j^{th} element in the row with the i^{th} element in the column should be reciprocal value: $a_{ji} = 1/a_{ij}$. Consequently, the lower triangular part of the matrix should be completed with reciprocal values. The decision matrix is a nxn square matrix where n is the number of alternatives in that cluster.

$$A = |a_{ij}|_{nxn} \qquad where \qquad i, j = 1, 2, ..n \tag{4.1}$$

$$a_{ij} = 1 \qquad for \qquad i = j \tag{4.2}$$

$$a_{ij} = \frac{1}{a_{ji}} \qquad for \qquad i = j \tag{4.3}$$

Third step is determining the priority weights. After building the matrix of binary comparisons of factors with each other, matrix A is normalized and transformed to matrix B. Normalization is performed by taking the column sums for each column, then dividing each element by the summation of their column. Normalization is performed as indicated in Property 4.4 and the normalized matrix is shown in the property 4.5.

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \qquad where \qquad i, j = 1, 2, ..n \tag{4.4}$$

$$B = |b_{ij}|_{nxn} \qquad where \qquad i, j = 1, 2, ..n \tag{4.5}$$

The priority weight of i^{th} element in the row is calculated by taking the arithmetic average of the elements of that row in normalized matrix. The weights are calculated for each element as indicated in the Property 4.6. Then weight vector W is obtained as indicated in the Property 4.7. The sum of all the elements in weight vector must always be equal to one unless there is an error in the calculations.

$$w_i = \frac{\sum_{j=1}^{n} b_{ij}}{n} \qquad for \qquad i, j = 1, 2, ..n \tag{4.6}$$

$$W = |w_i|_{nx1} \qquad i = 1, 2, ..n \tag{4.7}$$

The fourth step is consistency control. The model should be consistent in order to be considered as valid. The eigen vector method is used in order to measure consistency to prevent wrong decisions. The basic equation is stated below where λ is eigen value and x is eigen vector.

$$A * x = \lambda * x \tag{4.8}$$

Since the eigen vectors of matrix A are each column and non-zero vector, maximum eigen value can be found by following equation as indicated in Saaty's method [38].

$$\lambda_{max} = \frac{1}{n} \frac{\sum_{i=1}^{n} (Aw_i)}{w_i} \tag{4.9}$$

Inconsistency index and consistency ratio are two indices proposed by Saaty [2]. Inconsistency index is calculated as follows;

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{4.10}$$

Next consistency ratio is calculated by dividing consistency index to the random consistency index. Random consistency index values are shown in Table 4.2.

$$CR = \frac{CI}{RI} \tag{4.11}$$

Table 4.2. Random Consistency Index for AHP

Size of Matrix (n)	1	2	3	4	5	6	7	8	9	10
Random Consistency Index (RI)	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Consistency ratio should be lower than 0.10 to confirm that the results are acceptable. A value greater than 0.10 indicates discrepancy in the responses of the expert who made the factor comparisons have to review the decisions and reduce non-compliance or it should be discarded from data set.

4.1.1.1. Strengths and Weaknesses of the AHP Method. The restrictions of this method are summarized as follows [39];

- There may be a change in the order of alternatives when any decision alternative is added to the problem or removed from the problem.
- This methodology cannot guarantee that it will lead an absolutely correct solution since it has subjective structure.
- As the number of steps in a decision hierarchy increases, the number of binary comparisons naturally increases. This means that more effort and time will be required to set up the AHP model. Although various software programs reduce the time and effort required to use it, it is suggested that the methodology still requires more time and effort than less formal methods.

The strengths of AHP can be summarized as follows [39];

- It has a nature that simplifies complex problems. It provides to decision-maker for better understanding of the problem and alternatives.
- AHP provides an easy to implement decision-making methodology that enables decision-makers to accurately determine their preferences for the purpose.
- AHP provides a judgment of both qualitative and quantitative information in the same decision process.
- Allows decision makers to measure the degree of consistency of judgments.
- It is possible to perform a sensitivity analysis to measure the flexibility of the final decision.
- It is possible to apply in group decisions.
- It allows to reach correct and quick results via software packages of AHP.

4.1.2. Fuzzy AHP Method

4.1.2.1. Fuzzy Sets and Fuzzy Numbers. To be able to introduce the FAHP method, firstly fuzzy sets and fuzzy numbers are briefly explained. Fuzzy logic is based on

uncertainty. The main feature that distinguishes fuzzy sets from classic clusters is that they are composed of elements with different membership degrees that are only in the range [0, 1], and if set values are determined from this range, the cluster A becomes a fuzzy set [40]. The main feature that distinguishes fuzzy sets from classic clusters is that they are composed of elements with different membership degrees. For each element, if the change is in between 0 and 1, it is called a membership degree and the change of membership within a subset is called membership function. In fuzzy set theory, special algorithms have been developed for the process of defining membership functions, but many applications have been implemented with parametric membership functions in order to provide ease of operation. Triangular and trapezoidal membership functions are the most widely used among parametric membership functions. In our thesis we prefer to use a triangular membership function.

A triangular fuzzy number is composed of an element in the left, lowest point, and right, the highest, support areas are represented by the parameters (l, m, u). A triangular fuzzy number stated in Figure 4.2.

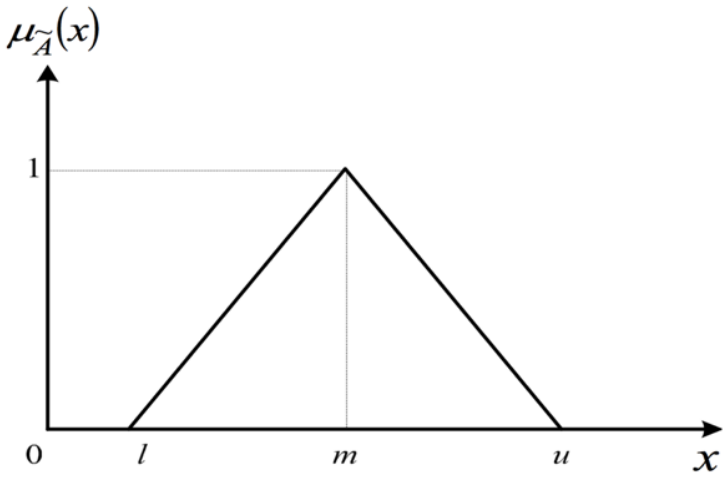

Figure 4.2. Triangular Fuzzy Number Graph

The membership function of a fuzzy set can be expressed mathematically as follows.

$$\mu_{\tilde{A}}(x) = \begin{cases} (x-l)/(m-l) & \text{if } l \leqslant x \leqslant m \\ (u-x)/(u-m), & \text{if } m \leqslant x \leqslant u \\ 0 & \text{otherwise} \end{cases} \tag{4.12}$$

Let $\tilde{A}_1$ *and* $\tilde{A}_2$ be two triangular fuzzy numbers. Four most frequently used mathematical operations are stated below.

$$\tilde{A}_1 = (l_1,\ m_1, u_1)$$
$$\tilde{A}_2 = (l_2,\ m_2, u_2)$$

Addition;

$$\tilde{A}_1 \oplus \tilde{A}_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \qquad \text{for } l_i > 0, m_i > 0, u_i > 0 \tag{4.13}$$

Multiplication;

$$\tilde{A}_1 \otimes \tilde{A}_2 = (l_1.l_2, m_1.m_2, u_1.u_2) \qquad \text{for } l_i > 0, m_i > 0, u_i > 0 \tag{4.14}$$

Division;

$$\tilde{A}_1 \oslash \tilde{A}_2 = (l_1/u_2, m_1/m_2, u_1/l_2) \qquad \text{for } l_i > 0, m_i > 0, u_i > 0 \tag{4.15}$$

Reciprocal value;

$$\tilde{A}_1^{-1} = (1/u_1, 1/m_1, 1/l_1) \qquad \text{for } l_i > 0, m_i > 0, u_i > 0 \tag{4.16}$$

4.1.2.2. Fuzzy AHP. Real world cases are not certain in most of the situations and human beings evaluate, judge and decide based on linguistic questions and give linguistic answers. Since the perception may differ from person to person the same answer may intent to express different meaning. When multi-criteria decision-making systems are combined with fuzzy logic, fuzzy sets and fuzzy numbers, this problem is minimized [36].

Table 4.3. Triangular Fuzzy Conversion Scale [3]

Linguistic Scales of Importance	**Ranking**	**Fuzzy Scale**	**Reciprocal Values**
Just Equal	1	(1,1,1)	(1,1,1)
Equally Important	1	(1,1,3)	(1/3,1,1)
Equally to Slightly	2	(1, 2, 3)	(1/3 1/2, 1)
Slightly More	3	(2, 3, 4)	(1/4, 1/3, 1/2)
Slightly to Strongly	4	(3, 4, 5)	(1/5, 1/4, 1/3)
Strongly More	5	(4, 5, 6)	(1/6, 1/5, 1/4)
Strongly to Very Strongly	6	(5, 6, 7)	(1/7, 1/6, 1/5)
Very Strongly More	7	(6, 7, 8)	(1/8, 1/7, 1/6)
Very strongly to Absolutely	8	(7, 8, 9)	(1/9, 1/8, 1/7)
Absolutely More	9	(8, 9, 9)	(1/9, 1/9, 1/8)

As in the AHP method, prioritization of the alternatives can be performed through Fuzzy AHP method. Fuzzy AHP method does not have one exact single way of application since the first time it is used. Van Laarhoven and Pedrycz [41] who are the pioneers of Fuzzy AHP, used logarithmic least squares method obtain fuzzy weights and score [40]. Later Buckley [42] and Chang [43] improved method. We used Buckley's method of geometric mean fuzzy AHP. Triangular fuzzy numbers are used. Nine points scale rankings are converted to fuzzy numbers as indicated in Table 4.3.

Based on fuzzy pair-wise comparisons nxn-sized square matrix is obtained where $a_{ij} = (l_{ij}, m_{ij}, u_{ij})$ is the fuzzy comparison value of alternative i to alternative j.

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & .. & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & .. & \tilde{a}_{2n} \\ .. & .. & .. & .. \\ \tilde{a}_{n1} & \tilde{a}_{n2} & .. & 1 \end{bmatrix}$$

When there is more than one decision maker, aggregation of individual judgments should be converted to final group decision matrix. Assume that k decision-makers are exists, then $a_{ijk} = (l_{ijk}, m_{ijk}, u_{ijk})$ represents the relative importance of alternative i to alternative j evaluated by the expert k. For triangular fuzzy numbers in the group judgment matrix can be obtained by using the following equation [44].

$$l_{ijk} = \left(\prod_{k=1}^{K} l_{ijk} \right)^{(1/K)} \qquad for\ k = 1, 2, ...K \tag{4.17}$$

$$m_{ijk} = \left(\prod_{k=1}^{K} m_{ijk} \right)^{(1/K)} \qquad for\ k = 1, 2, ...K \tag{4.18}$$

$$u_{ijk} = \left(\prod_{k=1}^{K} u_{ijk} \right)^{(1/K)} \qquad for\ k = 1, 2, ...K \tag{4.19}$$

Then the next step in Fuzzy AHP is finding weight dimensions. For criterion i, r_i refers to geometric mean of fuzzy comparison value which is called weight dimension.

$$\tilde{r}_i = \left(\prod_{j=1}^{n} \tilde{a}_{ij} \right)^{(1/n)} \qquad for\ i = 1, 2, ...n \tag{4.20}$$

For criterion i, $\tilde{w}_i$ is the fuzzy weight.

$$\tilde{w}_i = \frac{\tilde{r}_i}{\sum_{i=1}^{n} \tilde{r}_i} \qquad for\ i = 1, 2, ...n \tag{4.21}$$

The fuzzy weight vector W is constructed as:

$$\tilde{W} = (\tilde{w}_1, \tilde{w}_2, ..., \tilde{w}_n)^T \tag{4.22}$$

5. MODEL CONSTRUCTION

5.1. Strategic Map Development

It is important that strategic objectives are homogeneously distributed in the areas financial, customers, internal processes and learning and growth to manage a company effectively as well as to create a sustainable strategy. We indicated the company's strategic objectives through BSC since it acts as a strategy map. Benefiting from earlier studies and reviewing both ergonomics and TQM contribution to companies' strategical objectives, a general map is constructed based on six main strategic objectives to use in our model [11, 12]. Suryaningkusuma *et al.* [11] worked on a strategic performance measurement system that effectively and efficiently responded to real-life events. Authors draw attention to the importance of sustainability issues by adding the fifth perspective as a sustainability perspective. Their study achieved finding vital performance measures and their importance levels determined in a balance scorecard frame for constructing a strategic performance measurement system as well as maintaining a competitive advantage. It is also possible to integrate the dimensions in the BSC. That integration can mostly be used for special cases. However, we used the standard template and common strategic objectives generally set by companies.

To define a general strategy map, strategic objectives are implemented into the balance scorecard frame based on a financial perspective, customer perspective, internal processes perspective and learning and growth perspective. In the frame below, as we go from the bottom to the top, the stated objectives feed each other. It is not possible to achieve an important result without clearly defined objectives and without narrowing targets. Six main targets derived from the literature and improved to implement into the BSC frame in Figure 5.1. These six main targets are; profit maximization, market share increase, company credibility and reputation increase, competitiveness increase, attracting and maintaining highly motivated and skilled employees, creating sustainable business. It is critical to prioritize ergonomics and TQM factors to accelerate the attainment of the objectives.

Figure 5.1 shows the visual template of the strategy that demonstrates the determined critical targets in a cause-and-effect relationship.

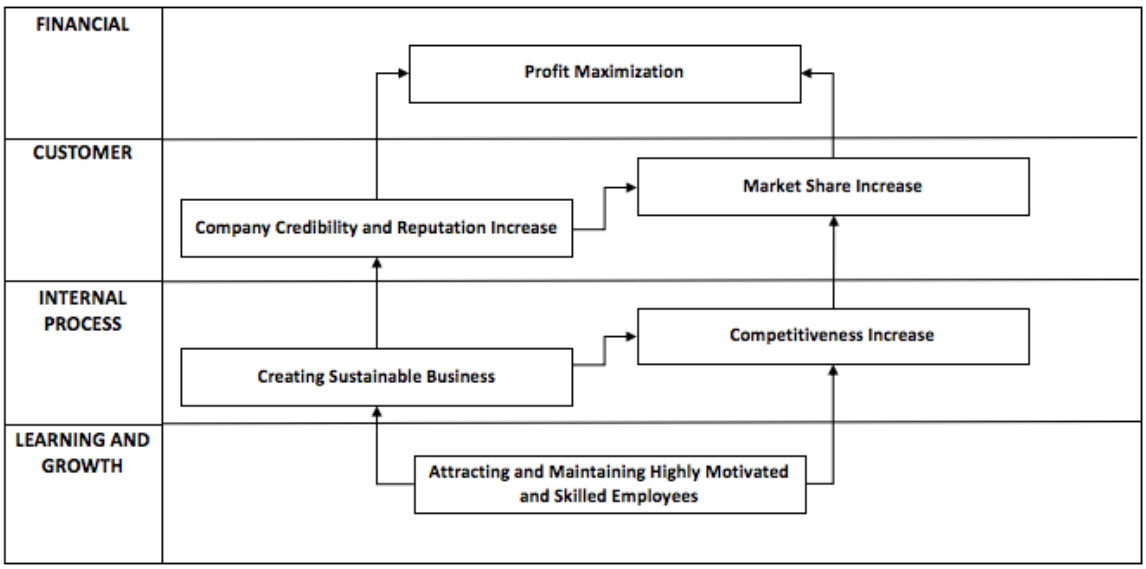

Figure 5.1. Strategic Objectives in Balance Score Card Frame

Figure 5.1 emphasizes causal links that explain the strategic relationship of the objectives. The tight connection between financial and non-financial items conduct a comprehensive system. The strategy is formed based on the cause and effect relationship of the objectives. For example, achieving maximum profitability is an objective stated in the financial dimension. However, it is directly effected by the company credibility and reputation as well as the change in market share which are indicated in the customer dimension. Positioning in the market is also affected by a trust to the company among customers. Company credibility and reputation lead to higher sales achievement, consequently increase the market share. It is necessary to maintain sustainability by increasing the process quality and process optimization of internal processes for creating competitive advantage. Attracting and maintaining highly motivated and skilled employees is a necessity to achieve create sustainable process and competitiveness increase.

5.2. Factors Used in the Model

5.2.1. Managerial Issues and Leadership

Managerial issues and leadership category includes following factors; management commitment and involvement, organizational design, long-term view and strategic planning, performance evaluation and rewarding and empowerment.

5.2.1.1. Management Commitment and Involvement. Management involvement and commitment are highly correlated with business activity performance [19]. Low-level management leadership is a necessity for controlling smooth progress of work whereas the upper managements' leadership plays a significant role on establishing and maintaining corporate values, company vision and performance expectations. Leadership involvement positively accelerates the formation of work culture that everybody carries on own responsibility to finish work on time, inspire people for creative ideas and stimulate learning [19]. Hendrick [8] pointed out that, in order to be accepted by managers, ergonomic project proposals must be specified in terms of cost of implementation, expected financial return and how they will be measured. In case of price benefit analysis, if the positive effect outweighs, more managers will be involved in processes. Management involvement and commitment should perform with leader features. For TQM, leadership is one the most significant elements that has the role of examining management style, controlling the share of individual contributions of employees in creating strategic directions of the company and setting up efficient coordination to have a better performing and learning organization in an inspiring working atmosphere [28]. A study carried by McKinsey company demonstrate 95 percent of chief executive officers in Europe believe that top management attention is a crucial element of TQM [1].

5.2.1.2. Organizational Design. Organizational design is a structure, including the structure of its management processes of planning, directing, coordinating, and controlling the activities of the system to accomplish its goals. As part of the system design process, macroergonomics indicates, organizational design should involve or-

ganizational goal identification and making them operationally explicit for use as a human-centered design [14]. The organizational design includes supervision style and staffing levels and workload distribution. TQM emphasized that organizational design is one of the crucial factors that need to be embedded in the strategic planning process. Work schedule arrangement is also under the organizational design which has a significant impact on workers life quality, employee satisfaction and performance level and productiveness [21].

5.2.1.3. Long Term View and Strategic Planning. Planning and long term view are crucial for determining how to do the right thing, how to eliminate waste and how to change procedures flexible enough for effective improvement [45]. The strategic planning process in itself is an important tool for determining priorities, making important decisions about company activities and making long lasting plans. When the ergonomics implementations involved in strategic planning and business goals then it is possible to integrate ergonomics correctly to the company culture [46]. Long term view and strategic planning provide seeing the big picture. A strong relationship exist between strategic planning and quality performance and firm performance [5]. Actions in the way of reaching organizational targets, planning is a necessity for the effectiveness of all system elements. Planning creates opportunity for the improvement in organizational practices by developing the organization and infrastructure. Additionally, planning provides allocating resources on time and better coordination [1].

5.2.1.4. Performance Evaluation and Rewarding. Performance evaluation and rewarding system in a corporation have improving impact on employees and working atmosphere by raising the idea to be cared by management [21]. It is indicated as a macroergonomic factor since the rewarding system increases motivation [26]. In TQM philosophy; performance evaluation regarding quality performance, operations according to gained experience and manager reviews are essential to prioritize improvement potentials [26]. There is a positive correlation between management evaluation of employees' feedback and employees motivation. This leads to higher work interest and early problem detection in processes [47]. As Danish and Usman [1] stated by analyzing

the correlation between rewarding-recognition and motivation with 220 questionnaires in a variety of sectors; the rewarding mechanism is critical to be well-known and admired in the sector.

5.2.1.5. Empowerment. Empowerment is guiding employees to have a common goal and strengthening with leadership support. It is explained as a balance between alignment of activities to the goals and the freedom people have to take action [1]. Chiun et al. [34] stated operational performance affected in a positive way by empowering people. Additionally, engaging employees with empowerment has a great impact on psychological empowerment, which stimulates internal thoughts or feelings that feed one´s desire to perform and become involved in creative processes [21]. Empowering leadership, especially in operational level increases the likelihood of success [1]. The freedom that people have to take action rises the level of voluntary participation to business process as well rises the level of involvement in decision-making [1]. This also enhances participatory ergonomics where everybody elaborates ergonomics principles.

5.2.2. Employees

Employee category includes following factors; employee motivation and needs, development of skills by supporting employees' training, employee involvement in the processes and teamwork among employees.

5.2.2.1. Motivation and Needs. When the motivation of the employees is low, problems regarding task adaption or lower work quality can be seen. It is essential to have highly motivated employees for better work performance [21]. Ergonomics work design implementation creates a suitable working atmosphere to self-authorization, professional growth opportunities and learning more, thus higher motivation as well as job satisfaction among employees can be achieved through macroergonomic point of view [16]. Similarly when the needs are met by the company, employees will be eager to work. Consequently, work quality and quantity will be raised [47].

5.2.2.2. Training, Education and Skills. Throughout the ergonomics the selection of appropriate training program knowledge and capability can be enhanced [19]. For an education program to be effective; upper-level management must support education and form it as a part of the business culture. In that process budget for training should be considered as an investment, not an expense. Continuous education brings continuous development. It is also important to train employees in such a way as to internalize quality management philosophy and ergonomics principles. Education leads changes in the knowledge, skills, attitudes and social behaviors of employees. Quality is highly affected by the skills and talents of all the employees in a company. Training and workshops in specific topics raise up workforce ability to perform better their job, broaden their view to alternative solutions, and utilization of the employee potential and higher quality [29]. This leads employees to satisfaction. Educational activities by itself may not be enough to change behaviors however educational activities prepare the base for change. By the help of educating employees can adopt the change easier [29].

5.2.2.3. Employee Involvement. Employee involvement is another element that affects company performance and business outputs. Active employee participation and contribution via total quality management enhance employee dedication, self-reliance, and inventiveness that results in organizational innovation [5]. The word total in total quality management indicates the participation of all employees. Employee involvement is also important from the ergonomic aspect, which can be also named as participatory ergonomics [47]. Utilization of the knowledge, skills and expertise usage can be achieved through active participation [19]. Hendrick [8] pointed out when the employees committed their work, they tend to act as "good citizenship behavior". Employee complaints decrease, nonappearance reduces, wider responsibility taking by employees to complete unfinished jobs even though it is not their duty.

5.2.2.4. Teamwork. Teamwork is a key organizational element when it comes to improving work system performance [21]. There are many benefits of performing tasks in a group such as; colleagues can support each other when a member faces a difficulty, idea sharing and brainstorming generates solutions to problems, employees can have

an opportunity to have feedback on their performance [48]. Moreover, responsibility divided into team members increases the likelihood of risk-taking. Working within a team enhance professional knowledge and work consistency, in this way boost to organizational performance regarding cost reduction and quality [21]. Vargas et. al. [21] indicated 116 studies out of 146 have shown the same characteristic which supports the idea of team-based rewarding has a higher impact when compared to equally distributed rewards. Teamwork factor under the TQM implies rather than a person by itself, cooperatively work to achieve an objective or to overcome daily problems. It helps to empower and motive people [29].

5.2.3. Social and Physical Environment

Social and physical environment category includes following factors; organizational culture, consideration of employees health and safety by the company, use of technology and working environment design.

5.2.3.1. Organizational Culture. Organizational culture is the way of activities that perform in a company. A well-built culture maintains the endless loop of improvement actions in the company by giving a chance to members of an organization to take active roles in processes [1]. When a company implements TQM to its culture, company culture creates a working atmosphere that everybody can be involved in improvement processes where colleagues are transmitted to continuous improvement activities to others while quality assurance can be embeded all departments and business activities [1]. It is also a significant factor in shaping the social environment. Erensal et. al. [19] states habits of employees point out how they think, decide and attend in the organization. Culture influences employees habits, allows change acceptance and willingness to be a part of change implementation. As an human being, people in an organization have essential requirements available to sign under well-achieved tasks and be strongly supported to improve themselves both in personal and job-related areas. Organizational culture provides a suitable atmosphere to perform in the most efficient way.

5.2.3.2. Employee Wellbeing. Efforts given by company to provide a safer working atmosphere, better quality of working life and care about employee wellbeing increase likelihood to worker commitment [8]. Design or redesign of working place, optimization of system elements correct usages can lead successful results on physical improvements, psychological and social wellbeing [16]. Ergonomics also provides desired working environments which decreases the levels of health and safety problems, increases the motivation of employees. Therefore, adoption of ergonomics approach significantly contributes productivity of employees and improves the quality of work which the organization provide while maintaining employees well-being [8]. Unhealthy employees get tired faster and cause a decrease in quality and efficiency. Failure to pay attention to the well-being of the employees at rises the problem of absenteeism. Processes disrupted, total participation cannot be achieved if an organization cannot maintain employees health and safety. Due to these reasons supporting employees well-being is also crucial for TQM.

5.2.3.3. Use of Technology. Use of technology has a great influence on the motivation and performance of employees. When it is truly and effectively oriented, it can support employees and company together. However, in the case of wrong application, it may create extra stress [21]. When adopting a software system into any business process, it is important to prefer a user-friendly design to decrease user effort and to gain time advantage. Today's technology enables automation in many activities and reduces labor force unnecessary effort as well as reducing quality deficiencies. Advanced manufacturing technology allows lower production costs, higher product quality, greater employee involvement and reduces risks of injuries. There exists a relationship between innovation and technology utilization. Technology may help to create new options for customers, meet their demand, and even exceed their expectations. End users tend to choose product or service that has the most advanced technology. Additionally, Technological leadership and competition power can be created by taking advantage of the uniqueness of product or service.

5.2.3.4. Workplace Design. The work environment is one important asset which affects the mood and performance of employees. Reactions of employees to stressful business conditions, irritability of stuff and energy saving are directly influenced by the noise level, lighting, layout and climate of the office [21]. If ergonomic elements are taken into account during design of workplace, that will help the system to get rid of organizational failures and make a clear improvement in employees' performance. Workplace should be designed by considering two tools of ergonomics. Firstly the best in the safety and comfort level of employees should be targeted. Secondly, the essentials of motion economy should be answered [19]. Workbenches and equipment, which are created according to the physical characteristics of the operators, increase the production efficiency and protect the health of the operators. Furthermore, thanks to the ergonomic units, operator effort can be reduced. The ergonomic workstations, storage and production units are built to provide the operators with easy access to the elements by offering them the ideal height and position. These structures reduce the number of movements needed to complete each task.

5.2.4. Third Parties

The third parties category includes following factors; the impact of supplier involvement in the processes and the impact of government and unions.

5.2.4.1. Supplier Involvement. Supplier selection and involvement have an inevitable effect on quality. Involving suppliers in processes and building strong relationship based on trust is important to meet ever-changing user expectation. Long lasting cooperation provides to increase in competitiveness by providing stable price and on-time deliveries [27]. The enterprise may stick to plans in internal business. However, third parties may cause shift in schedules. In today's environment, solidarity between suppliers and buyers is essential. In turn, effective communication allows suppliers and manufacturers to inform each other of the tasks they perform. This provides certainty and sticking to plans, consideration of sequential processes [21]. Suppliers should be forced to put emphasis on ergonomics. Assume that, a supplier provides a

part of the end product. When the delivery completed if it will be carried by a worker, suppliers packaging size, type, and weight should be suitable for carrying. Additionally, products or services taken by suppliers should not be harmful to employees or end-users. Ensuring the conditions agreed with suppliers enables the production of desired quality products. Failure to provide the demanded product and service may result in problems regarding production and low quality.

5.2.4.2. Government and Labour Unions. Governmental institutions, industry and non-governmental organizations should work in cooperation. The governmental authorities have duties such as making legislation, organizing and imposing sanctions. In particular, the minimum wage, weekly and daily working hours, holiday times, occupational safety and health regulations have created. Occupational safety fines are a deterrent in preventing occupational accidents and implementing occupational safety. The government and labor unions take preventive and coercive measures with laws and regulations for maintaining human safety and wellbeing.

5.2.5. Customers

Customers category includes following factors; recognizing customer demands, quick response to customer and initiatives about customer feedback.

5.2.5.1. Recognizing Customer Demand. Ergonomics puts the human into focus, customers will take the advantage of user-friendly design. Ergonomic design provides less time spent to understand and get familiar with the products, perfect fit to human characteristic, non-harmfull, fewer mistakes and more efficient products and services [16]. These features are mostly demanded features for any of products. It is crucial to track the customers' demands since they rapidly change. Human factor engineering takes into account clients expectancy and requirements, level of satisfaction in usage to create loyalty and customer increase. Similarly for quality one group claims quality intent to meet the customer requirements, while others assert that in addition to meeting customer requirements surpass the expected value. Both notions put the focus on cus-

tomers [1]. Customers are taken into account in all the internal business activities via TQM.

5.2.5.2. Quick Response To Customers. Understanding and predicting future demands is a requirement of a customer-oriented approach. When an opportunity arises in the market, companies that take faster action will be at the forefront of competition. Since TQM and ergonomics implementations ensure the most efficient way of work, companies that apply these principles will be one step ahead of other companies which are not adopted these methodologies. In order to respond quickly to customer demands, to maximize all operations with flexibility and accuracy, to replace the inventory that holds great costs, the information flow must be done in a timely and accurate manner. The main aim of understanding the customers is being able to take actions in response to the customers' demands. Polls of clients are beneficial in terms of defining quick activities on grievances of clients, triggering needed improvements and effective control of the field's pleasure on the product [49].

5.2.5.3. Initiatives About Customer Feedback. The value given to customer can be measured in parallel to the value given to customer feedback [49]. Feedback mechanism gives a chance for a deeper understanding of user perspective who actually experienced the product. Especially human factors engineers may benefit from that feedback mechanism for new product development processes. With the customer feedback tools, companies convert the data into valuable information to ensure customer satisfaction for the future. This data allows comprehending users behavior patterns regarding product quality and ergonomic features. Complaints regarding customer experiences strive continuous improvement in quality.Additionally, it investigates the effectiveness of control programs and helps to decide the business activities that need to be initiated. Moreover, through the evaluation of customer problems, it is possible to prevent future failures with the help of human factors engineering [49]. For a better understanding of further expectation, feedback mechanism plays a significant role in present-day product or services. For continuous improvement, a customer's requirements must be consistently measured and satisfied [27]. The high variety of complaints

requires various interventions. Acquired data provides to decide occasions to initiate. The contents of complaints should be grouped according to the vitality level, most crucial topics should immediately examine with a comprehensive investigation to reach problem sources. This process helps to prioritize complaints and to take quick action for more important ones [49].

5.2.6. Business Processes

Business processes category includes following factors; productivity and efficiency, innovation, waste elimination, continuous improvement and development, quality increase, costs reduction and data usage in decisions.

5.2.6.1. Productivity And Efficiency. Organizations always try to have the perfect running system with minimum source usage. Lead time for operations and the cycle time of the processes are the most common indicators of companies to track their productivity performance and efficiency [16]. Human factor engineering is widely preferred by supervisors because of its well-known impact on increasing efficiency by leaning operations in company procedures, supporting employees in self-development to increase their competence and optimizing the hardware distribution, layout and processes to increase the overall performance [16]. The study conducted by Yusuf et al. [29] demonstrates that in comparison of organizations that implement the TQM approach and organizations that not used TQM in their business, the former group manages the enhance their productivity level more than the latter group.

5.2.6.2. Innovation. Continuous improvement and innovation are considered as analyzing current processes and take lessons from them to improve the efficiency and quality of works in the future. Improvement of business process quality results with source efficiency which leads organizations to provide more innovative ideas and more innovative works [29]. Ergonomic working environment improves satisfaction and commitment of employees to their organizations. According to Dull et al. [16], improving working conditions and ergonomically designed work environment motivate employees

and increase their creativity which stimulates innovation. Organizations which care about innovation and continuous improvement of the processes and quality of work may enhanced by TQM implementation. According to Talib et al. [27], TQM philosophy has significant impact on the improvement of organizational output, continuous improvement and innovation.

5.2.6.3. Waste Elimination. Ergonomics considers human as a source, effective use of that source is the main concern of human factors engineering. Some unnecessarily allocated tasks or non-value-added effort required specific positions can be seen as a waste. Redundant repetition, overused effort, idle used forces are the wastes to diminish. Ergonomic design of the environment or tool offers a solution to get rid of these wastes [47]. Adaptation of TQM approach helps to minimize lead times in delivery processes, reduces unexpected errors and reworks, after all, TQM minimizes non-value adding activities in organizations and provide continuous improvements for both business processes and business performance [27]. TQM promotes lean activities which are incrementally promote improvements to eliminate waste, variation, and over-burden, in the regard of Japanese words “muda”, “mura”, and “muri”respectively, for creating more value to the customers [50] Product defects, processing waste, transportation waste, inventory waste, waiting time, overproduction and motion waste are seven types of wastes indicated in literature [51].

5.2.6.4. Continuous Improvement. For organizations, continuous improvement and development is a dynamic process that consistently renews itself. It is stated as PDCA cycle that has four stages of continuous improvement; plan, do, check and act [50]. By implementing following four into TQM and ergonomics, organizations can improve their performances and improve their business processes. Consequently, they improve quality of works day by day [50]. Continuous improvement is a never-ending approach that organizations should adopt to maintain their successes. Therefore, it is stated that the PDCA cycle promotes success and business sustainability. Four Deming’s principle is as follows [50];

Plan: The first and the most critical phase of the PDCA cycle is planning. It is decided by whom, where, how, where, when and how long the planned work will be done. At this stage, the more accurate tasks and the objectives are determined. Next step of this cycle is the "Do"stage. The less problem arises in the "Do"stage if "Planning"phase is well organized.

Do: The planned activities are carried out, with the determined sources, methods and time intervals. This stage is the input of "Check"phase, which is the third step of PDCA.

Check: In this stage, improvement is measured by checking how much the planned goals are achieved. If the targets are reached, the implementation activities are checked. Continuous monitoring should not pressure on employees and negatively affect them, oppositely in this stage performed work is controlled by regarding its effectiveness.

Act (improve): The last stage of PDCA cycle is "Act". The aim of this stage is to provide continuous improvement of the performed work which is planned, performed and controlled. With continuous improvement, the aim is to ensure customer satisfaction and deliver a good quality of work in every day.

5.2.6.5. Quality Increase. Organizations need to keep their quality level at a certain point to be able to keep themselves competitive in the market. As stated by Markova *et al.* [52] with field experiences; healthiness, relaxation of employees have a huge impact on the quality of the product. That is one of the most significant topics for companies to cope with in order to avoid decreasing quality level by work-related health problems. Ergonomic interventions lead rise in quality. Keeping employees qualified, obeying the instructions during operations and optimizing working conditions provide a higher and more sustainable quality level for the products and services [16]. On the other hand, TQM changes the mindset of old quality control systems by changing the keyword reactive to proactive and reduces the usage of terms extra control and examinations by this proactive approach [29]. "Zero defects"or "right at the first time"are the true

definitions to express the result of this proactive approach by keeping processes stable with certain measurements in true sample size and leaning the processes with correct data analysis to reduce failures. The idea of avoiding upcoming failures which are repeated in the organization regularly is a standard indicator which can change the old mindset of members if it is internalized by the managers in a permanent manner. That will influence the performance of the company [29]. Right at the first time provides a further connection between employees and creative solutions for struggles if it is continuously checked and developed in a routine. It gives the possibility to eliminate failures that are not yet occurred, just in the design phase. It helps management to place new goals easier and to understand the common points that bring the team together in success to get ready for upcoming challenges [29].

5.2.6.6. Cost Reduction. Cost reduction is vital for organizations to enhance their profit and their maintainability. Organizations may come up against many expenses such as; internal and external costs, unexpected expenditures, cost of exceeding or inconsistent customer requirements, and the cost of missing opportunities [53]. Employees working quality has a positive effect on cost reduction in organizations. The poor quality of work may result in a reduction of more than 20 percentage of the sales in manufacturing companies [29]. Reduction in sales brings additional costs, therefore, results decrease in income level of the organization [29]. Ergonomics approaches provides cost reduction by improving the quality of work and by lowering operating costs. Hendrick *et al.* [8] stated that, successful ergonomics projects enhance the likelihood of decrease in cost.

5.2.6.7. Data Driven Approach. Data based management, which is a successful solution for business problems in a fast decision-making environment. Analytically practices that play a major role in strengthening instant and effective decision-making capabilities are among the most important parts of data-based management culture. One of the strengths of TQM is benefiting from data in an effective way, instead of directly focusing quality. Certain measurements in true sample size and leaning the processes with correct data analysis to reduce failures [29]. similarly, for both product

or system design, ergonomics trusts on data. For instance human factor engineers uses anthropometric data to enhance work technique or the tools used by the workers which lead to efficiency in the process. Moreover, designs benefits from data usage protects the health and safety of end users and employees.

6. HIERARCHICAL MODEL

We transformed our problem into a hierarchical model, Figure 6.1 represent suggested hierarchy. By reviewing literature, we found out the common factors of ergonomics and TQM. Totally, 25 factors are determined to include in our hierarchical model.

As it can be seen from the Figure 6.1, the main objective is indicated at the top level of the hierarchy as prioritization of factors based on strategical importance. We attempt to determine which factors contribute more to company strategy, therefore at the second level, we implement strategic objectives of the company. This implementation is explained in detail under the relevant headings. At the third level, six main system elements are located to compare relative importance. We called these system elements as categories in the hierarchy. Under the categories related factors are located which constitutes the lowest level. These factors are separately explained in previous section. The main aim of building hierarchical model is through the MCDM applications with binary comparisons finding the factor priority weights.

In this thesis we assume all the strategic targets are independent. Additionally, all categories and all the factors are also independent.

We use abbreviations for elements of the hierarchy in order to make easier representation of mathematical formulations. Profit maximization is labeled as SO1, market share increase is labeled as SO2, company credibility and reputation increase is labeled as SO3, competitiveness increase is labeled as SO4, attracting and maintaining potential high performer, motivated and skilled employees is labeled as SO5 and creating sustainable business is labeled as SO6. Similarly abbreviations are also used for categories. Managerial issues and leadership is labeled as MIL, employees is labeled as EMP , Social and physical environment is labeled as SPE, third parties is labeled as TP, customers is labeled as CUS, Business Process is labeled as BP.

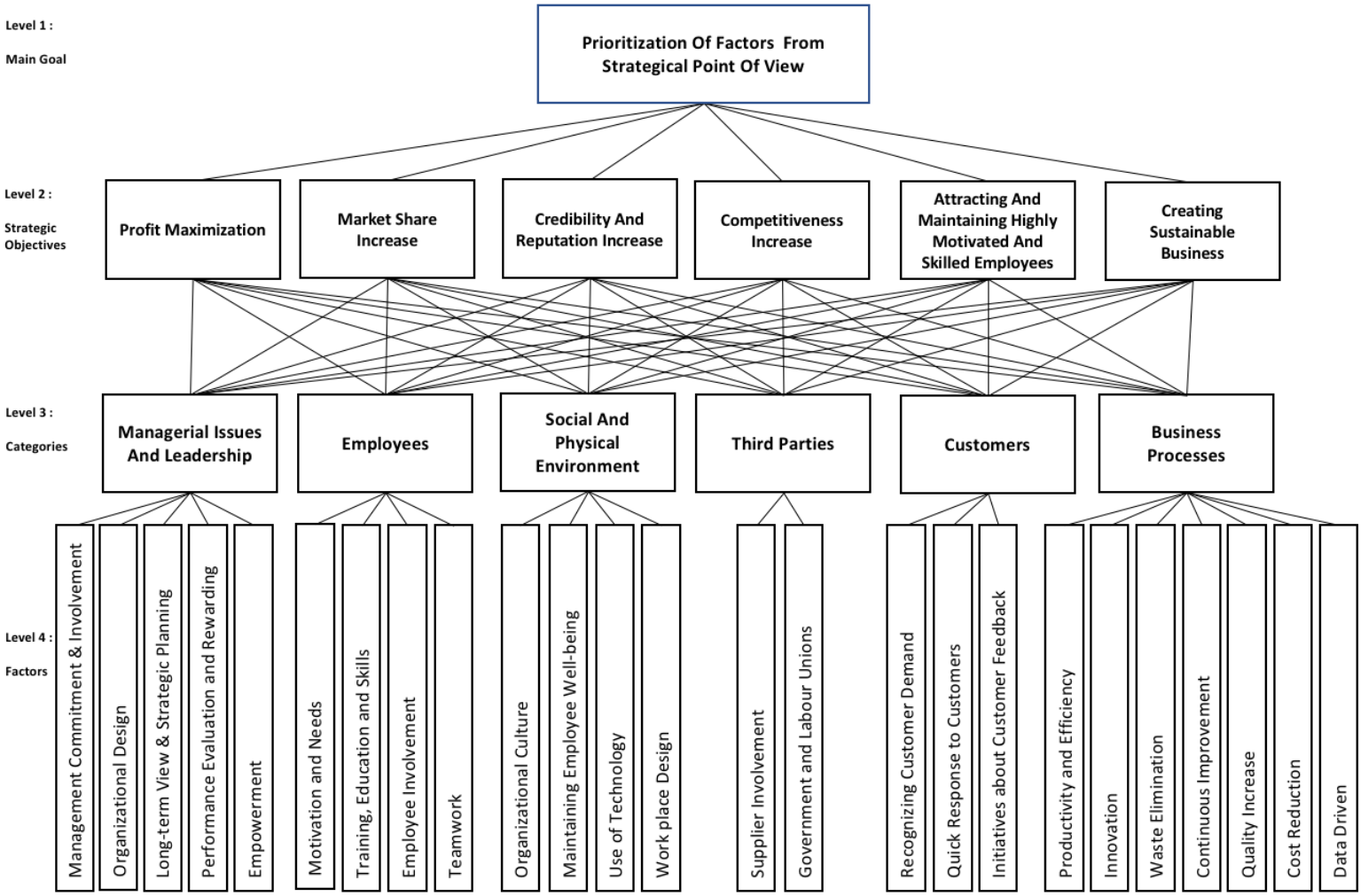

Figure 6.1. Hierarchical Structure for Prioritization of Ergonomics and TQM Factors

7. DATA GATHERING

The methods described in the previous section have been applied to the problem of factor prioritization.

7.1. Questionnaire

A questionnaire is developed to determine the relative importance of macro ergonomics and total quality management factors that can contribute to sustainable business strategies of enterprises. While developing the questionnaire, at first we decide question type to obtain the appropriate form of data for our methodology. We elaborate that expressions are clear. We avoid using complicated sentences that might confuse decision makers. We have designed questions that are understandable and have made additional disclosures in some sections. Language of questionnaire is determined as Turkish since it is participants mother language.

The questionnaire starts with a consent request, participators are asked to confirm that participation is fully volunteered and all information obtained is only used for this study. First section consists of questions about personal information, and questions about recognizing the people who carried out the survey and total work experience of attendees, experience in the current position, information about the sector on which the company worked. This part of the questionnaire aims to reach a general phenomenon related to the professional experience and qualifications of the decision makers. In the next section, brief information is given about the questionnaire. Company's strategic objectives are indicated. Then a detailed explanation is written about how to fill the survey with an example. Third section includes survey questions. There are four subsections in the questions part. In the first subsection, it is expected to compare the strategic objectives on the basis of the relative importance scale. In the second subsection, attendees are asked to compare categories with each other in terms of their contribution to these strategic objectives. In the third subsection, prioritization of the factors are performed by pairwise comparisons on the basis of the relative importance

scale. In the last subsection, participants suggestions and opinions are requested by asking the open-ended question.

7.2. Data Collection

The questionnaire in Appendix A.1 is used for data collection. The questionnaire is prepared in the electronic environment. Printed versions are also prepared. Considering the length, format, content of the questionnaire and similar studies 30 surveys is found sufficient to carry out for the study.

The questionnaire is applied via face to face interviews, delivering printed survey and by e-mail depending on availability of the participators program. The survey took approximately 40 to 60 minutes depends on participators familiarity to survey style. Totally 43 surveys are shared via e-mail. 5 survey could not be delivered since mail address is not active. 9 have made a positive return and interviewed by e-mail. Although the return rate is seen low, it is indicated mailed questionnaires returns rate is generally around 10 percent [**?**]. When the return rate reaches 25 percent it is labeled as successful rate. We achieved 24 percent returns rate by the help of telephone follow ups and reminder mailings. Rest of the data was gathered through one-to one meetings. Our target group was the managers and additionally team leaders at specific positions such quality department or occupational and safety departments who has the expertise in ergonomics or TQM were also included.

Questionnaires were mainly distributed to manufacturing based companies in a wide variety of sector including household, automotive, fast moving consumer goods (FMCG), healthcare, textile and management consultancy organizations. The age range of the attendees were varied between 29 and 63 with the age average 38.2 year. Total working experience average was 14.8 year while the total time in current company average was 8.5 year. 23 male and 7 female were attended. Statistical representation of sector and gender distributions are shown in Figure 7.1 and in Figure 7.2.

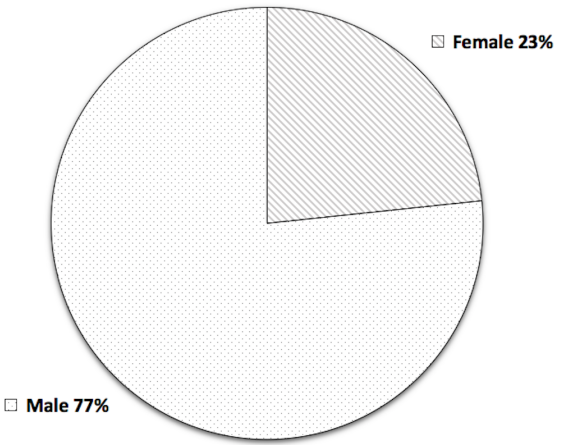

Figure 7.1. Gender Distribution

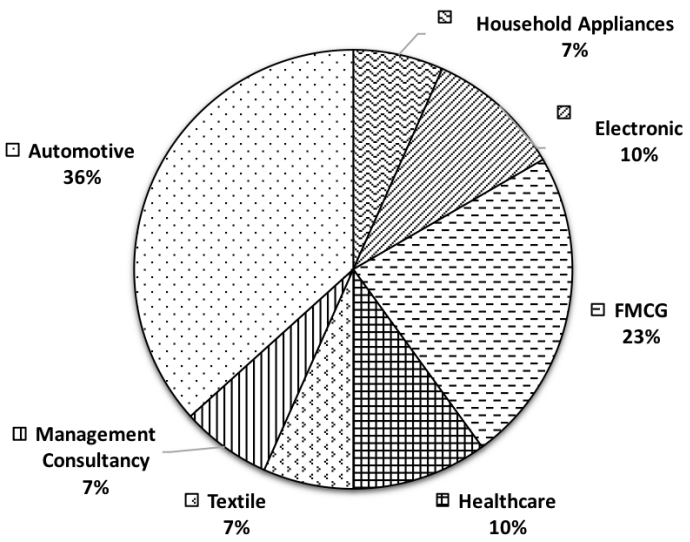

Figure 7.2. Sector Distribution

8. MODEL APPLICATION

As it is explained in the methodology, AHP and FAHP have been applied to our problem. The main goal is prioritization of common factors for more effective usage of sources. The same hierarchy model and questionnaires are used for both AHP and FAHP methodologies.

Inconsistency rates of matrices were analyzed for individuals responses. Consistency rate higher than 0.1 are discarded from our data set. Based on inconsistent data elimination 23 questionnaire out of 30 responses have found consistent. Consistent responses belong to 17 male and 6 female from household, automotive, fast moving consumer goods (FMCG), healthcare, management consultancy and textile industries. Gender distribution and sector distribution of consistent matrices are shown in Figure 8.1 and Figure 8.2 respectively.

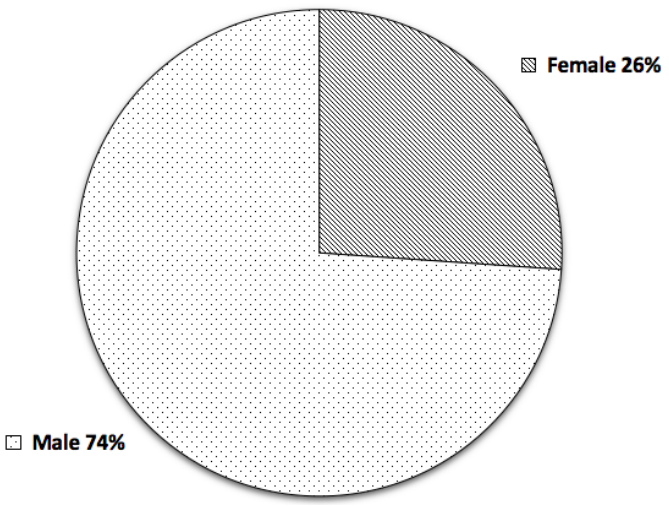

Figure 8.1. Gender Distribution of Consistent Questionnaires

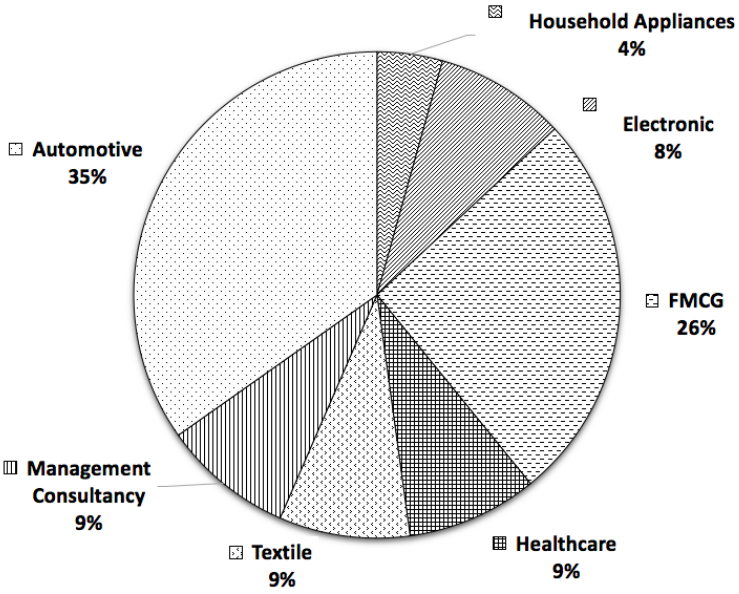

Figure 8.2. Sector Distribution of Consistent Questionnaires

8.1. AHP Application to Our Model

Responses of attendees obtained from questionnaires were transferred into matrix form where binary comparisons can be seen between i^{th} element in the row and j^{th} element in the column. From one questionnaire response 13 matrices were constructed; 1 matrix was for strategic objectives comparison, 6 matrices for category comparisons based on 6 strategic objectives and 6 matrices were obtained for factors under 6 category. For each questionnaire these matrices were constructed.

From these consistent responses, a new overall group decision matrix was obtained for each comparison matrix. Since there are more than one decision maker, geometric means were used to obtain overall group decision matrix. Assume that K decision-makers are exists, then a_{ijk} represents the relative importance of alternative i to alternative j evaluated by the expert k. Group judgment matrix can be obtained by using the following equation for consistent 23 survey [44].

$$a_{ij\ group\ decision\ matrix} = \left(\prod_{k=1}^{K} a_{ijk} \right)^{(1/K)} \qquad for\ k = 1, 2, ...K \tag{8.1}$$

$$a_{12\ group\ decision\ matrix} = [(6) * (3) * (3) * (1/5) * (1/3) * (7) * (1/3) * (1) * (5) * (5) * (4) * (2) * (5) * (1/3)(3) * (3) * (3) * (1) * (1) * (1) * (1/5) * (1/3) * (1/2)]^{(1/23)} = 1.41$$

Overall group decision matrix shows the results of how relatively valuable is the i^{th} strategic objective in the row than j^{th} strategic objective in the column. Table 8.1 shows the group decision matrix for strategic objectives. For instance, $a_{12} = 1.4$ which means that when profit maximization goal (SO1) compared with market share increase goal (SO2), profit maximization is 1.4 times more valuable than market share increase based on the group evaluation. Another example is $a_{24} = 1.0$ which indicates that when market share increase goal (SO2) compared with (SO4) they are equally important. Lastly, the value of a_{ij} is smaller than 1 indicates i^{th} strategic objective in the row is less valuable than j^{th} strategic objective in the column. When profit maximization goal (SO1) compared with creating sustainable business goal (SO6), profit maximization is 0.8 times less valuable than creating sustainable business. Group decision matrices enable us to calculate priority weights.

An example priority weight calculation is given for profit maximization (SO1), similarly the other priority weights were calculated.

Table 8.1. Group Decision Matrix of Strategic Objectives in AHP

	SO1	**SO2**	**SO3**	**SO4**	**SO5**	**SO6**
SO1	1.00	1.41	1.47	1.64	1.47	0.76
SO2	0.71	1.00	0.94	1.04	0.80	0.72
SO3	0.68	1.06	1.00	1.34	1.25	0.63
SO4	0.61	0.96	0.75	1.00	0.74	0.53
SO5	0.68	1.26	0.80	1.36	1.00	0.84
SO6	1.31	1.38	1.60	1.90	1.20	1.00

Table 8.1 was normalized and transformed to matrix into Table 8.2. Normalization was performed by using Property 4.4. An example is given for b_{11} element.

$$b_{11} = a_{11}/(a_{11} + a_{21} + a_{31} + a_{41} + a_{51} + a_{61})$$

$$b_{11} = 1.00/(1.00 + 0.71 + 0.68 + 0.61 + 0.68 + 1.31)$$
$$= 0.20$$

Table 8.2. Normalized Matrix of Strategic Objectives in AHP and Weight Values

	SO1	**SO2**	**SO3**	**SO4**	**SO5**	**SO6**	**w**
SO1	0.20	0.20	0.22	0.20	0.23	0.17	0.20
SO2	0.14	0.14	0.14	0.13	0.12	0.16	0.14
SO3	0.14	0.15	0.15	0.16	0.19	0.14	0.16
SO4	0.12	0.14	0.11	0.12	0.11	0.12	0.12
SO5	0.14	0.18	0.12	0.16	0.16	0.19	0.16
SO56	0.26	0.20	0.24	0.23	0.19	0.22	0.22

Then the priority weight of profit maximization (SO1) was calculated as indicated in the Property 4.6.

$$w_{SO1} = (0.20 + 0.20 + 0.22 + 0.20 + 0.23 + 0.17)/6$$
$$= 0.20$$
$$w_{SO2} = 0.14 \qquad w_{SO3} = 0.16$$
$$w_{SO4} = 0.12 \qquad w_{SO5} = 0.16$$
$$w_{SO6} = 0.22$$

Then weight vector W was obtained as indicated in the Property 4.7. The sum of all the elements in weight vector was equal to one, which indicates that there is not an error in the calculations.

$W = [0.20\ 0.14\ 0.16\ 0.12\ 0.16\ 0.22]$

To control consistency of group decision matrix, eigenvector method was used to prevent wrong decisions.

Firstly, non-normalized matrix in Table 8.1 and priority weight products were calculated for each row.

$$\begin{aligned} A * w_{SO1} &= (1.00) * (0.20) + (1.41) * (0.14) + (1.47) * (0.16) + (1.64) * (0.12) \\ &\quad + (1.47) * (0.16) + (0.76) * (0.22) \\ &= 1.23 \end{aligned}$$

$A * w_{SO2} = 0.84$ $\qquad$ $A * w_{SO3} = 0.94$

$A * w_{SO4} = 0.73$ $\qquad$ $A * w_{SO5} = 0.95$

$A * w_{SO6} = 1.35$

Property 4.9 was used to find λ_{max} value.

$$\begin{aligned} \lambda_{max} &= (1.00/6.00) * [(1.23/0.20) + (0.84/0.14) + (0.94/0.12) \\ &\quad + (0.73/0.16) + (0.95/0.16) + (1.35/0.22) \\ &= 6.03 \end{aligned}$$

The inconsistency index was calculated based on Property 4.10.

$$\begin{aligned} CI &= (6.03 - 6.00)\ /\ (6.00 - 1.00) \\ &= 0.01 \end{aligned}$$

Lastly inconsistency ratio was calculated based on Property 4.11 for $n = 6$.

$$\begin{aligned} CR &= 0.01/1.24 \\ &= 0.01 \end{aligned}$$

Inconsistency ratio was lower than 0.10, thus the results are acceptable.

Graphical representation of priority weights of strategical objectives are shown in the Figure 8.3.

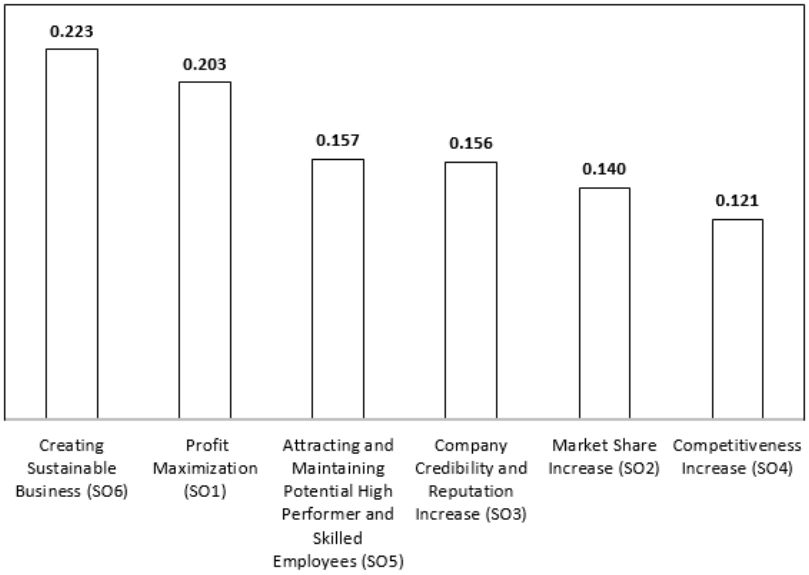

Figure 8.3. Priority Weights of Strategic Objectives for AHP

Table 8.3. Group Decision Matrix of Category Weights for Profit Maximization

	MIB	**EMP**	**SPE**	**STP**	**CUS**	**BP**
MIB	1.00	1.17	2.17	1.69	0.70	0.69
EMP	0.86	1.00	2.12	1.01	0.81	0.51
SPE	0.46	0.47	1.00	0.64	0.51	0.31
TP	0.59	0.99	1.56	1.00	0.44	0.42
CUS	1.43	1.23	1.97	2.27	1.00	0.79
BP	1.44	1.95	3.23	2.39	1.26	1.00

Since a cross-linked structure exists, at the third level of hierarchy category weights were determined based on each strategic objectives. Group decision matrix of category prioritization to achieve profit maximization (SO1) is given in Table 8.3.

In the next step, group decision matrix is normalized and transform to matrix Table 8.4. Normalization is performed by using Property 4.4 and the normalized matrix is obtained as indicated in the Property 4.5. Table 8.4 also shows the priority weights.

Table 8.4. Normalized Matrix of Category Weights for Profit Maximization and Weight Values

	MIB	**EMP**	**SPE**	**TP**	**CUS**	**BP**	**w**
MIB	0.17	0.17	0.18	0.19	0.15	0.19	0.17
EMP	0.15	0.15	0.18	0.11	0.17	0.14	0.15
SPE	0.08	0.07	0.08	0.07	0.11	0.08	0.08
TP	0.10	0.15	0.13	0.11	0.09	0.11	0.12
CUS	0.25	0.18	0.16	0.25	0.21	0.21	0.21
BP	0.25	0.29	0.27	0.27	0.27	0.27	0.27

Then weights are calculated for each categories to achieve profit maximization as indicated in the Property 4.6.

$$w_{MIB} = (0.17 + 0.17 + 0.18 + 0.19 + 0.15 + 0.19)/6.00$$
$$= 0.17$$
$$w_{SO2} = 0.15 \qquad w_{SO3} = 0.08$$
$$w_{SO4} = 0.12 \qquad w_{SO5} = 0.21$$
$$w_{SO6} = 0.27$$

Then for consistency control, inconsistency ratio is calculated. Property 4.9 is used to find λ_{max} value.

$$\lambda_{max} = (1.00/6.00) * [(1.06/0.17) + (0.90/0.15) + (0.50/0.08)$$
$$+ /(0.70/0.12) + (1.28/0.21) + (1.62/0.27)$$
$$= 6.05$$

Then inconsistency index is calculated based on Property 4.10.

$$CI = (6.05 - 6.00) \ / \ (6.00 - 1.00)$$
$$= 0.01$$

Lastly, inconsistency ratio was calculated as in Property 4.11 for $n = 6$.

$$CR = 0.01/1.24$$
$$= 0.01$$

Inconsistency ratio is lower than 0.10, thus the results were acceptable. Graphical representation of priority weights of categories according to profit maximization (SO1) goal are shown in the Figure 8.4.

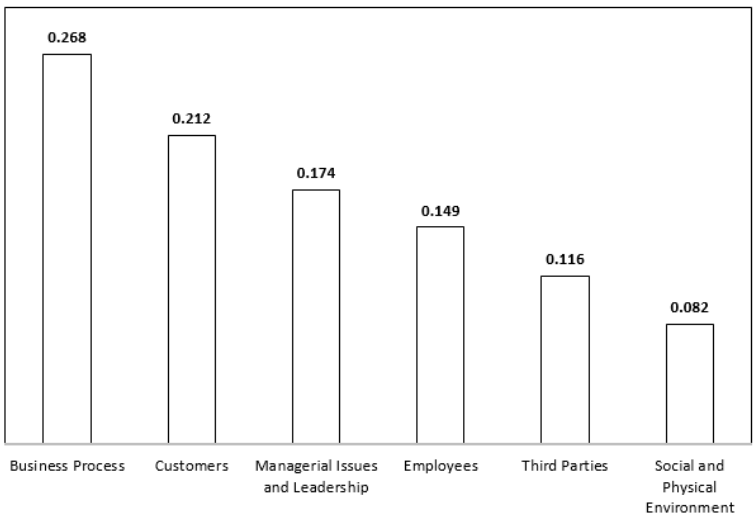

Figure 8.4. Category Priority Weights for Profit Maximization (SO1) in AHP Solution

For other strategic objectives calculations were repeated in the same manner. The results are shown in the Figure 8.5, Figure 8.6, Figure 8.7, Figure 8.8 and Figure 8.9 show each category priority with respect to strategic objectives. The business process is at top two rank to achieve all the strategic objectives. Results show that the importance weight of the business process for all categories are at least 22 percent or higher which indicates it is an effective topic in the overall performance. According to strategic objectives category rankings are changed. For example focus on customer category has become a necessity to achieve higher market share, higher credibility and reputation. However, to create a sustainable business, business processes come into prominence.

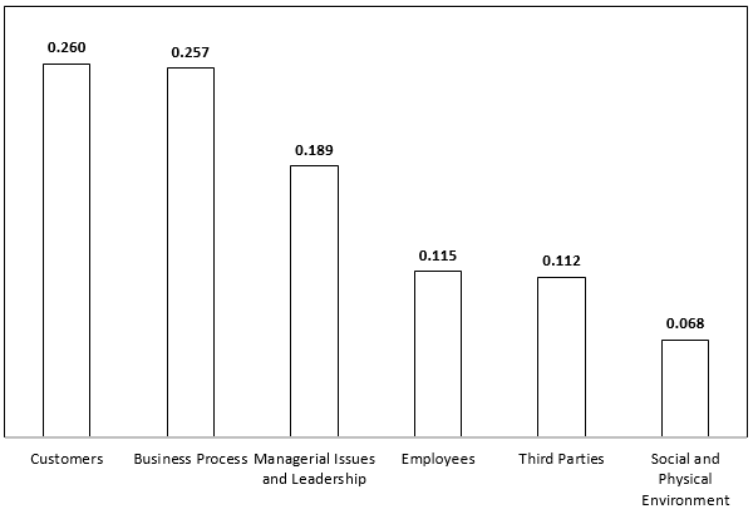

Figure 8.5. Category Priority Weights for Market Share Increase (SO2) in AHP Solution

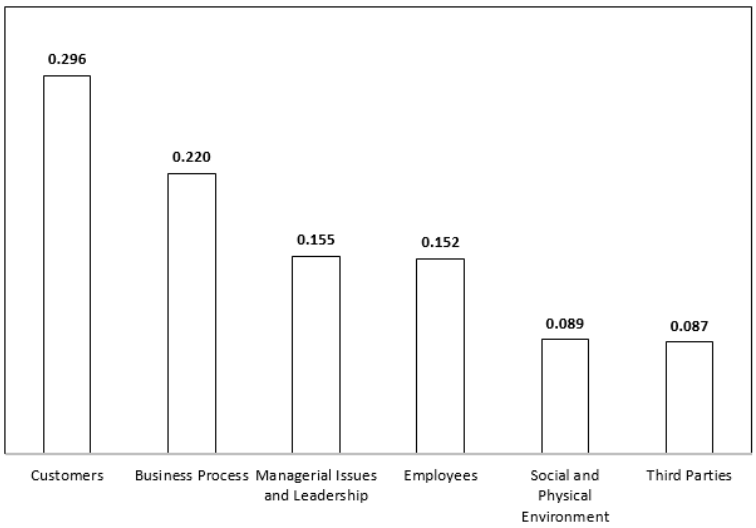

Figure 8.6. Category Priority Weights for Company Credibility and Reputation Increase (SO3) in AHP Solution

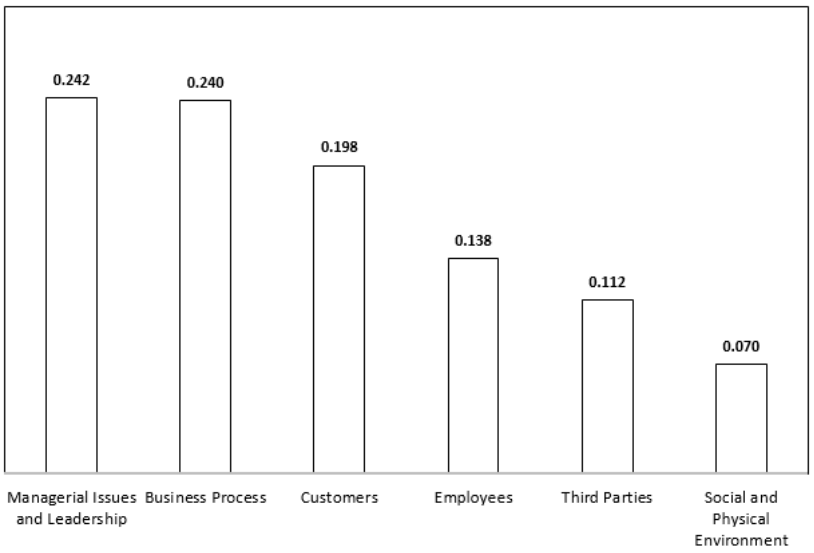

Figure 8.7. Category Priority Weights for Competitiveness Increase (SO4) in AHP Solution

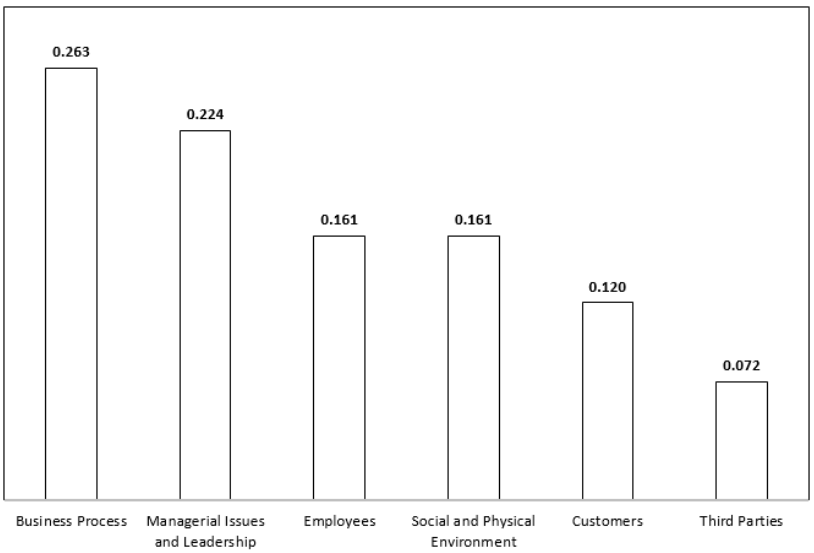

Figure 8.8. Category Priority Weights for Attracting and Maintaining High Performer and Skilled Employees (SO5) in AHP Solution

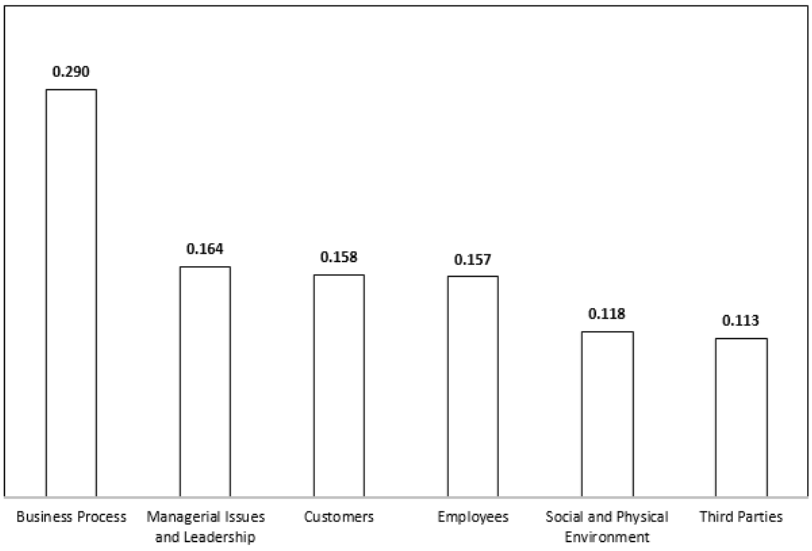

Figure 8.9. Category Priority Weights for Creating Sustainable Business (SO6) in AHP Solution

Prioritization of strategic objectives are determined in pairwise comparisons at the second level. Then the category elements are weighted according to each objective at the third level. If such cross-linked structure exists as it is in our model, a matrix should be created where the weight of the categories are shown with respect to each objective. That matrix is shown in Table 8.5.

Table 8.5. Determination of Overall Category Weights in AHP and Weight Values

	SO1	**SO2**	**SO3**	**SO4**	**SO5**	**SO6**	**w**
MIL	0.17	0.19	0.15	0.24	0.23	0.16	0.19
EMP	0.15	0.12	0.15	0.14	0.16	0.16	0.15
SPE	0.08	0.07	0.09	0.07	0.17	0.12	0.10
TP	0.12	0.11	0.09	0.11	0.07	0.11	0.10
CUS	0.21	0.26	0.29	0.20	0.12	0.16	0.20
BP	0.27	0.25	0.22	0.24	0.24	0.29	0.26

Rows consist of categories and columns consist of objectives. One more step is necessary to find the final priority of categories based on the consideration of all objectives effects. Elements at the row of the matrix represent the weights with respect to strategic objectives. Since all the strategic objectives vary in degree of importance, by multiplying category priority weight with related objective weight can provide to consist of weight effects and lead single ranking result instead of six different results.

An example weight calculation for managerial issues and leadership category is given below. This calculation is repeated for other five categories. Category priority weights are indicated in Figure 8.10.

$$w_{MIL} = (0.17)*(0.20)+(0.19)*(0.14)+(0.15)*(0.16)+(0.24)*(0.12)+(0.23)*(0.16) + (0.16)*(0.22) = 0.19$$

$w_{EMP} = 0.15$ $\quad$ $w_{SPE} = 0.10$

$w_{TP} = 0.10$ $\quad$ $w_{CUS} = 0.20$

$w_{BP} = 0.26$

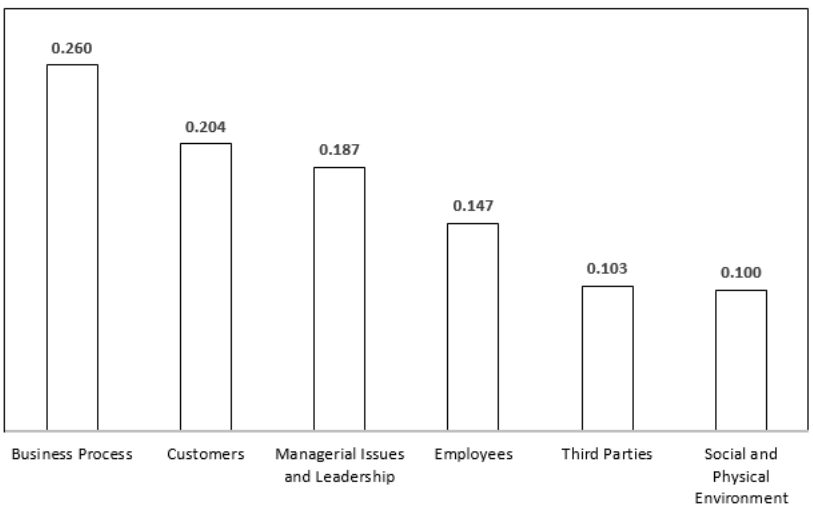

Figure 8.10. Final Category Priority Weights for AHP Solution

Computations are completed as it is in the first and in the second level. Results are shown in Figure 8.11, Figure 8.12, Figure 8.13, Figure 8.14, Figure 8.15 and Figure 8.16. The factors under the managerial issues and leadership are examined and

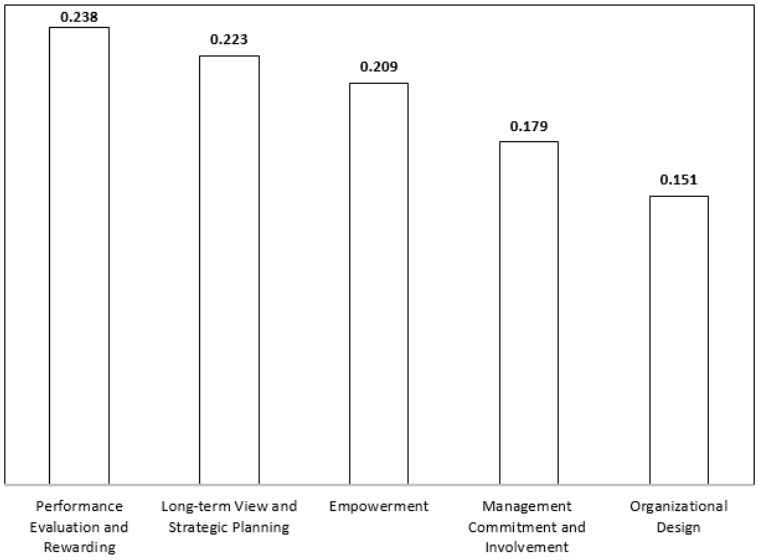

Figure 8.11. Local Priority Weights of Managerial Issues and Leadership Factors in AHP

prioritized in Figure 8.11. Accordingly, with the priority of 0.238, the performance evaluation and rewarding appear to be the most significant factor. It is followed by the long-term view and strategic planning with the 0.223 priority weight. Empowerment is obtained 0.209 priority weight which is ranked as third important factor. Management commitment and involvement factor is ranked as fourth important factor where organizational design has the lowest importance based on the evaluation.

The priorities of the factors under the employees category are given in Figure 8.12. Training, education and employees skills is the most important factor with 0.313 priority weight which is almost two times more important than the least important factor; teamwork. within that category. Motivation and needs factor is ranked at second order and employee involvement is ranked at third order.

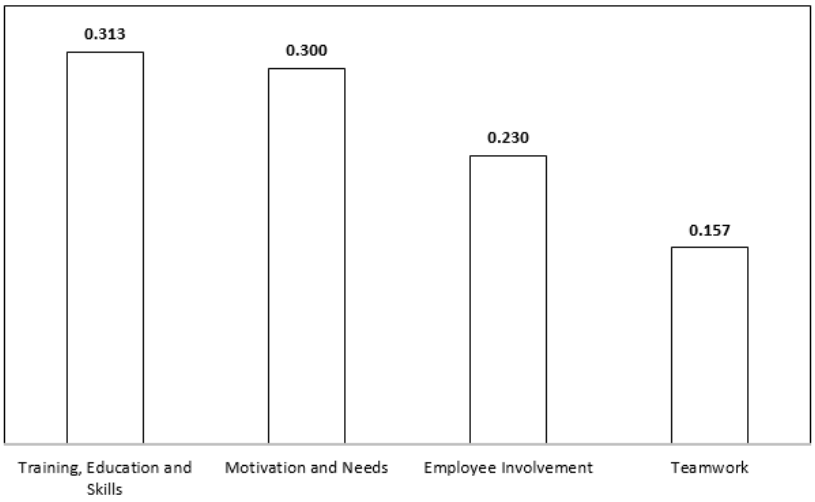

Figure 8.12. Local Priority Weights of Employees Factors in AHP

The priorities of the factors under the social and physical environment category are given in Figure 8.13. According to graph, with 0.310 priority, maintaining employee well-being is the most significant factor. Use of technology is the second important factor with 0.254. Organizational culture is the least important factor.

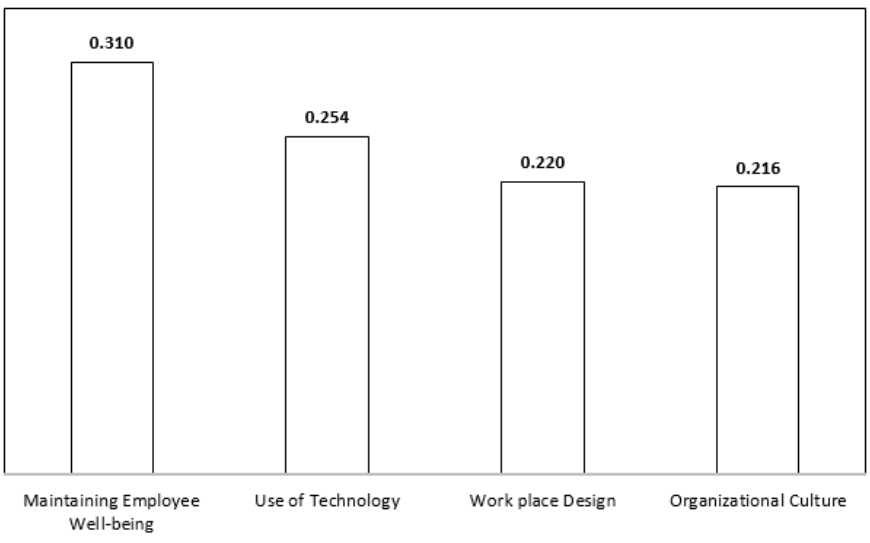

Figure 8.13. Local Priority Weights of Social and Physical Environment Factors in AHP

According to Figure 8.14, supplier involvement is more critical than the effect of authorities such as government and labor unions.

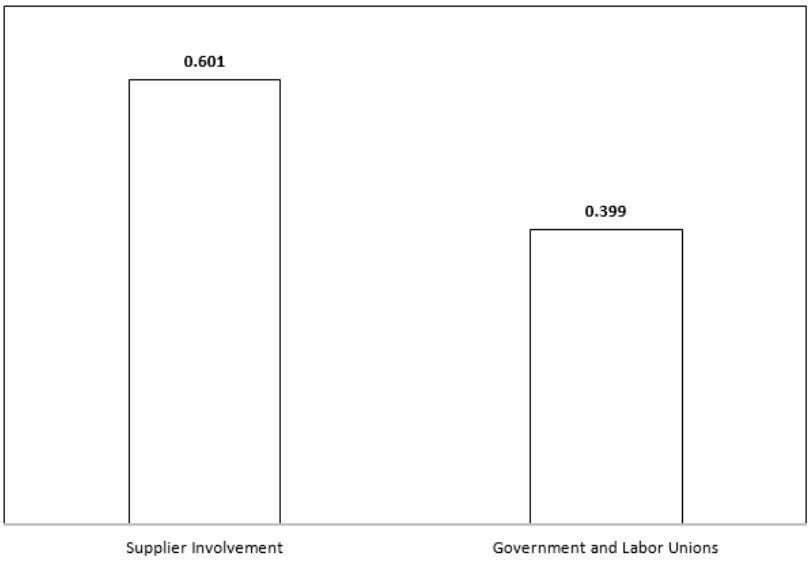

Figure 8.14. Local Priority Weights of Third Parties Factors in AHP

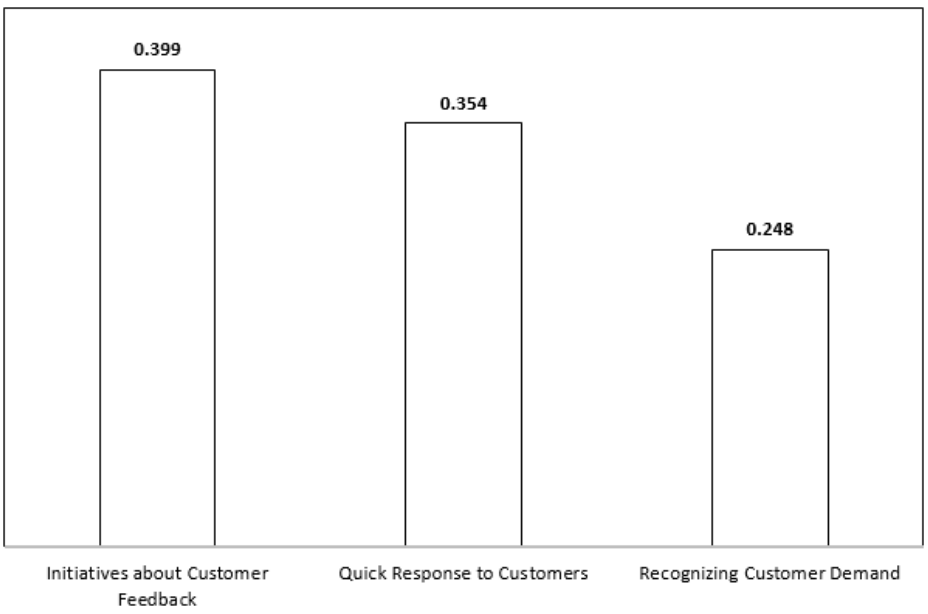

Figure 8.15. Local Priority Weights of Customers Factors in AHP

The factors under the customer category are examined and resulted as initiatives about customer feedback factor has the highest importance with 0,399 priority weight. Quick response the customers factor is the second important factor with 0,354 priority weight where recognizing customer demand factor has the least significance level within the category as indicated in 8.15.

Among the business processes category factors, the most significant factor appears as quality increase. Cost reduction, continuous improvement and productivity and efficiency factors come right after quality improvement with slight differences in priority weights. Factors followed by data driven, innovation and waste elimination in descending order.

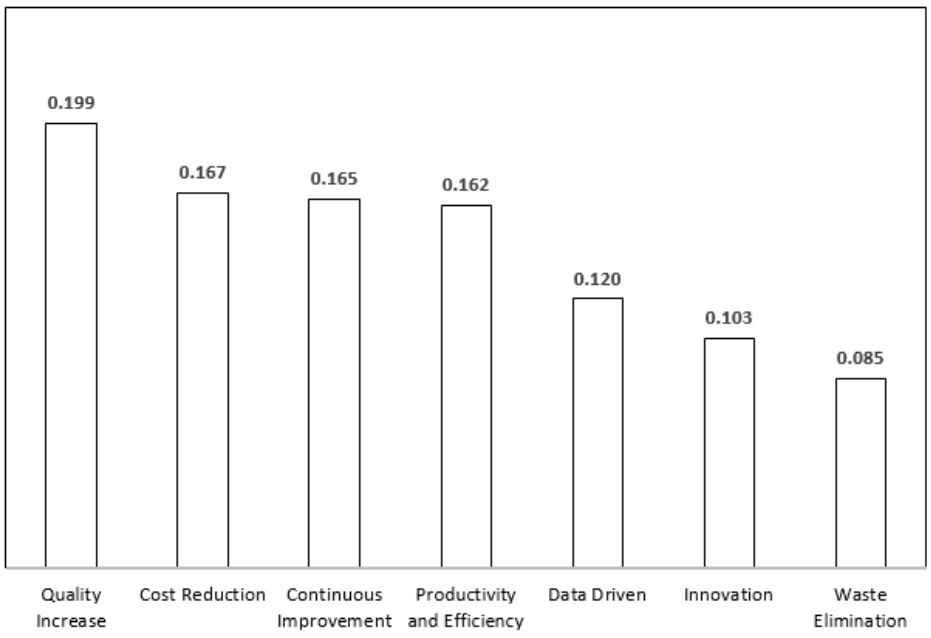

Figure 8.16. Local Priority Weights of Business Process Factors in AHP

If there exist more than two levels in a hierarchy two types of weights can be mentioned as a part of methodology; local and global weights. Local priority weights determine the preference order within the cluster. Until now all the calculations were conducted for local priority weights. On the other hand, global priority weights provide to compare two elements on the same scale even they are not in the same cluster. For example, if we compare quality increase with supplier involvement since supplier involvement local priority weight is higher than quality increase local priority, the former can be labeled as more significant. However, when local priority weights are used for ranking category weight effects are discarded. Due to the fact that global weights should be identified. Global weights are found by multiplying the local weight of that element with the linked upper-level elements weight.

We attempt to rank factors according to the importance level. For that, we have found global priority weight. In our model we realize since the factor numbers differ within the subgroups, even all factors are labeled as equal the global weights are differs from each other because of unbalances in number of factors. We attempt to solve this problem by designating coefficient for each category. Managerial issues and leadership category coefficient is decided as 1.5; employees category coefficient is decided as 1.2; social and physical environment category coefficient is decided as 1.2; third parties category coefficient is decided as 0.6; customers category coefficient is decided as 0.9; business process category coefficient is decided as 2.1. Global priority weights are multiplied with these coefficients and adjusted to be sure that summation of all the factors equal to one.

Global and local weights for categories of ergonomics and TQM factors are indicated in Table 8.6 for AHP solution.

Figure 8.17 demonstrate factors importance levels in descending order. Values are indicated as percentage, summation of all 25 factors are equal to one.

Table 8.6. Local, Global, Adjusted Factor Priority Weights for AHP Solution

	Local	**Global**	**Adjusted**
Managerial Issues and Leadership	0.187		
Performance Evaluation and Rewarding	0.238	0.045	0.049
Long-term View and Strategic Planning	0.223	0.042	0.046
Empowerment	0.209	0.039	0.043
Management Commitment and Involvement	0.179	0.033	0.037
Organizational Design	0.151	0.028	0.031
Employees	0.147		
Training, Education and Skills	0.313	0.046	0.040
Motivation and Needs	0.300	0.044	0.039
Employee Involvement	0.230	0.034	0.030
Teamwork	0.157	0.023	0.020
Social and Physical Environment	0.100		
Maintaining Employee Wellbeing	0.310	0.031	0.027
Use of Technology	0.254	0.025	0.022
Workplace Design	0.220	0.022	0.019
Organizational Culture	0.216	0.022	0.019
Third Parties	0.103		
Supplier Involvement	0.601	0.062	0.027
Government and Labor Unions	0.399	0.041	0.018
Customers	0.204		
Initiatives about Customer Feedback	0.399	0.081	0.053
Quick Response to Customers	0.354	0.072	0.047
Recognizing Customer Demand	0.248	0.050	0.033
Business Process	0.260		
Quality Increase	0.199	0.052	0.079
Cost Reduction	0.167	0.043	0.067
Continuous Improvement	0.165	0.043	0.066
Productivity and Efficiency	0.162	0.042	0.064
Data Driven	0.120	0.031	0.048
Innovation	0.103	0.027	0.041
Waste Elimination	0.085	0.022	0.034

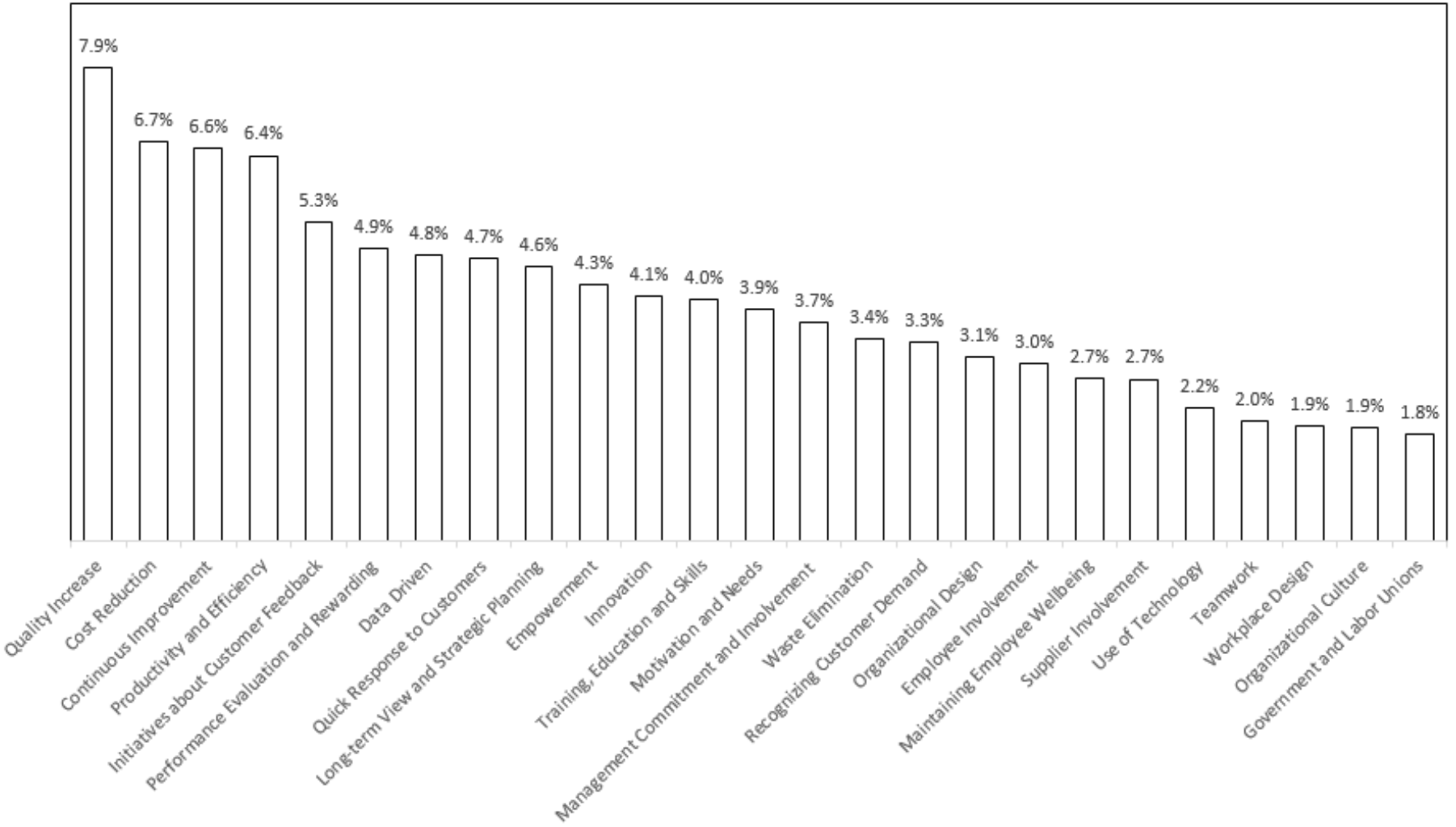

Figure 8.17. Factor Prioritization Results for AHP Solution

8.2. Fuzzy AHP Application to Our Model

In previous topic, AHP was applied to our problem. When a preference cannot be made between two severity levels, in AHP methodology based on nine point scale the appropriate values are selected among 2,4,6 and 8. The data is examined, intermediate values are observed among the answers. This leads us to apply FAHP methodology. In addition, due to the risk of the responses obtained by e-mail survey might not completely understood by decision-makers, a solution with FAHP method was proposed to eliminate uncertainty. The same data from consistent survey responses are also used in Fuzzy AHP solution.

Each comparison value in the questionnaires were first fuzzed and l_{ij}, m_{ij}, u_{ij} values were obtained for each questionnaire response. Aggregation of individual judgments as a final group decision matrix is decided for 23 decision-makers responses where $a_{ijk} = (l_{ijk}, m_{ijk}, u_{ijk})$ represents the relative importance of criterion i to j as assessed by the expert k. The group judgment matrix is obtained by using triangular fuzzy numbers.

Since the first level of hierarchy indicates the goal pairwise comparisons are started from the second level of hierarchy. Fuzzy group decision matrix for strategic objectives is given in Table 8.7.

The geometric mean of fuzzy comparison value for each objective; r_i values are calculated by using Property 4.20 and w_i values are calculated by using Property 4.21. An example calculation is given for profit maximization, similarly the other r values and w values are calculated.

Table 8.7. Fuzzy Group Decision Matrix for Strategic Objectives

	SO1	**SO2**	**SO3**	**SO4**	**SO5**	**SO6**
SO1	(1.00 1.00 1.00)	(1.09 1.41 2.18)	(1.11 1.47 2.23)	(1.20 1.64 2.33)	(1.05 1.47 2.07)	(0.60 0.76 1.19)
SO2	(0.46 0.71 0.92)	(1.00 1.00 1.00)	(0.74 0.94 1.47)	(0.85 1.04 1.96)	(0.62 0.80 1.16)	(0.57 0.72 1.07)
SO3	(0.45 0.68 0.90)	(0.68 1.06 1.35)	(1.00 1.00 1.00)	(1.01 1.34 1.97)	(0.97 1.25 2.14)	(0.51 0.63 0.93)
SO4	(0.43 0.61 0.83)	(0.51 0.96 1.18)	(0.51 0.75 0.99)	(1.00 1.00 1.00)	(0.58 0.74 1.03)	(0.42 0.53 0.75)
SO5	(0.48 0.68 0.95)	(0.87 1.26 1.62)	(0.47 0.80 1.03)	(0.97 1.36 1.74)	(1.00 1.00 1.00)	(0.70 0.84 1.09)
SO6	(0.84 1.31 1.67)	(0.93 1.38 1.77)	(1.08 1.60 1.96)	(1.34 1.90 2.37)	(0.92 1.20 1.42)	(1.00 1.00 1.00)

Fuzzy weight dimensions of profit maximization (SO1) is calculated below.

$$\begin{aligned}\tilde{r}_{SO1} &= [(1.00\ 1.00\ 1.00) \otimes (1.09\ 1.41\ 2.18) \otimes (1.11\ 1.47\ 2.23) \otimes (1.20\ 1.64\ 2.33) \\ &\quad \otimes (1.05\ 1.47\ 2.07) \otimes (0.60\ 0.76\ 1.19)]^{1/6} \\ &= (0.99\ 1.25\ 1.74)\end{aligned}$$

$\tilde{r}_{SO2} = (0.68\ 0.86\ 1.22)$ $\quad$ $\tilde{r}_{SO3} = (0.73\ 0.95\ 1.30)$

$\tilde{r}_{SO4} = (0.55\ 0.74\ 0.95)$ $\quad$ $\tilde{r}_{SO5} = (0.72\ 0.96\ 1.20)$

$\tilde{r}_{SO6} = (1.01\ 1.37\ 1.64)$

Fuzzy priority weight of profit maximization (SO1) is calculated below.

$$\begin{aligned}\tilde{w}_{SO1} &= (0.99\ 1.25\ 1.79) \oslash [(0.70\ 0.86\ 1.26) \oplus (0.78\ 0.95\ 1.38) \oplus (0.61\ 0.74\ 1.06) \\ &\quad \oplus (0.79\ 0.96\ 1.32) \oplus (1.12\ 1.37\ 1.82)] \\ &= (0.12\ 0.20\ 0.37)\end{aligned}$$

$\tilde{w}_{SO2} = (0.08\ 0.14\ 0.26)$ $\quad$ $\tilde{w}_{SO3} = (0,09\ 0.16\ 0.28)$

$\tilde{w}_{SO4} = (0.07\ 0.12\ 0.20)$ $\quad$ $\tilde{w}_{SO5} = (0.09\ 0.16\ 0.26)$

$\tilde{w}_{SO6} = (0.13\ 0.22\ 0,35)$

The fuzzy mean and spread method is used to defuzzify these weight vectors for obtaining non-fuzzy numbers. Defuzzification is performed for a triangular fuzzy number as [54];

$$M_{a_{ij}} = (l_{ij} + m_{ij} + u_{ij})/3 \tag{8.2}$$

Defuzzification for w_{SO1} is performed as follows.

$M_{w_{SO1}}$ is;

$$\begin{aligned}&= (0.12 + 0.20 + 0.37)/3 \\ &= 0.23\end{aligned}$$

$M_{w_{SO2}} = 0.16$ $M_{w_{SO3}} = 0.17$

$M_{w_{SO4}} = 0.13$ $M_{w_{SO5}} = 0.17$

$M_{w_{SO6}} = 0.23$

Then normalization is performed for defuzzied priority weights as;

$$N_{w_i} = w_i / \left(\sum_{i=1}^{n} w_i \right) \qquad i = 1, 2, ..n \tag{8.3}$$

Normalized priority weight is found for profit maximization as;

w_{SO1} is;

$= 0.23/(0.23 + 0.16 + 0.17 + 0.13 + 0.17 + 0.23)$

$= 0.21$

$w_{SO2} = 0.15$ $w_{SO3} = 0.16$

$w_{SO4} = 0.12$ $w_{SO5} = 0.15$

$w_{SO6} = 0.21$

After normalization is applied, priority weights constitute the vector as;

$$W(0.202\ 0.144\ 0.158\ 0.123\ 0.155\ 0.217)^T$$

At the second level of hierarchy strategic objectives priority weights are determined. When the six main strategic objectives were examined, none of those objectives differs as too high or too low in comparisons. Figure 8.18 demonstrates upper-level management evaluation has resulted that all the identified strategic objectives are important.

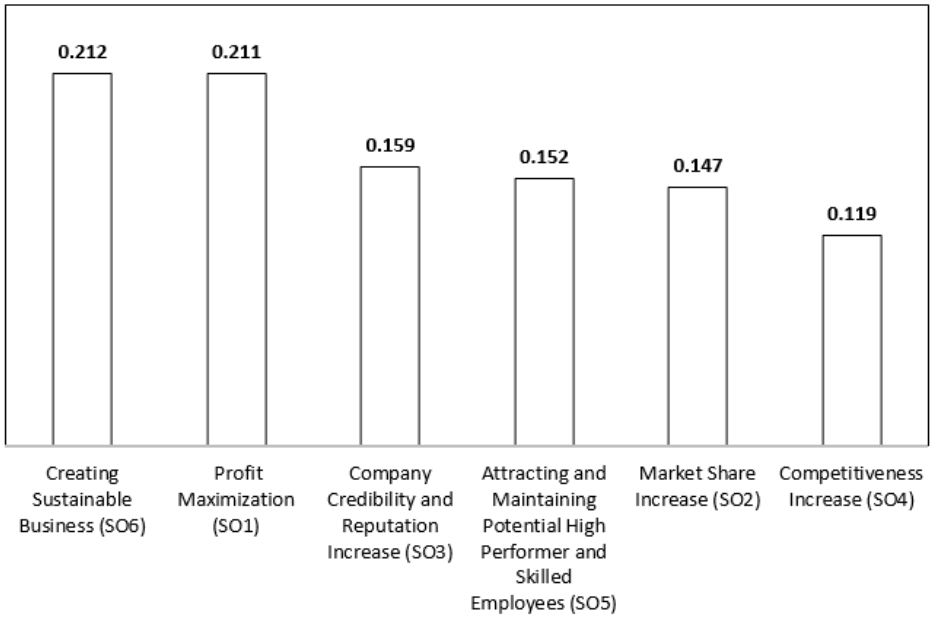

Figure 8.18. Priority Weights of Strategic Objectives for FAHP

Creating sustainable business is the most important strategical objective. Maximizing profit has the second highest rank in ordering. Company credibility and reputation is the third important factor and it is slightly more important than attracting and maintaining potential high performer and skilled employees. Market share is is in the fifth ranked while competitiveness increase is appear as the least important objective.

Then at the third level of hierarchy category weights are determined based on each strategic objectives, since a cross-linked structure exists as in our model. An example group decision matrix for category prioritization to achieve maximum profit is given in Table 8.8.

Table 8.8. Fuzzy Group Decision Matrix of Category Weights for Profit Maximization

	Managerial Issues and Leadership	**Employees**	**Social and Physical Environment**	**Third Parties**	**Customers**	**Business Process**
Managerial Issues and Leadership	(1.00 1.00 1.00)	(0.88 1.17 1.96)	(1.63 2.17 2.92)	(1.27 1.69 2.68)	(0.61 0.70 1.20)	(0.52 0.69 1.08)
Employees	(0.51 0.86 1.14)	(1.00 1.00 1.00)	(1.56 2.12 2.98)	(0.80 1.01 1.73)	(0.61 0.81 1.08)	(0.40 0.51 0.75)
Social and Physical Environment	(0.34 0.46 0.61)	(0.34 0.47 0.64)	(1.00 1.00 1.00)	(0.53 0.64 1.12)	(0.39 0.51 0.78)	(0.25 0.31 0.40)
Third Parties	(0.37 0.59 0.79)	(0.58 0.99 1.26)	(0.90 1.56 1.88)	(1.00 1.00 1.00)	(0.36 0.44 0.68)	(0.33 0.42 0.63)
Customers	(0.83 1.43 1.64)	(0.93 1.23 1.64)	(1.28 1.97 2.58)	(1.47 2.27 2.76)	(1.00 1.00 1.00)	(0.64 0.79 1.31)
Business Process	(0.93 1.44 1.91)	(1.33 1.95 2.47)	(2.50 3.23 4.02)	(1.60 2.39 3.07)	(0.77 1.26 1.57)	(1.00 1.00 1.00)

An example calculation is given below for the first strategic objective based on Table 8.8 is given below, similarly the other categories weight dimensions and priority weights are calculated.

$$\begin{aligned}\tilde{r}_{MIL} &= [(1.00\ 1.00\ 1.00) \otimes (0.88\ 1.17\ 1.96) \otimes (0.63\ 2.17\ 2,92) \otimes (1.27\ 1.69\ 2.68) \\ &\quad \otimes (0.61\ 0.70\ 1.20) \otimes (0.52\ 0.69\ 1.08)]^{1/6} \\ &= (0.91\ 1.13\ 1,65)\end{aligned}$$

$\tilde{r}_{EMP} = (0.73\ 0.96\ 1.30)$ $\quad$ $\tilde{r}_{SPE} = (0.42\ 0.53\ 0.72)$

$\tilde{r}_{TP} = (0.53\ 0.74\ 0.96)$ $\quad$ $\tilde{r}_{CUS} = (0.99\ 1.36\ 1.71)$

$\tilde{r}_{BP} = (1.25\ 1.74\ 2.12)$

$$\begin{aligned}\tilde{w}_{MIL} &= (0.91\ 1.13\ 1.65) \oslash [(0.91\ 1.13\ 1.65) \oplus (0.73\ 0.96\ 1.30) \oplus (0.42\ 0.53\ 0.72) \\ &\quad \oplus (0.53\ 0.74\ 0.96) \oplus (0.99\ 1.36\ 1.71) \oplus (1.25\ 1.74\ 2.12)] \\ &= (0.11\ 0.18\ 0.34))\end{aligned}$$

$\tilde{w}_{EMP} = (0.09\ 0.15\ 0.27)$ $\quad$ $\tilde{w}_{SPE} = (0.05\ 0.08\ 0.15)$

$\tilde{w}_{TP} = (0.06\ 0.12\ 0.20)$ $\quad$ $\tilde{w}_{CUS} = (0.12\ 0.21\ 0.35)$

$\tilde{w}_{BP} = (0.15\ 0.27\ 0.44)$

After normalization and defuzzification are applied category weight vector is found as below. Figure 8.19 shows the priority weights to reach maximum profit.

$$W(0.19\ 0.15\ 0.08\ 0.11\ 021\ 0.26)^T$$

Similarly for market share increase category priority weights are shown in Figure 8.20, for company credibility and reputation increase category priority weights are shown in Figure 8.21, for competitiveness increase category priority weights are shown in Figure 8.22, for company credibility and reputation increase priority weights are shown in Figure 8.23, and for creating sustainable business priority weights are shown in Figure8.24.

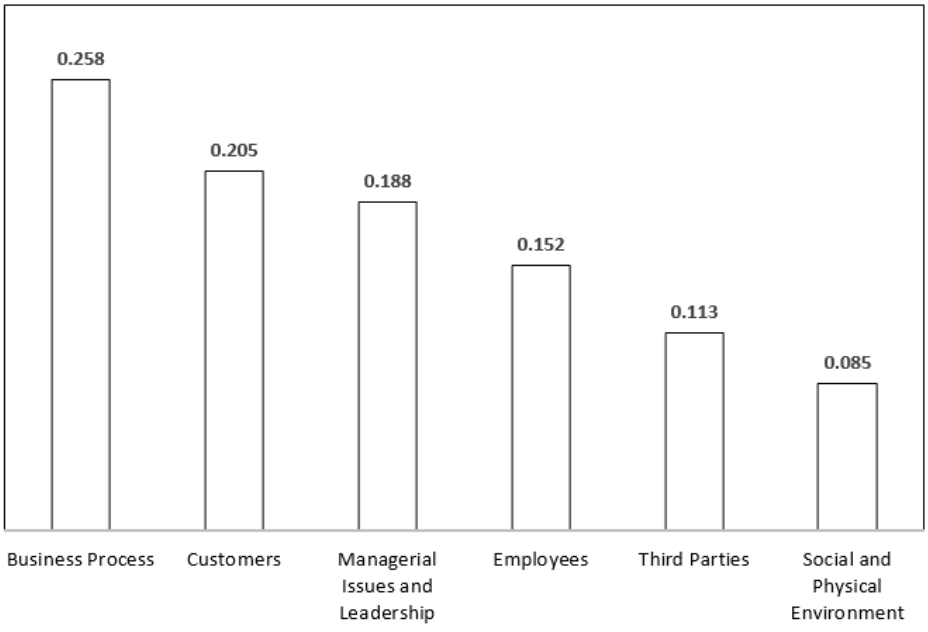

Figure 8.19. Category Priority Weights for Profit Maximization (SO1) in FAHP Solution

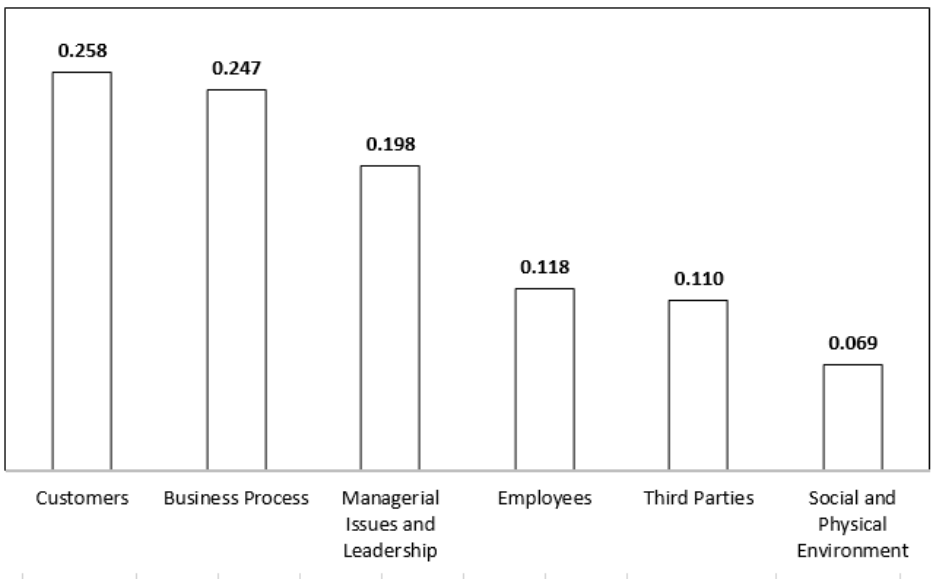

Figure 8.20. Category Priority Weights for Market Sharer Increase (SO2) in FAHP Solution

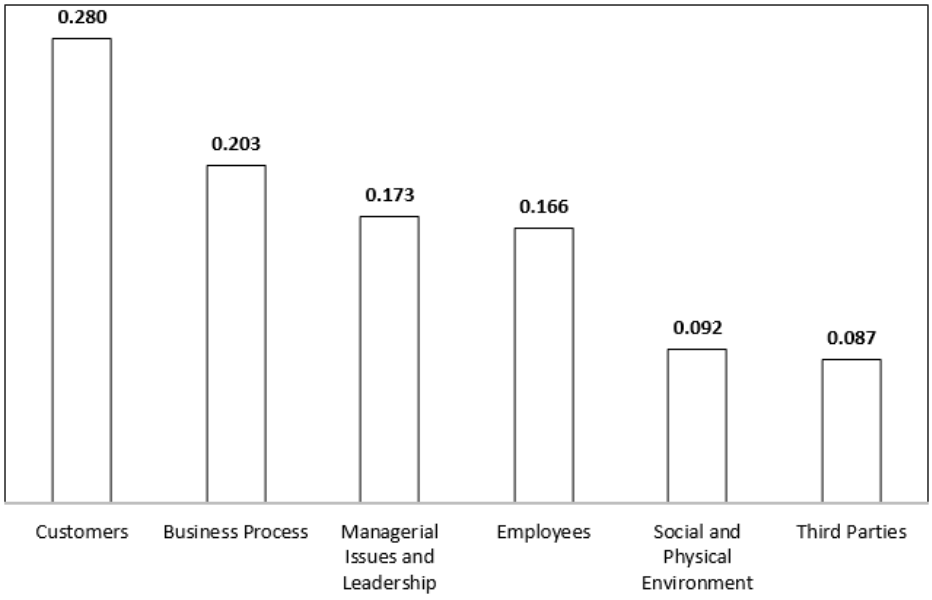

Figure 8.21. Category Priority Weights for Company Credibility and Reputation (SO3) in FAHP Solution

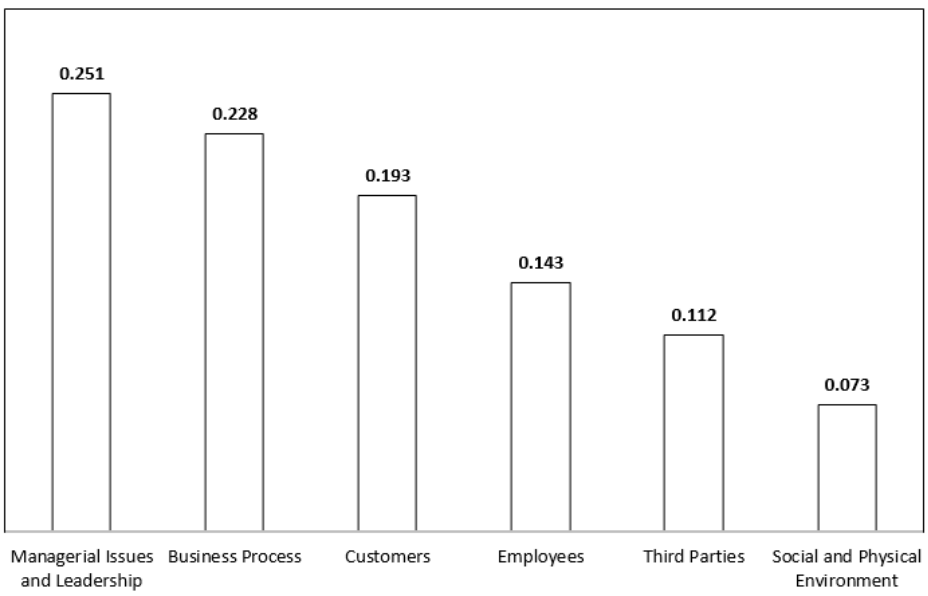

Figure 8.22. Category Priority Weights for Competitiveness Increase (SO4) in FAHP Solution

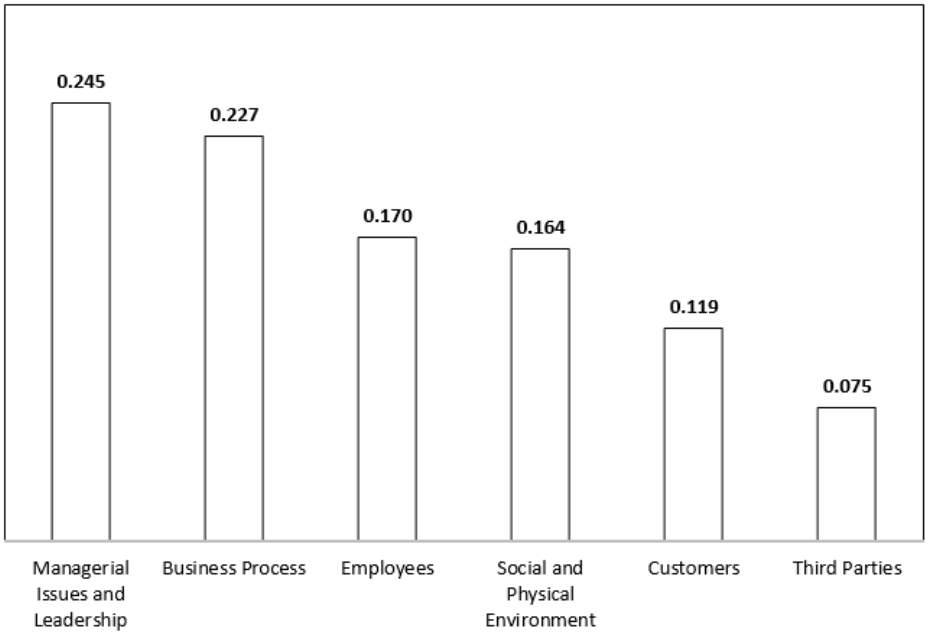

Figure 8.23. Category Priority Weights for Attracting High Performer and Skilled Employees (SO5) in FAHP Solution

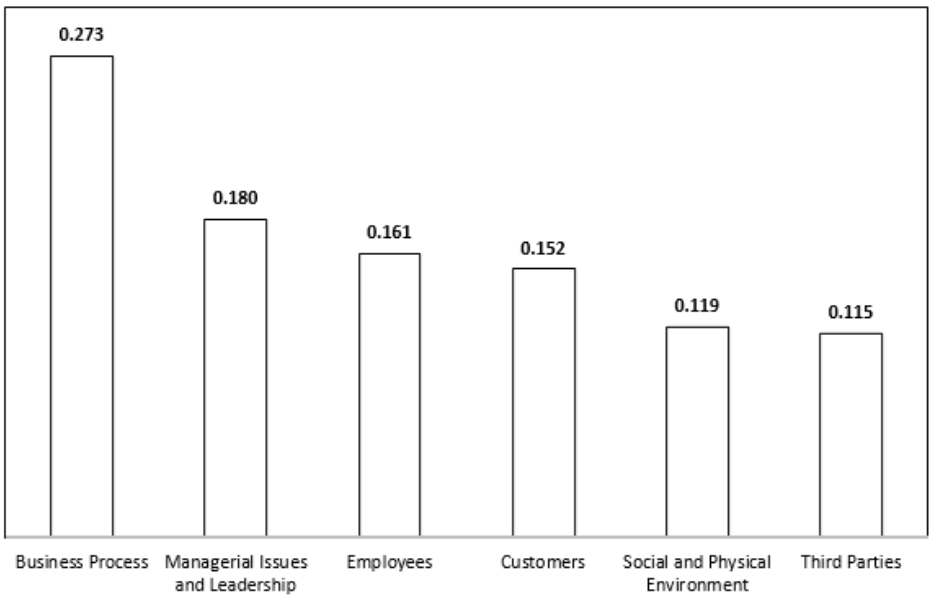

Figure 8.24. Category Priority Weights for Creating Sustainable Business (SO6) in FAHP Solution

Prioritization of strategic objectives are determined in pairwise comparisons at the second level. Then the category elements are weighted according to each objectives at the third level. In our model cross-linked structure exists, a matrix is created where the weight of the categories are shown with respect to each objective. Rows consist of categories and columns consist of objectives. One more step is necessary to find the final priority of categories with the consideration of all objectives effects. Since all the strategic objectives vary in degree of importance, by multiplying category priority weights at a row with related objective weight can provide to consider the weight effects.

Table 8.9. Determination of Overall Category Priority Weights in FAHP

	SO1	**SO2**	**SO3**	**SO4**	**SO5**	**SO6**
MIL	0.18	0.19	0.16	0.24	0.23	0.17
EMP	0.15	0.12	0.16	0.14	0,17	0.16
SPE	0.08	0.07	0.09	0.07	0.16	0.12
TP	0.12	0.11	0.09	0.12	0.07	0.11
CUS	0.21	0.26	0.29	0.20	0.12	0.16
BP	0.26	0.25	0.22	0.24	0.25	0.29

An example weight calculation for managerial issues and leadership category is given below. This calculation is repeated for other five categories. Graphical representation of overall category Category priority weights are indicated in Figure 8.25.

$$
\begin{aligned}
w'_{MIL} &= (0.18) * (0.20) + (0.19) * (0.14) * (0.16) * (0.16) * (0.24) * (0.12) \\
&\quad + (0.23) * (0.16) + (0.17) * (0.22) \\
&\quad = 0.189
\end{aligned}
$$

$w_{EMP} = 0.148$ $\qquad$ $w_{SPE} = 0.100$

$w_{TP} = 0.105$ $\qquad$ $w_{CUS} = 0.204$

$w_{BP} = 0.254$

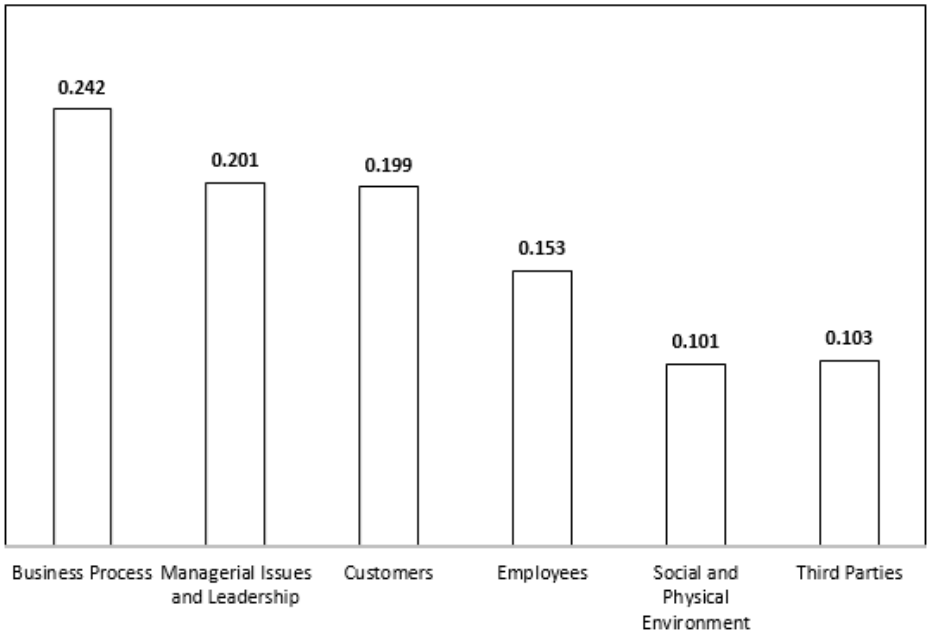

Figure 8.25. Final Category Priority Weights for FAHP Solution

At the fourth level factors priority weights are calculated for each category. Figure 8.26 is shown managerial issues and leadership factors priority weights, Figure 8.27 is shown employees factors priority weights, Figure 8.28 is shown social and physical environment factors priority weights, Figure 8.29 is shown third parties factors priority weight, Figure 8.30 is shown customer factors priority weights, Figure 8.31 is shown business processes factors priority weights.

Global, local and adjusted weights of categories and ergonomics and TQM factors are indicated in Table 8.10. Figure 8.32 is used to demonstrate importance levels in descending order for FAHP solution. Values are indicated as percentage, summation of all 25 factors equals to 1.

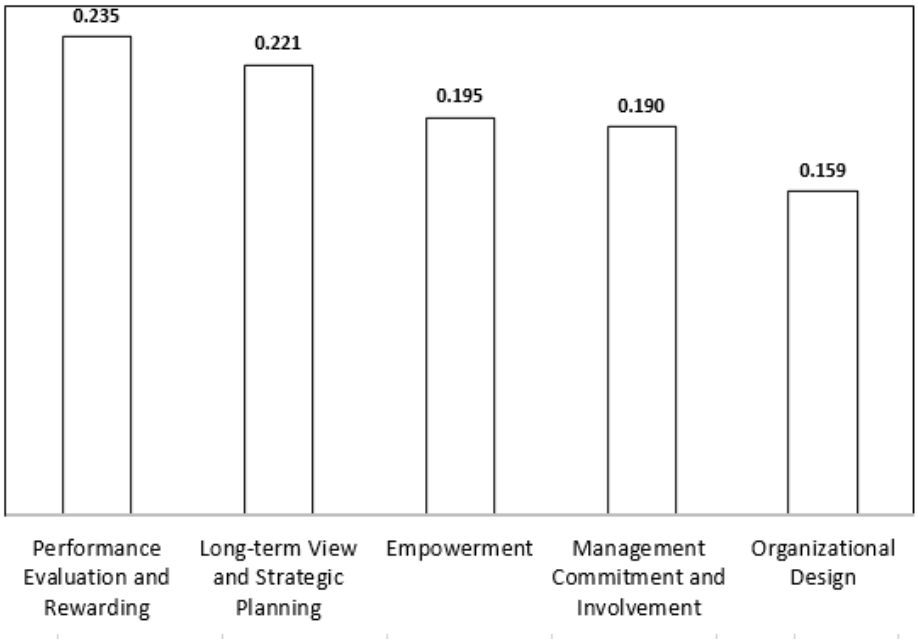

Figure 8.26. Local Priority Weights of Managerial Issues and Leadership Factors in FAHP

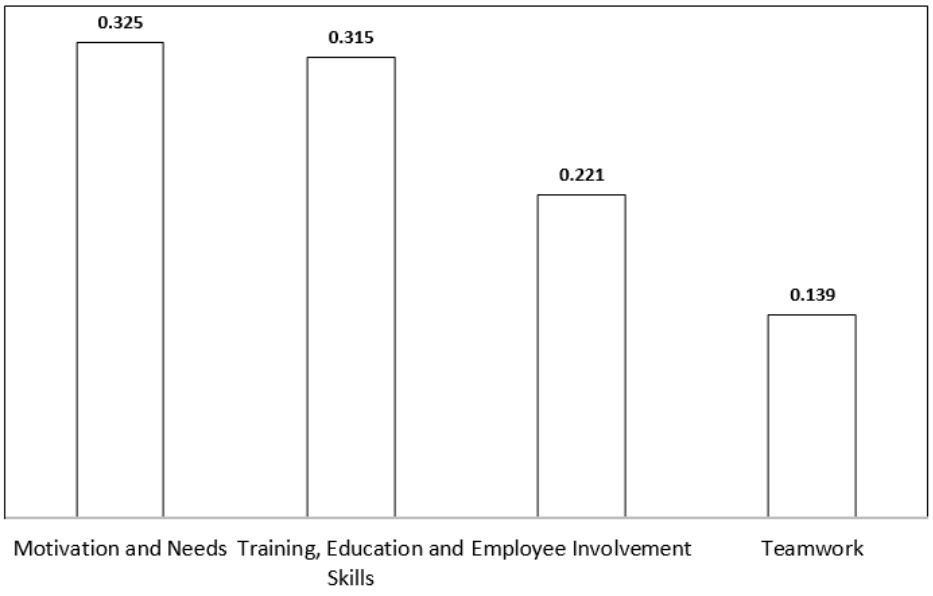

Figure 8.27. Local Priority Weights of Employees Factors in FAHP

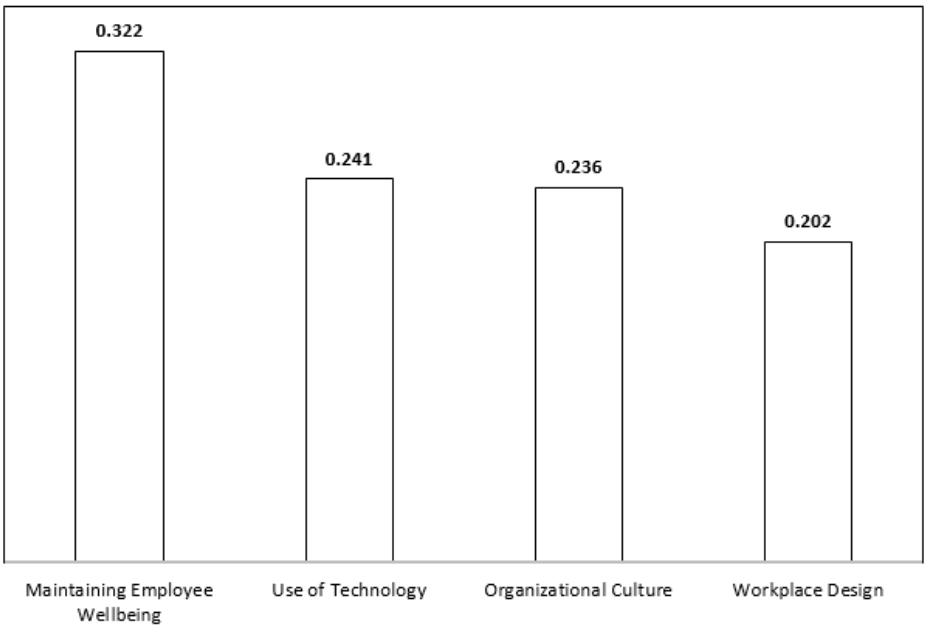

Figure 8.28. Local Priority Weights of Social and Physical Environment Factors in FAHP

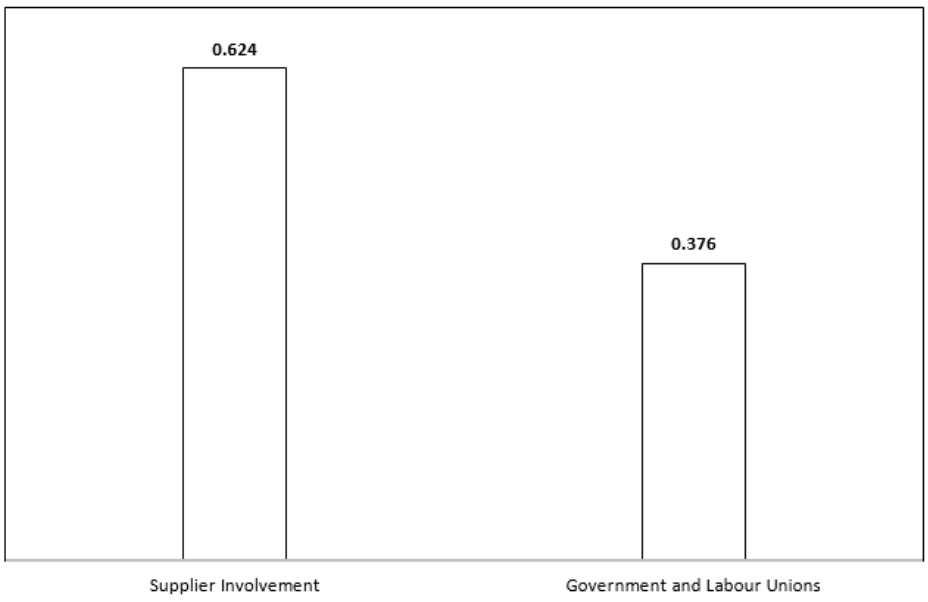

Figure 8.29. Local Priority Weights of Third Parties Factors in FAHP

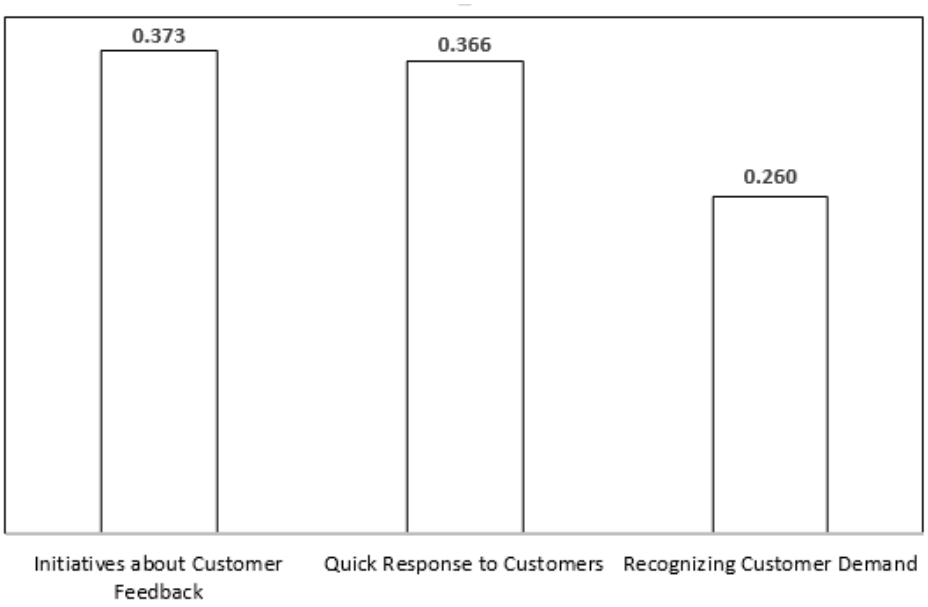

Figure 8.30. Local Priority Weights of Customers Factors in FAHP

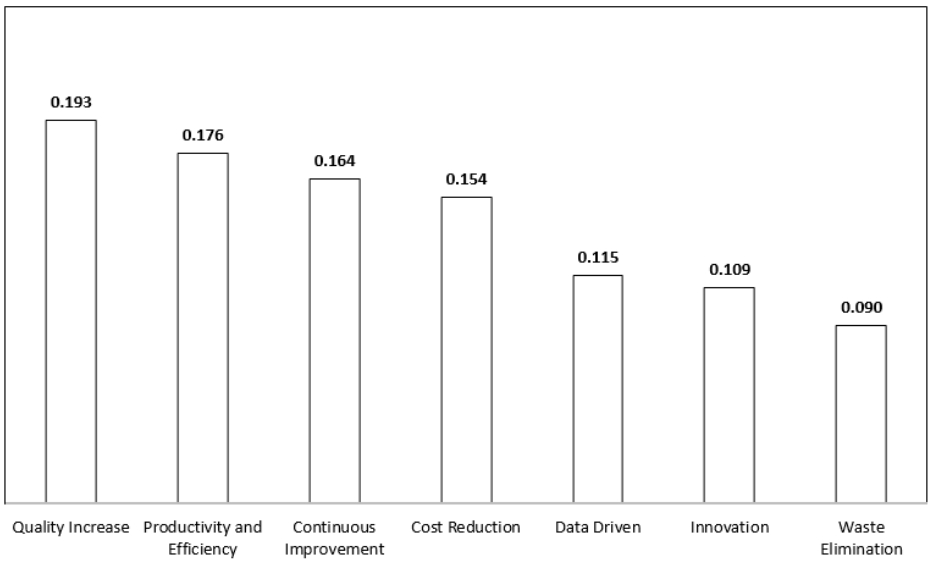

Figure 8.31. Local Priority Weights of Business Processes Factors in FAHP

Table 8.10. Local, Global, Adjusted Factor Priority Weights for FAHP Solution

	Local	**Global**	**Adjusted**
Managerial Issues and Leadership	0.189		
Performance Evaluation and Rewarding	0.235	0.044	0.049
Long-term View and Strategic Planning	0.221	0.042	0.046
Empowerment	0.195	0.037	0.041
Management Commitment and Involvement	0.190	0.036	0.040
Organizational Design	0.159	0.030	0.033
Employees	0.148		
Motivation and Needs	0.325	0.048	0.043
Training, Education and Skills	0.315	0.047	0.041
Employee Involvement	0.221	0.033	0.029
Teamwork	0.139	0.021	0.018
Social and Physical Environment	0.099		
Maintaining Employee Wellbeing	0.322	0.032	0.028
Use of Technology	0.241	0.024	0.021
Organizational Culture	0.236	0.023	0.021
Workplace Design	0.202	0.020	0.018
Third Parties	0.105		
Supplier Involvement	0.624	0.065	0.029
Government and Labour Unions	0.376	0.039	0.017
Customers	0.205		
Initiatives about Customer Feedback	0.373	0.076	0.051
Quick Response to Customers	0.366	0.075	0.050
Recognizing Customer Demand	0.260	0.053	0.035
Business Process	0.254		
Quality Increase	0.193	0.049	0.076
Productivity and Efficiency	0.176	0.045	0.069
Continuous Improvement	0.164	0.042	0.064
Cost Reduction	0.154	0.039	0.060
Data Driven	0.115	0.029	0.045
Innovation	0.109	0.028	0.043
Waste Elimination	0.090	0.023	0.035

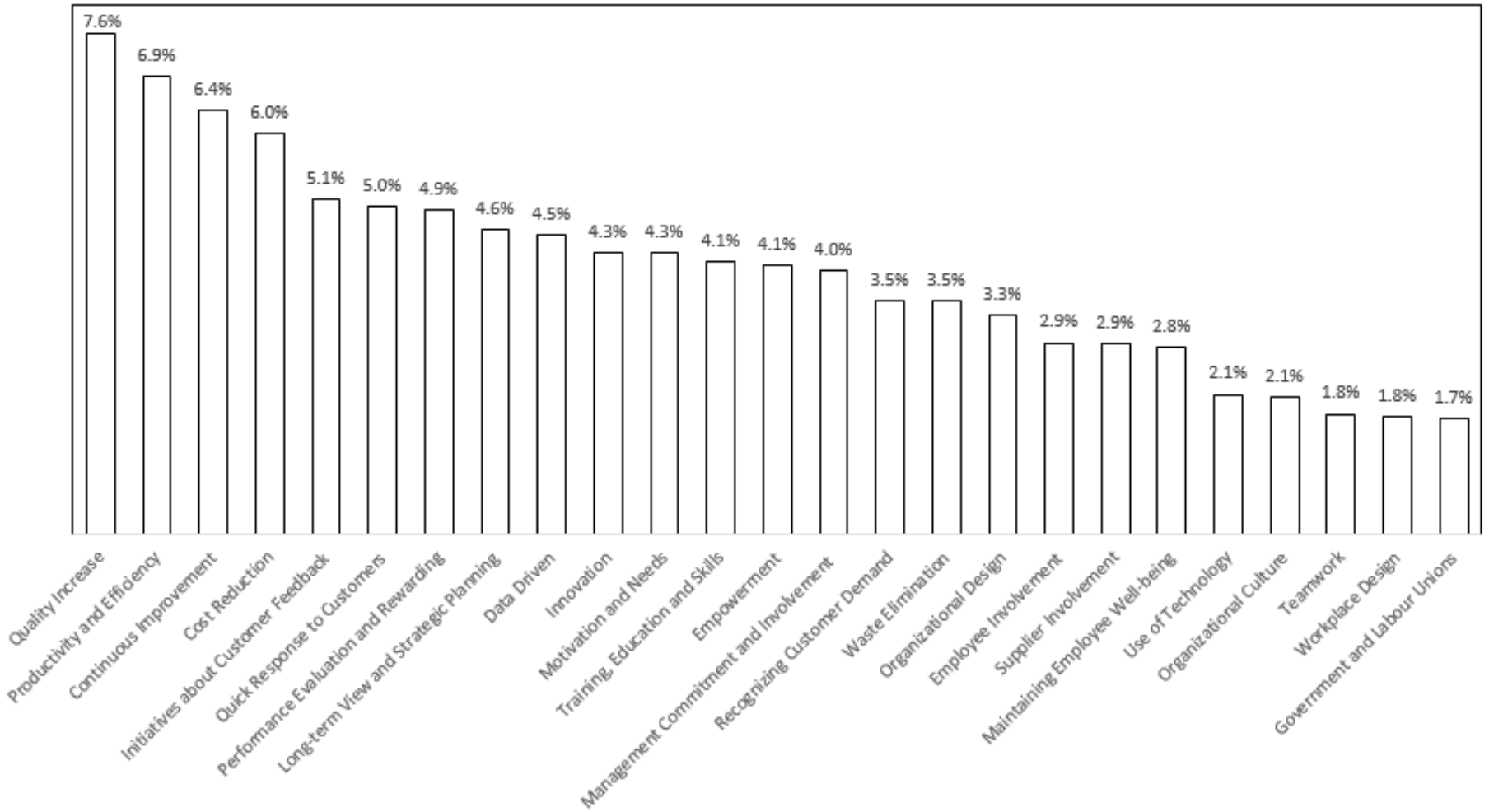

Figure 8.32. Factor Prioritization Results for FAHP Solution

8.3. Model Suggestion

Based on the factor prioritization results, a conceptual model is suggested. As a result of the FAHP method, 25 factors were ranked in the order of importance. The average weight of all factors was 4 percent; 13 factors were identified above the average and 12 factors were equals to average or below the average.

Factors with a significance 5.1 percent and above were classified as first-degree important factors group. This group mainly consists of factors related to the business process category. The most important for the company is quality increase. Productivity and efficiency, cost Reduction, continuous improvement and initiatives about customer feedback are the factors to be addressed in the first degree important group.

Factors with a significance value more than 4.0 percent and less than 5.0 percent were grouped as second-degree important factors. Quick response to customers is significant for organizational success which has the highest ranked among second-degree important factors. This group mainly focuses on internal business management and employees.

Two different groups were formed from the factors below the average priority weights. Third-degree important factors group consists of factors which ranked between 4.0 and 2.1 percent. There are 9 factors in this group. Management commitment and involvement, recognizing customer demand, waste elimination, organizational design, employee involvement, supplier involvement, maintaining employee wellbeing, use of technology and organizational culture.

The last group is the fourth-degree important factors group. This group factors cannot be announced as factors that need to take attention at first however it is wrong to label them as unimportant. The lowest rated factor was government and labor unions effect with 1.7 percent.

Factors were prioritized and all factors were significant, none of them discarded from the model. These factors are identified as input. While applying these factors in an organization, ergonomics and TQM point of view should be integrated as indicated in previous section (see 5.2). The output of the model is an achievement in company targets; higher profit, higher market share, company credibility and reputation increase, maintaining a sustainable business and attracting and maintaining potential high performer and highly motivated and skilled employees.

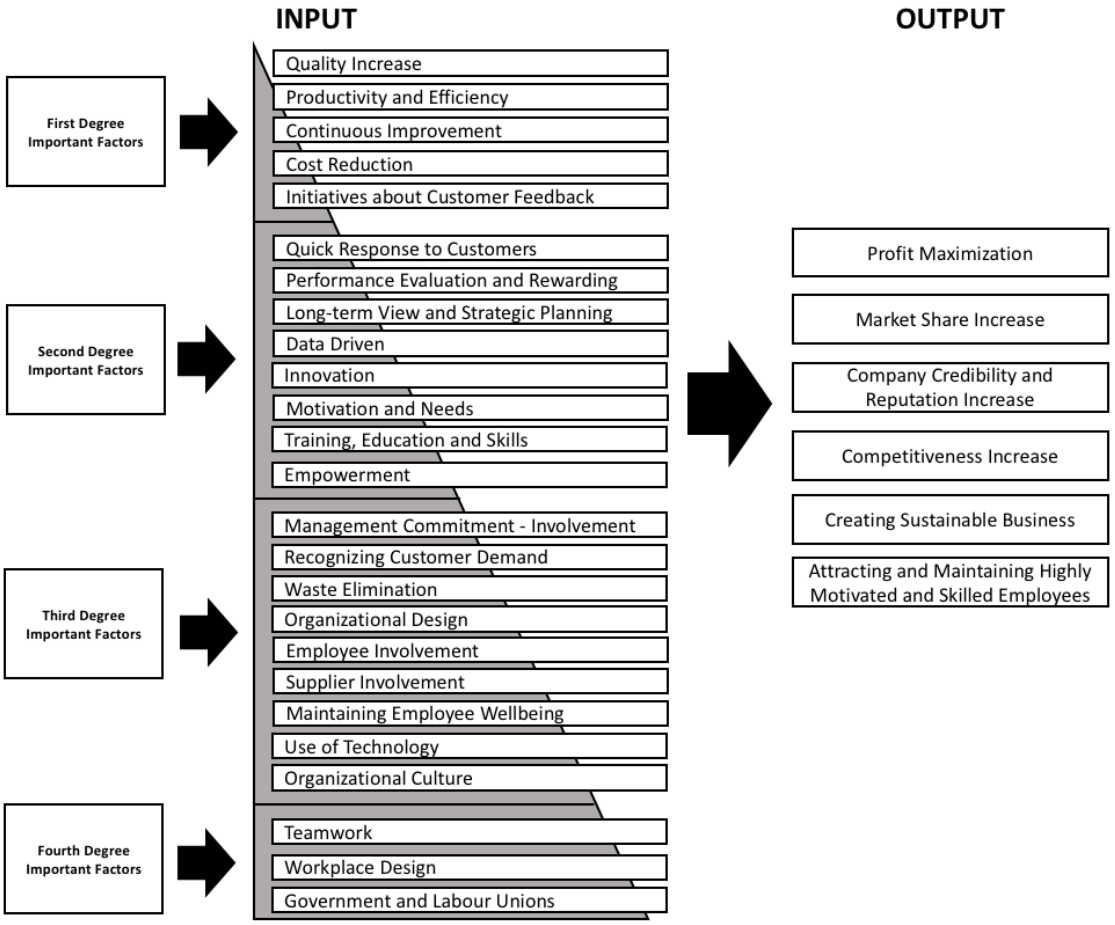

Figure 8.33. Conceptual Model Suggestion

9. DISCUSSION

Attempts at improving quality and having better working conditions for employees lead companies to the advancement of the management philosophies and auxiliary approaches such as TQM and ergonomics. Companies aim to improve their quality because of the ever-growing competition in the marketplace.

Firstly, we list the critical success factors of TQM and ergonomics then in order to prioritize these critical success factors we applied AHP and FAHP methods. All the strategical objectives, as well as all the factors, were assumed to be independent of each other. The first solution was obtained by the AHP method. The weights of the strategic objectives and the weights of the categories were calculated according to each strategic objective. Then the global and local factor weights were determined in AHP solution. Then, the second solution was obtained by the FAHP method. The weights of the strategic objectives and the weights of the categories according to each strategic objectives were calculated. Then the global and local weights of the factors were found in the FAHP solution. The conceptual model was developed through FAHP results since fuzzy numbers are more satisfying for the uncertainties in humanistic thinking.

Prioritization results are compared between classical AHP and FAHP methodologies, small differences are observed. In AHP solution strategic objectives importance are found in descending order as; SO6, SO1, SO5, SO3, SO2, SO4 while in FAHP solution it is found as; SO6, SO1, SO3, SO5, SO2, SO4. The order of categories according to significance in AHP solution is determined as; BP, CUS, MIL, EMP, TP, SPE while in FAHP solution it is found as; BP, MIL, CUS, EMP, SPE, TP. It is observed the ranked of the elements which has similar priority weights, can change to one upper or one lower level.

The suggested model based on FAHP solution can be used in the prioritization of ergonomics and TQM interventions in an industrial organization. Factors are indicated in the model as the input. If the proper implementation of these factors succeeded,

the output of the model will be an achievement in strategic goals. In that point, our model brings the benefit to organizations in order to be competitive, increase the quality of their products and to remain sustainable. Organizations could achieve to have optimum systems to find the highest profit, the product or marketing strategy that will bring the widest market share and company reputation, the ability to compete with the rivals and maintaining the sustainability of an organization. As well as having the highly motivated employees that produce the desired output.

When we compare our results with previous studies, it is observed that similar factors are prioritized. A doctoral study was conducted by Dzissah [**?**] at the University of Louisville examines ergonomics and TQM factors to satisfy stakeholder requirements by applying AHP to 5 expert. Following factors receive a high degree of importance in descending order as;

- Management commitment and involvement
- Customer relations and vendor selection
- Ergonomics safety and employee wellbeing

Our study results are differ from that study. Moreover we applied AHP to 30 experts. We determined top three factor as follows;

- Quality increase
- Productivity and efficiency
- Continuous improvement

Kiarazm and Koohkan [23] were aimed to prioritize TQM values on financial performance indices with AHP method from organizations managers' point of view. First three values were found in descending order as;

- Top management committed
- Focus on customers
- Continuous improvement

When we compare category prioritization for profit maximization in FAHP solution, determined values and categories are similar. However the rank is changed in our study as follows;

- Business process category which includes continuous improvement
- Customers category
- Managerial issues and leadership category

10. CONCLUSION

The fact that the success of time management, quality management and human management in the internal business within the restricted budget mostly depends on the interventions at the right time. Selection of the most important and strategically the most accurate factors for a company is critical. In order to decide critical factors, organizations should prioritize these factors according to their needs first. In this study, we aimed to prioritize common and the most significant factors for TQM and ergonomics approaches, in order to achieve organizational strategic goals. Based on the present study, the following can be concluded;

(i) The most important twenty-five factors for companies for building a business strategy in terms of ergonomics and TQM to accomplish simultaneous improvement within the organization are determined.
(ii) A strategic decision making guide for companies to achieve business goals in terms of simultaneous application of TQM and ergonomics is developed.
(iii) Creating sustainable business is found to be the most important strategic objective, followed by profit maximization and company credibility and reputation increase, respectively.
(iv) Business process category is found to be the most important category, followed by managerial issues and leadership and customers, respectively.
(v) Quality increase is found to be the most important factor, followed by productivity and efficiency and continuous improvement, respectively.

The developed strategic guide may aid to the company decision-makers to prioritize their strategic goals and invest their resources wisely.

For future studies we suggest the following. We assumed that all the elements in our hierarchical structure are independent and thus we used AHP approach. However, if the factors are assumed interdependent analytic network process (ANP) should be used instead of AHP. Another point is that, the present study has been focused on

production-oriented companies; the approach presented in this study can be applied service-oriented companies as well.

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APPENDIX A: QUESTIONNAIRE

KİŞİSEL KABUL FORMU

Bu tez çalışmasında, işletmelerin sürdürülebilir iş stratejilerine katkıda bulunabilecek makro ergonomik ve toplam kalite yönetimi faktörlerinin sizlerin bilgi birikimi ve tecrübelerinize dayanarak belirlenmesi amaçlanmaktadır.

Lütfen aşağıdaki hususlara dikkat ediniz.

1. Ankete başlamadan önce adınız, soyadınız, bünyesinde bulunduğunuz şirket, şirketin faaliyet gösterdiği sektör, şirketteki pozisyonunuz, bulunduğunuz şirkette toplam çalışma süreniz ve toplam mesleki deneyiminiz gibi sorular sorulacaktır.
2. Katılımınız tamamen gönüllü olup, katılmanız için herhangi bir zorunluluk bulunmamaktadır.
3. Elde edilecek kişisel bilgiler kimseyle paylaşılmayacaktır. Tez çalışmasında ise sadece verilerin ortalaması (kime ait olduğu belirtilmeksizin), maksimum ve minimum değerleri belirtilecektir.

Bu çalışmayla ilgili sorularınız ve katkılarınız olması durumunda Boğaziçi Üniversitesi Endüstri Mühendisliği Bölümü yüksek lisans öğrencisi İrem Sancar veya Prof. Dr. Mahmut Ekşioğlu ile temasa geçebilirsiniz.

Eğer katılmaya karar verdiyseniz aşağıdaki onay kutucuğu işaretleyerek, bu çalışmaya gönüllü olarak katılmak istediğinizi belirtmiş olacaksınız.

Çalışmaya katılmayı onaylıyorum: ☐

Tarih:

Figure A.1. Poll Form Page 1

ANKET SAHİBİ BİLGİLERİ

Lütfen aşağıdaki bilgileri doldurunuz.

1. **Ad Soyad:**
2. **Şirket Adı:**
3. **Yaş:**
4. **Cinsiyet:**
5. **Şirketin Faaliyet Gösterdiği Sektör:**
6. **Pozisyon:**
7. **Bulunduğunuz Şirkette Toplam Çalışma Süresi:**
8. **Toplam Mesleki Deneyim:**

SÜRDÜRÜLEBİLİR STRATEJİ OLUŞUMUNDA ETKİLİ OLAN MAKROERGONOMİK VE TOPLAM KALİTE YÖNETİMİ FAKTÖRLERİNİN ÖNEM SIRALARININ DEĞERLENDİRİLMESİ

Anketin;

1. İlk bölümünde, stratejik amaçların göreli önem ölçeğine dayanarak ikili karşılaştırılması istenmektedir.
2. İkinci bölümünde ise, faktörlerin bu stratejik amaçlara yaptıkları katkı açısından birbirleri ile göreli önem ölçeğine dayanarak ikili karşılaştırılması istenmektedir.
3. Üçüncü bölümünde, alt faktörlerin göreli önem ölçeğine dayanarak ikili karşılaştırılması ile önceliklendirilmesi istenmektedir.
4. Dördüncü bölümünde, açık uçlu soru sorularak katılımcıların öneri ve görüşleri istenmektedir.

Figure A.2. Poll Form Page 2

ŞİRKET STRATEJİK AMAÇLARI:

- Maksimum kârlılık,
- Şirket pazar payının artırılması,
- Şirket bilinirliğinin ve saygınlığının artırılması,
- Şirket rekabet gücünün artırılması,
- Performans potansiyeli yüksek iş gücünü şirkete çekebilme ve tutabilme,
- Sürdürülebilirlik.

GÖRELİ ÖNEM ÖLÇEĞİ:

Önem Derecesi	Tanımı	Açıklaması
1	Eşit önemde	Öğeler amaca eşit önemde katkı sağlıyor.
3	Biraz daha önemli	Tecrübe ve değerlendirmeler sonucunda bir seçenek diğerine göre biraz daha fazla tercih edilir.
5	Daha önemli	Tecrübe ve değerlendirmeler sonucunda bir seçenek diğerine göre daha fazla tercih edilir.
7	Çok daha önemli	Bir seçenek diğerine göre çok daha fazla tercih edilir.
9	Kesinlikle daha önemli	Bir seçenek diğerine göre şüpheye yer bırakmayacak kesinlikle tercih edilir.
2-4-6-8	Ara değerler	İki önem derecesi arasında bir tercih yapılamadığında, bu ara değerlerden uygun olan seçilir.

- İki ögenin amaca eşit önemde katkı sağladığı düşünülüyorsa **'eşit önemde'** olarak ifade edilir **1** değerine karşılık gelir.
- Bir seçenek diğerine göre biraz daha fazla tercih edilirse **'biraz daha önemli'** ile ifade edilir **3** değerine karşılık gelir.
- Bir seçenek diğerine göre daha fazla tercih edilirse **'daha önemli'** ile ifade edilir **5** değerine karşılık gelir.
- Bir seçenek diğerine göre çok daha fazla tercih edilirse **'çok daha önemli'** ile ifade edilir **7** değerine karşılık gelir.
- En yüksek önem derecesi **'kesinlikle daha önemli'** ile ifade edilir **9** değerine karşılık gelir;
- İki önem derecesi arasında bir tercih yapılamadığında, ara değerlerden $(2, 4, 6, 8)$ uygun olan seçilir.

Figure A.3. Poll Form Page 3

Anket soruları tablosunda sağ ve sol tarafta olmak üzere karşılaştırılacak öğeler belirtilmiştir. Aşağıda anketin nasıl cevaplandırılması gerektiği anlatılmaktadır:

- **Sol taraftaki öğenin sağ taraftaki öğeden daha önemli olduğu düşünüldüğünde, tablodan o öğeye yakın olan değerlerden yani sol taraftaki değerler arasından işaretleme yapmanız gerekmektedir.**
- **Sağ taraftaki öğenin sol tarafta belirtilen öğeden daha önemli olduğu düşünüldüğünde ise sağ taraftaki değerler arasından işaretleme yapmanız gerekmektedir.**

ÖRNEK DEĞERLENDİRME TABLOSU:

Aşağıda verilen örnek değerlendirme tablosunda, **Şirket stratejik amaçları**ndan bir olan **"Maksimum kârlılık"** diğer beş stratejik amaçlardan her biriyle ikili olarak önem açısından kıyaslanmıştır.

	SOL ←									→ SAĞ								
	Kesinlikle daha önemli		Çok daha önemli		Daha önemli		Biraz daha önemli		Eşit önemde	Biraz daha önemli		Daha önemli		Çok daha önemli		Kesinlikle daha önemli	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Maksimum kârlılık					X													Şirket pazar payının arttırılması
																	X	Şirket bilinirliğinin ve saygınlığının artırılması
									X									Şirket rekabet gücünün artırılması
							X											Performans potansiyeli yüksek iş gücünü şirkete çekebilme ve tutabilme
															X			Sürdürülebilirlik

Figure A.4. Poll Form Page 4

Bu tabloda;

1. İlk satırda, **maksimum kârlılığın** mı yoksa **şirket pazar payının arttırılmasının** mı daha önemli olduğunun derecelendirilerek belirtilmesi istenmektedir.
   - Eğer maksimum kârlılığın pazar payı artışından daha önemli olduğu düşünülüyorsa; tablonun sol tarafında, yani maksimum kârlılığa yakın olan tarafta, **daha önemli** (rakamsal değer ile 5) kutucuğunun yukarıdaki gibi işaretlenmesi gerekmektedir.
2. İkinci satırda, **maksimum kârlılığın** mı yoksa **şirket bilinirliğinin ve saygınlığının artırılmasının** mı daha önemli olduğunun derecelendirilerek belirtilmesi istenmektedir.
   - Eğer şirket bilinirliğinin ve saygınlığının artırılmasının maksimum kârlılıktan kesinlikle daha önemli olduğu düşünülüyorsa; bu durumda tablonun sağ tarafında, şirket bilinirliğinin ve saygınlığının arttırılmasına yakın olan tarafta, **kesinlikle daha önemli** kutucuğunun (rakamsal değer ile 9) işaretlenmesi gerekmektedir.
3. Üçüncü satırda, **maksimum kârlılığın** mı yoksa **şirket rekabet gücünün artırılmasının** mı daha önemli olduğunun derecelendirilerek belirtilmesi istenmektedir.
   - Eğer maksimum kârlılığın ve şirket rekabet gücünün artırılmasının eşit derecede önemli olduğu düşünülüyorsa; her iki seçeneğe de aynı uzaklıkta bulunan **eşit önemde** kutucuğu (rakamsal değer ile 1) işaretlenmelidir.
4. Dördüncü satırda, **maksimum kârlılığın** mı yoksa **performans potansiyeli yüksek (motivasyonu, bilgi ve becerisi yüksek) iş gücünü şirkete çekebilme ve tutabilmenin** mi daha önemli olduğunun derecelendirilerek belirtilmesi istenmektedir.
   - Eğer maksimum kârlılığın performans potansiyeli yüksek iş gücünü şirkete çekebilme ve tutabilmeden biraz daha önemli olduğu düşünülüyorsa; maksimum kârlılığa yakın olan sol taraftaki **biraz daha önemli** (rakamsal değer ile 3) kutucuğunun yukarıdaki gibi işaretlenmesi gerekmektedir.
5. Beşinci satırda, **maksimum kârlılığın** mı yoksa **sürdürülebilirliğin** mi daha önemli olduğunun derecelendirilerek belirtilmesi istenmektedir.
   - Eğer sürdürülebilirliğin maksimum kârlılıktan çok daha önemli olduğu düşünülüyorsa; sürdürülebilirliğe yakın olan sağ bölümdeki **çok daha önemli** (rakamsal değer ile 7) kutucuğunun yukarıdaki gibi işaretlenmesi gerekmektedir.

Figure A.5. Poll Form Page 5

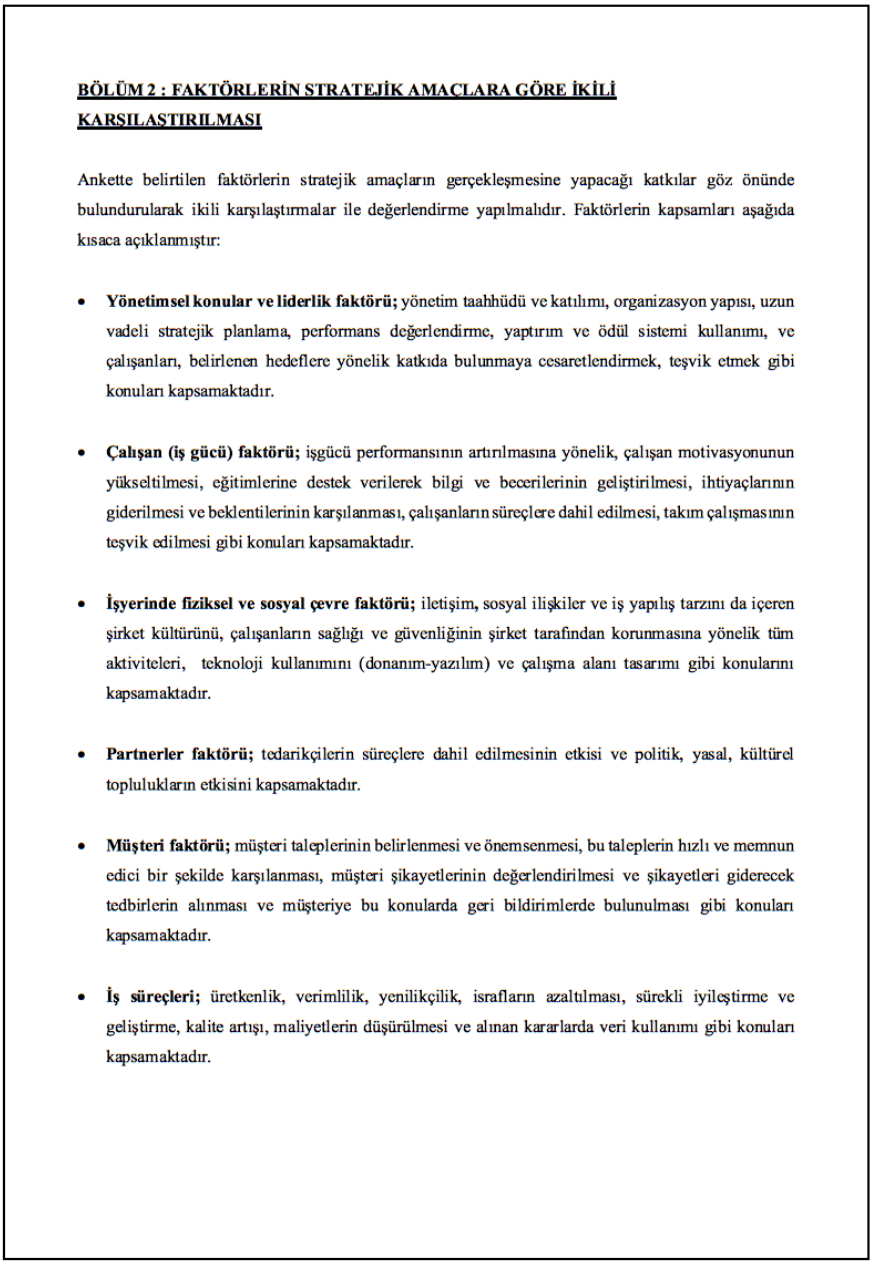
ANKET SORULARI

BÖLÜM 1 : STRATEJİK AMAÇLARIN İKİLİ KARŞILAŞTIRILMASI

Deneyimlerinizi göz önünde bulundurarak, size sunulan seçenekler arasından hangisinin daha önemli olduğunu düşünüyorsanız, tablodan o ögeye yakın olan önem değerini işaretlemeniz istenmektedir.

	Kesinlikle daha önemli		Çok daha önemli		Daha önemli		Biraz daha önemli		Eşit önemde		Biraz daha önemli		Daha önemli		Çok daha önemli		Kesinlikle daha önemli	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Maksimum kârlılık																		Şirket pazar payının artırılması
																		Şirket bilinirliğinin ve saygınlığının artırılması
																		Şirket rekabet gücünün artırılması
																		Performans potansiyeli yüksek işgücünü şirkete çekebilme ve tutabilme
																		Sürdürülebilirlik
Şirket pazar payının arttırılması																		Şirket bilinirliğinin ve saygınlığının artırılması
																		Şirket rekabet gücünün artırılması
																		Performans potansiyeli yüksek işgücünü şirkete çekebilme ve tutabilme
																		Sürdürülebilirlik
Şirket bilinirliğinin ve saygınlığının artırılması																		Şirket rekabet gücünün artırılması
																		Performans potansiyeli yüksek işgücünü şirkete çekebilme ve tutabilme
																		Sürdürülebilirlik
Şirket rekabet gücünün artırılması																		Performans potansiyeli yüksek işgücünü şirkete çekebilme ve tutabilme
																		Sürdürülebilirlik
Performans potansiyeli yüksek işgücünü şirkete çekebilme ve tutabilme																		Sürdürülebilirlik

Figure A.6. Poll Form Page 6



BÖLÜM 2 : FAKTÖRLERİN STRATEJİK AMAÇLARA GÖRE İKİLİ KARŞILAŞTIRILMASI

Ankette belirtilen faktörlerin stratejik amaçların gerçekleşmesine yapacağı katkılar göz önünde bulundurularak ikili karşılaştırmalar ile değerlendirme yapılmalıdır. Faktörlerin kapsamları aşağıda kısaca açıklanmıştır:

- **Yönetimsel konular ve liderlik faktörü;** yönetim taahhüdü ve katılımı, organizasyon yapısı, uzun vadeli stratejik planlama, performans değerlendirme, yaptırım ve ödül sistemi kullanımı, ve çalışanları, belirlenen hedeflere yönelik katkıda bulunmaya cesaretlendirmek, teşvik etmek gibi konuları kapsamaktadır.

- **Çalışan (iş gücü) faktörü;** işgücü performansının artırılmasına yönelik, çalışan motivasyonunun yükseltilmesi, eğitimlerine destek verilerek bilgi ve becerilerinin geliştirilmesi, ihtiyaçlarının giderilmesi ve beklentilerinin karşılanması, çalışanların süreçlere dahil edilmesi, takım çalışmasının teşvik edilmesi gibi konuları kapsamaktadır.

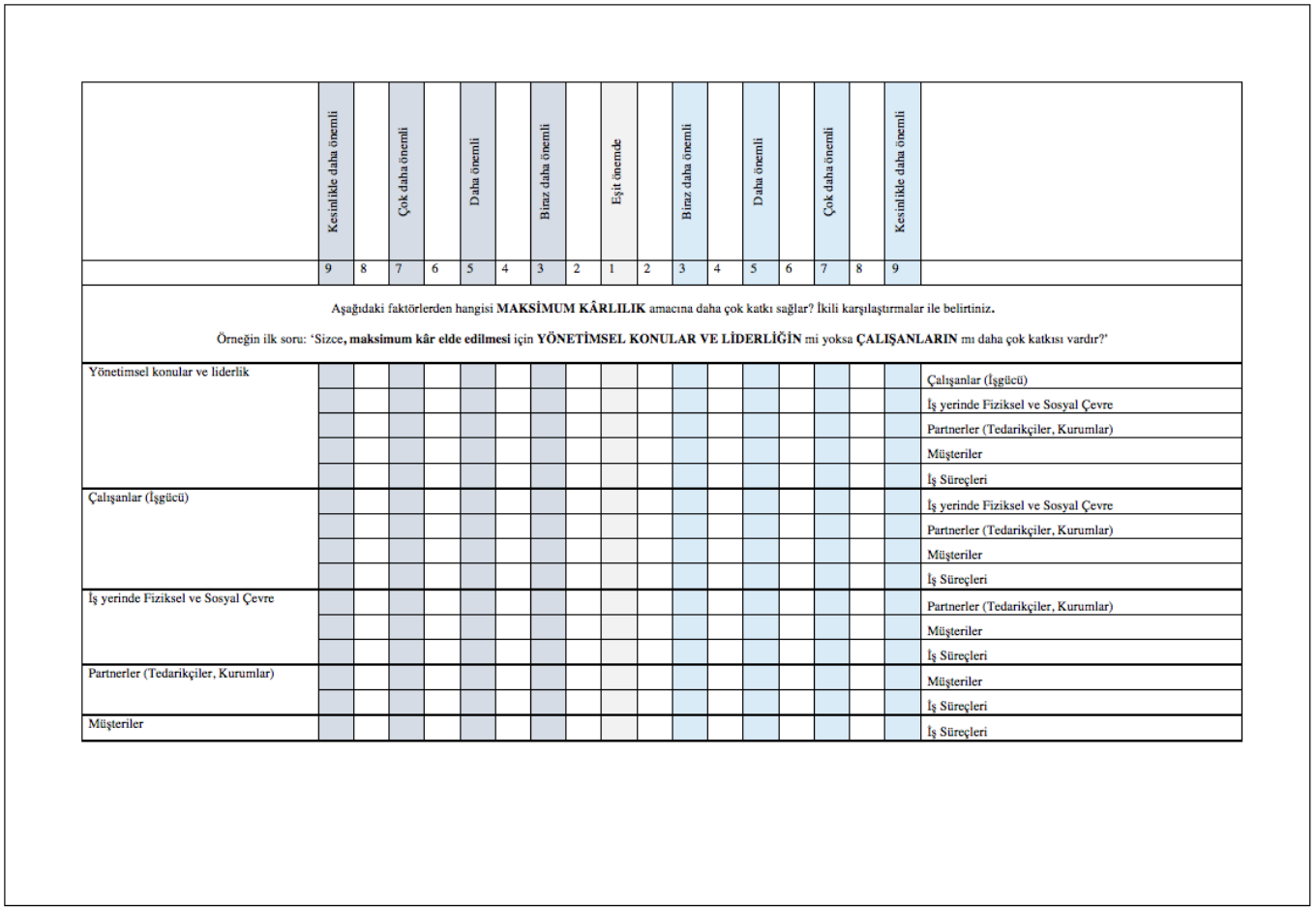
- **İşyerinde fiziksel ve sosyal çevre faktörü;** iletişim, sosyal ilişkiler ve iş yapılış tarzını da içeren şirket kültürünü, çalışanların sağlığı ve güvenliğinin şirket tarafından korunmasına yönelik tüm aktiviteleri, teknoloji kullanımını (donanım-yazılım) ve çalışma alanı tasarımı gibi konularını kapsamaktadır.

- **Partnerler faktörü;** tedarikçilerin süreçlere dahil edilmesinin etkisi ve politik, yasal, kültürel toplulukların etkisini kapsamaktadır.

- **Müşteri faktörü;** müşteri taleplerinin belirlenmesi ve önemsenmesi, bu taleplerin hızlı ve memnun edici bir şekilde karşılanması, müşteri şikayetlerinin değerlendirilmesi ve şikayetleri giderecek tedbirlerin alınması ve müşteriye bu konularda geri bildirimlerde bulunulması gibi konuları kapsamaktadır.

- **İş süreçleri;** üretkenlik, verimlilik, yenilikçilik, israfların azaltılması, sürekli iyileştirme ve geliştirme, kalite artışı, maliyetlerin düşürülmesi ve alınan kararlarda veri kullanımı gibi konuları kapsamaktadır.

Figure A.7. Poll Form Page 7



	Kesinlikle daha önemli		Çok daha önemli		Daha önemli		Biraz daha önemli		Eşit önemde		Biraz daha önemli		Daha önemli		Çok daha önemli		Kesinlikle daha önemli	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Aşağıdaki faktörlerden hangisi **MAKSİMUM KÂRLILIK** amacına daha çok katkı sağlar? İkili karşılaştırmalar ile belirtiniz. Örneğin ilk soru: 'Sizce, **maksimum kâr elde edilmesi** için **YÖNETİMSEL KONULAR VE LİDERLİĞİN** mi yoksa **ÇALIŞANLARIN** mı daha çok katkısı vardır?'																		
Yönetimsel konular ve liderlik																		Çalışanlar (İşgücü)
																		İş yerinde Fiziksel ve Sosyal Çevre
																		Partnerler (Tedarikçiler, Kurumlar)
																		Müşteriler
																		İş Süreçleri
Çalışanlar (İşgücü)																		İş yerinde Fiziksel ve Sosyal Çevre
																		Partnerler (Tedarikçiler, Kurumlar)
																		Müşteriler
																		İş Süreçleri
İş yerinde Fiziksel ve Sosyal Çevre																		Partnerler (Tedarikçiler, Kurumlar)
																		Müşteriler
																		İş Süreçleri
Partnerler (Tedarikçiler, Kurumlar)																		Müşteriler
																		İş Süreçleri
Müşteriler																		İş Süreçleri

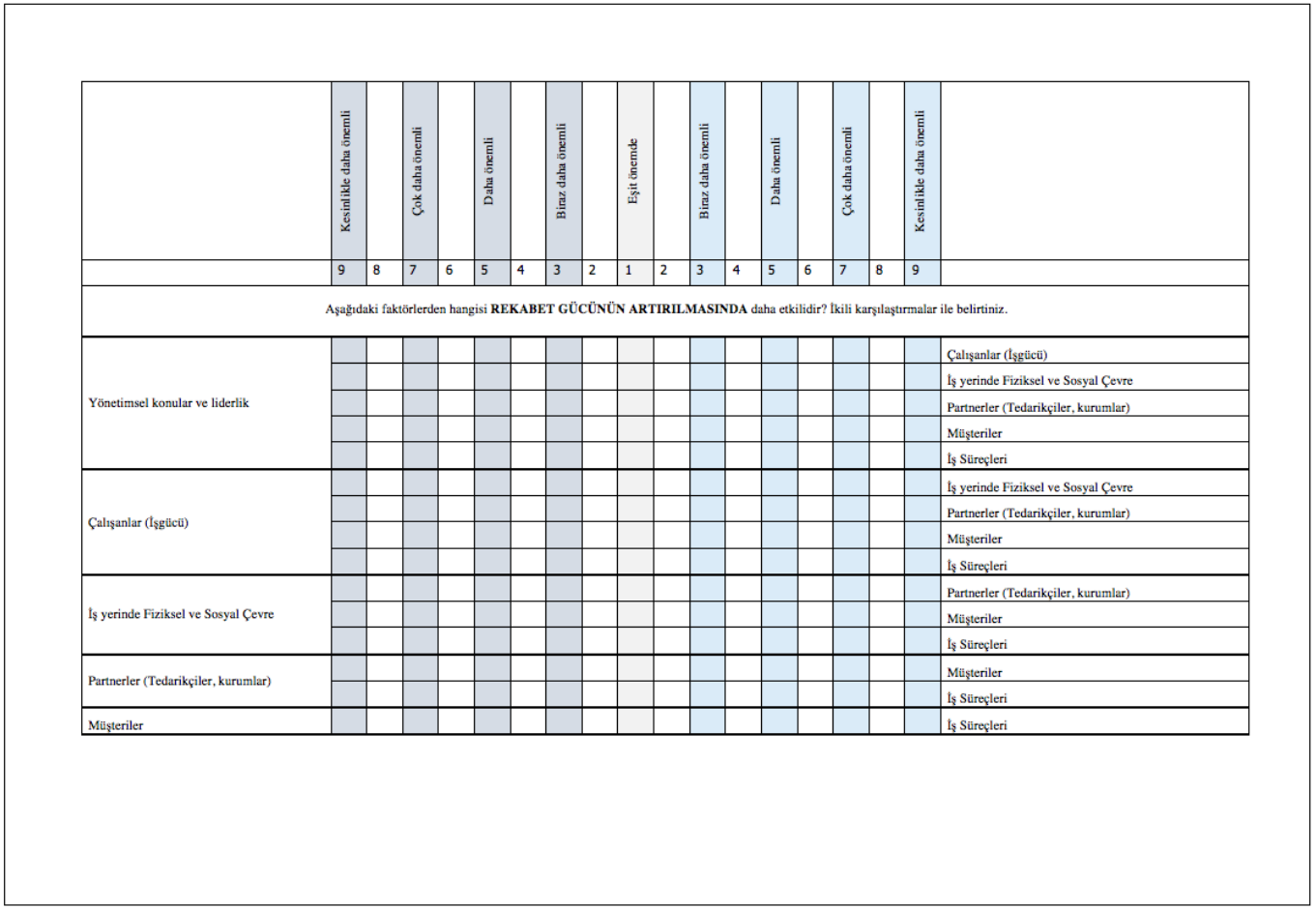
Figure A.8. Poll Form Page 8

	Kesinlikle daha önemli		Çok daha önemli		Daha önemli		Biraz daha önemli		Eşit önemde		Biraz daha önemli		Daha önemli		Çok daha önemli		Kesinlikle daha önemli	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Aşağıdaki faktörlerden hangisi **ŞİRKET PAZAR PAYININ ARTIRILMASINDA** daha etkilidir? İkili karşılaştırmalar ile belirtiniz. Örneğin ilk soru: 'Sizce, **şirket pazar payının artırılmasında YÖNETİMSEL KONULAR VE LİDERLİĞİN** mi yoksa **ÇALIŞANLARIN** mı daha çok katkısı vardır?'																		
Yönetimsel konular ve liderlik																		Çalışanlar (İşgücü)
																		İş yerinde Fiziksel ve Sosyal Çevre
																		Partnerler (Tedarikçiler, kurumlar)
																		Müşteriler
																		İş Süreçleri
Çalışanlar (İşgücü)																		İş yerinde Fiziksel ve Sosyal Çevre
																		Partnerler (Tedarikçiler, kurumlar)
																		Müşteriler
																		İş Süreçleri
İş yerinde Fiziksel ve Sosyal Çevre																		Partnerler (Tedarikçiler, kurumlar)
																		Müşteriler
																		İş Süreçleri
Partnerler (Tedarikçiler, kurumlar)																		Müşteriler
																		İş Süreçleri
Müşteriler																		İş Süreçleri

Figure A.9. Poll Form Page 9

	Kesinlikle daha önemli		Çok daha önemli		Daha önemli		Biraz daha önemli		Eşit önemde		Biraz daha önemli		Daha önemli		Çok daha önemli		Kesinlikle daha önemli	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Aşağıdaki faktörlerden hangisi **ŞİRKET BİLİNİRLİĞİ VE SAYGINLIĞININ ARTIRILMASINDA** daha etkilidir? İkili karşılaştırmalar ile belirtiniz.																		
Yönetimsel konular ve liderlik																		Çalışanlar (İşgücü)
																		İş yerinde Fiziksel ve Sosyal Çevre
																		Partnerler (Tedarikçiler, kurumlar)
																		Müşteriler
																		İş Süreçleri
Çalışanlar (İşgücü)																		İş yerinde Fiziksel ve Sosyal Çevre
																		Partnerler (Tedarikçiler, kurumlar)
																		Müşteriler
																		İş Süreçleri
İş yerinde Fiziksel ve Sosyal Çevre																		Partnerler (Tedarikçiler, kurumlar)
																		Müşteriler
																		İş Süreçleri
Partnerler (Tedarikçiler, kurumlar)																		Müşteriler
																		İş Süreçleri
Müşteriler																		İş Süreçleri

Figure A.10. Poll Form Page 10

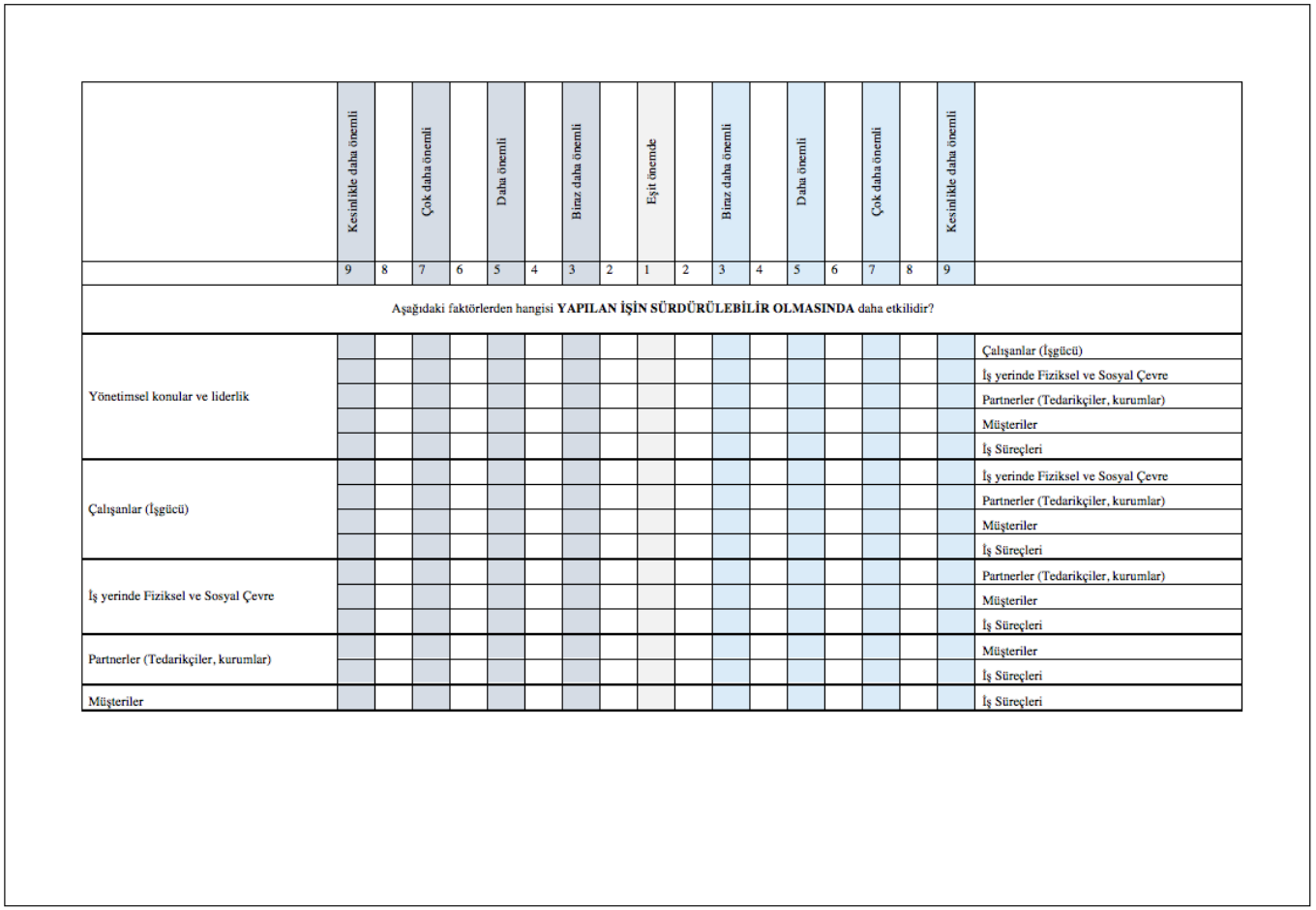


	Kesinlikle daha önemli		Çok daha önemli		Daha önemli		Biraz daha önemli		Eşit önemde		Biraz daha önemli		Daha önemli		Çok daha önemli		Kesinlikle daha önemli	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Aşağıdaki faktörlerden hangisi **REKABET GÜCÜNÜN ARTIRILMASINDA** daha etkilidir? İkili karşılaştırmalar ile belirtiniz.																		
Yönetimsel konular ve liderlik																		Çalışanlar (İşgücü)
																		İş yerinde Fiziksel ve Sosyal Çevre
																		Partnerler (Tedarikçiler, kurumlar)
																		Müşteriler
																		İş Süreçleri
Çalışanlar (İşgücü)																		İş yerinde Fiziksel ve Sosyal Çevre
																		Partnerler (Tedarikçiler, kurumlar)
																		Müşteriler
																		İş Süreçleri
İş yerinde Fiziksel ve Sosyal Çevre																		Partnerler (Tedarikçiler, kurumlar)
																		Müşteriler
																		İş Süreçleri
Partnerler (Tedarikçiler, kurumlar)																		Müşteriler
																		İş Süreçleri
Müşteriler																		İş Süreçleri

Figure A.11. Poll Form Page 11

	Kesinlikle daha önemli		Çok daha önemli		Daha önemli		Biraz daha önemli		Eşit önemde		Biraz daha önemli		Daha önemli		Çok daha önemli		Kesinlikle daha önemli	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Aşağıdaki faktörlerden hangisi **PERFORMANS POTANSİYELİ YÜKSEK İŞ GÜCÜNÜ ŞİRKETE ÇEKEBİLMEK VE TUTABİLMEK** açısından daha etkilidir?																		
Yönetimsel konular ve liderlik																		Çalışanlar (İşgücü)
																		İş yerinde Fiziksel ve Sosyal Çevre
																		Partnerler (Tedarikçiler, kurumlar)
																		Müşteriler
																		İş Süreçleri
Çalışanlar (İşgücü)																		İş yerinde Fiziksel ve Sosyal Çevre
																		Partnerler (Tedarikçiler, kurumlar)
																		Müşteriler
																		İş Süreçleri
İş yerinde Fiziksel ve Sosyal Çevre																		Partnerler (Tedarikçiler, kurumlar)
																		Müşteriler
																		İş Süreçleri
Partnerler (Tedarikçiler, kurumlar)																		Müşteriler
																		İş Süreçleri
Müşteriler																		İş Süreçleri

Figure A.12. Poll Form Page 12



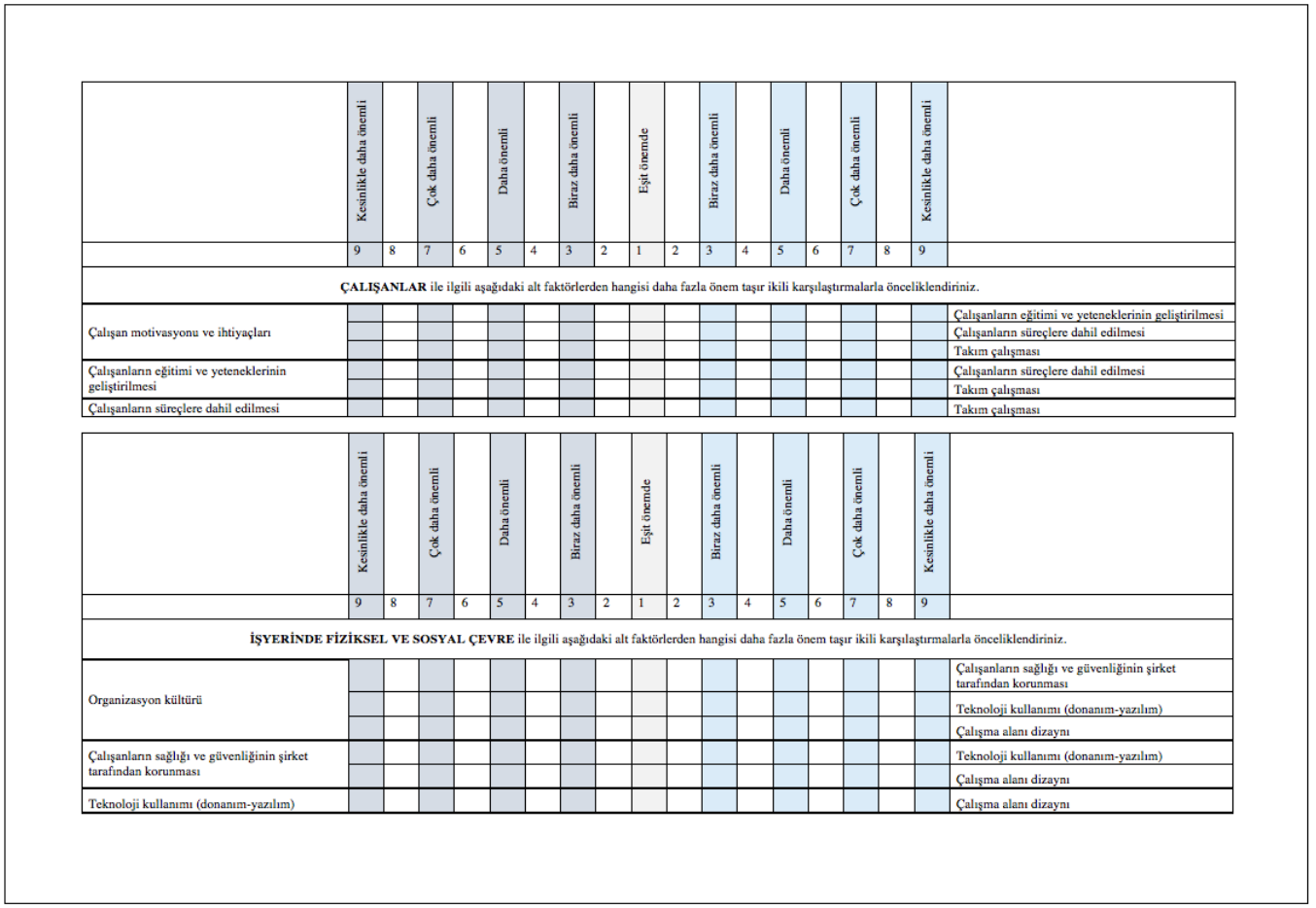
	Kesinlikle daha önemli		Çok daha önemli		Daha önemli		Biraz daha önemli		Eşit önemde		Biraz daha önemli		Daha önemli		Çok daha önemli		Kesinlikle daha önemli	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Aşağıdaki faktörlerden hangisi **YAPILAN İŞİN SÜRDÜRÜLEBİLİR OLMASINDA** daha etkilidir?																		
Yönetimsel konular ve liderlik																		Çalışanlar (İşgücü)
																		İş yerinde Fiziksel ve Sosyal Çevre
																		Partnerler (Tedarikçiler, kurumlar)
																		Müşteriler
																		İş Süreçleri
Çalışanlar (İşgücü)																		İş yerinde Fiziksel ve Sosyal Çevre
																		Partnerler (Tedarikçiler, kurumlar)
																		Müşteriler
																		İş Süreçleri
İş yerinde Fiziksel ve Sosyal Çevre																		Partnerler (Tedarikçiler, kurumlar)
																		Müşteriler
																		İş Süreçleri
Partnerler (Tedarikçiler, kurumlar)																		Müşteriler
																		İş Süreçleri
Müşteriler																		İş Süreçleri

Figure A.13. Poll Form Page 13

BÖLÜM 3 : ALT FAKTÖRLERİN ÖNCELİKLENDİRİLMESİ

	Kesinlikle daha önemli		Çok daha önemli		Daha önemli		Biraz daha önemli		Eşit önemde		Biraz daha önemli		Daha önemli		Çok daha önemli		Kesinlikle daha önemli	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
YÖNETİMSEL KONULAR VE LİDERLİK ile ilgili aşağıdaki alt faktörlerden hangisi daha fazla önem taşır ikili karşılaştırmalarla önceliklendiriniz.																		
Yönetim taahhüdü ve katılım																		Organizasyon Yapısı
																		Uzun vadeli stratejik planlama
																		Performans değerlendirme ve ödül sistemi
																		Çalışanları, belirlenen hedeflere yönelik katkıda bulunmaya cesaretlendirmek, teşvik etmek.
Organizasyon Yapısı																		Uzun vadeli stratejik planlama
																		Performans değerlendirme ve ödül sistemi
																		Çalışanları, belirlenen hedeflere yönelik katkıda bulunmaya cesaretlendirmek, teşvik etmek.
Uzun vadeli stratejik planlama																		Performans değerlendirme ve ödül sistemi
																		Çalışanları, belirlenen hedeflere yönelik katkıda bulunmaya cesaretlendirmek, teşvik etmek.
Performans değerlendirme ve ödül sistemi																		Çalışanları, belirlenen hedeflere yönelik katkıda bulunmaya cesaretlendirmek, teşvik etmek.

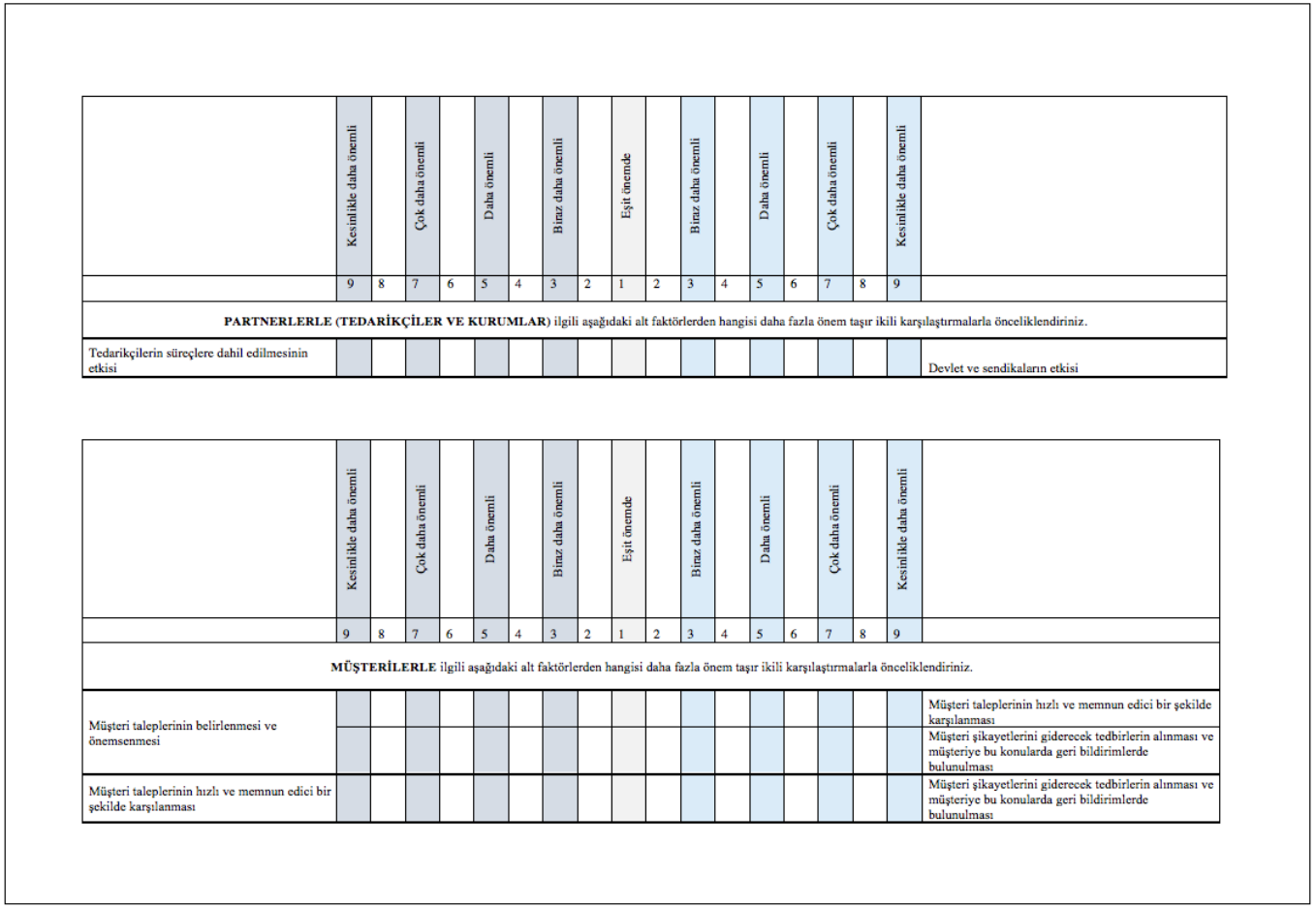
Figure A.14. Poll Form Page 14



	Kesinlikle daha önemli		Çok daha önemli		Daha önemli		Biraz daha önemli		Eşit önemde		Biraz daha önemli		Daha önemli		Çok daha önemli		Kesinlikle daha önemli	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
ÇALIŞANLAR ile ilgili aşağıdaki alt faktörlerden hangisi daha fazla önem taşır ikili karşılaştırmalarla önceliklendiriniz.																		
Çalışan motivasyonu ve ihtiyaçları																		Çalışanların eğitimi ve yeteneklerinin geliştirilmesi
																		Çalışanların süreçlere dahil edilmesi
																		Takım çalışması
Çalışanların eğitimi ve yeteneklerinin geliştirilmesi																		Çalışanların süreçlere dahil edilmesi
																		Takım çalışması
Çalışanların süreçlere dahil edilmesi																		Takım çalışması

	Kesinlikle daha önemli		Çok daha önemli		Daha önemli		Biraz daha önemli		Eşit önemde		Biraz daha önemli		Daha önemli		Çok daha önemli		Kesinlikle daha önemli	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
İŞYERİNDE FİZİKSEL VE SOSYAL ÇEVRE ile ilgili aşağıdaki alt faktörlerden hangisi daha fazla önem taşır ikili karşılaştırmalarla önceliklendiriniz.																		
Organizasyon kültürü																		Çalışanların sağlığı ve güvenliğinin şirket tarafından korunması
																		Teknoloji kullanımı (donanım-yazılım)
																		Çalışma alanı dizaynı
Çalışanların sağlığı ve güvenliğinin şirket tarafından korunması																		Teknoloji kullanımı (donanım-yazılım)
																		Çalışma alanı dizaynı
Teknoloji kullanımı (donanım-yazılım)																		Çalışma alanı dizaynı

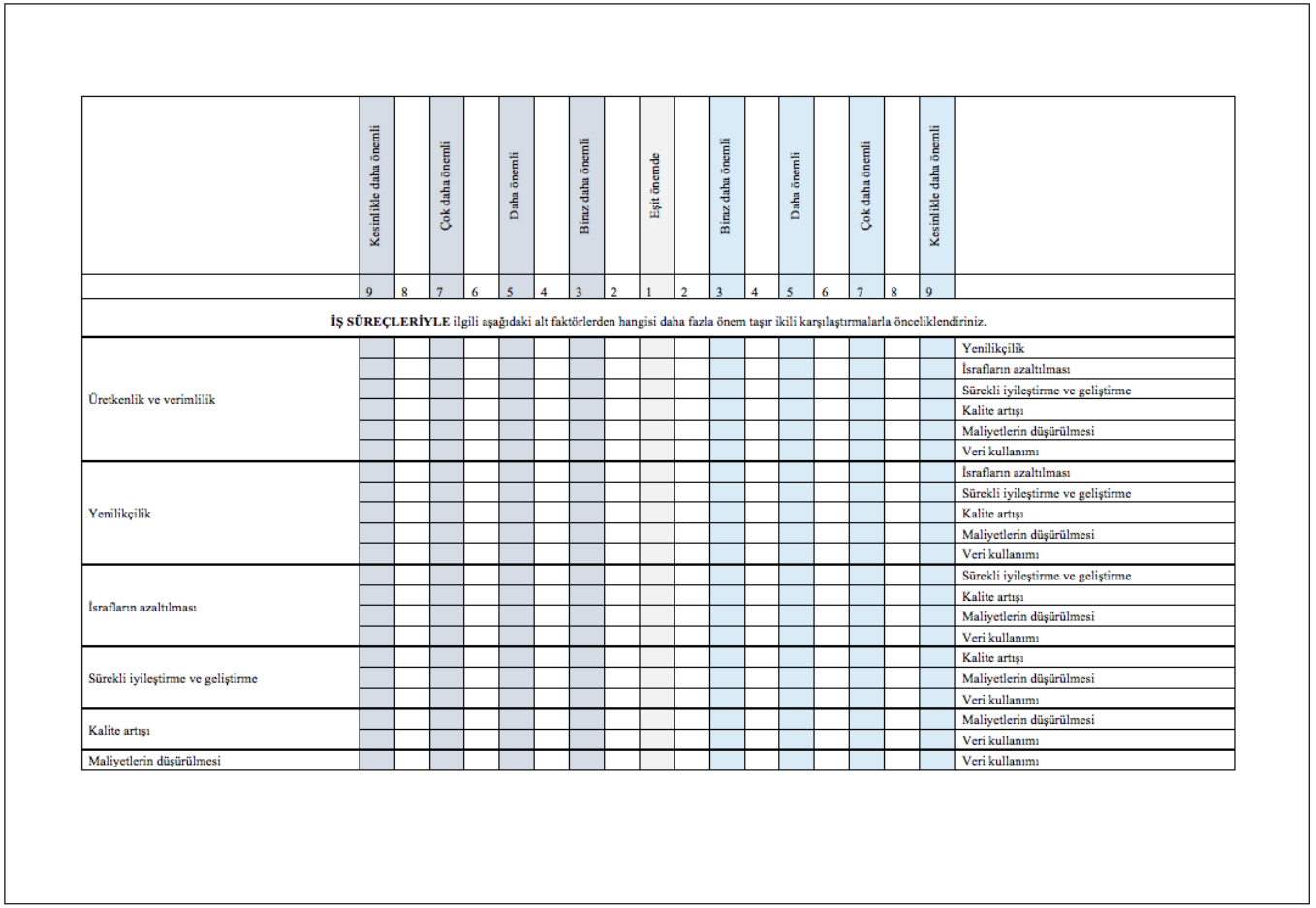
Figure A.15. Poll Form Page 15



	Kesinlikle daha önemli		Çok daha önemli		Daha önemli		Biraz daha önemli		Eşit önemde		Biraz daha önemli		Daha önemli		Çok daha önemli		Kesinlikle daha önemli	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
PARTNERLERLE (TEDARİKÇİLER VE KURUMLAR) ilgili aşağıdaki alt faktörlerden hangisi daha fazla önem taşır ikili karşılaştırmalarla önceliklendiriniz.																		
Tedarikçilerin süreçlere dahil edilmesinin etkisi																		Devlet ve sendikaların etkisi

	Kesinlikle daha önemli		Çok daha önemli		Daha önemli		Biraz daha önemli		Eşit önemde		Biraz daha önemli		Daha önemli		Çok daha önemli		Kesinlikle daha önemli	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
MÜŞTERİLERLE ilgili aşağıdaki alt faktörlerden hangisi daha fazla önem taşır ikili karşılaştırmalarla önceliklendiriniz.																		
Müşteri taleplerinin belirlenmesi ve önemsenmesi																		Müşteri taleplerinin hızlı ve memnun edici bir şekilde karşılanması
																		Müşteri şikayetlerini giderecek tedbirlerin alınması ve müşteriye bu konularda geri bildirimlerde bulunulması
Müşteri taleplerinin hızlı ve memnun edici bir şekilde karşılanması																		Müşteri şikayetlerini giderecek tedbirlerin alınması ve müşteriye bu konularda geri bildirimlerde bulunulması

Figure A.16. Poll Form Page 16



	Kesinlikle daha önemli		Çok daha önemli		Daha önemli		Biraz daha önemli		Eşit önemde		Biraz daha önemli		Daha önemli		Çok daha önemli		Kesinlikle daha önemli	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
İŞ SÜREÇLERİYLE ilgili aşağıdaki alt faktörlerden hangisi daha fazla önem taşır ikili karşılaştırmalarla önceliklendiriniz.																		
Üretkenlik ve verimlilik																		Yenilikçilik
																		İsrafların azaltılması
																		Sürekli iyileştirme ve geliştirme
																		Kalite artışı
																		Maliyetlerin düşürülmesi
																		Veri kullanımı
Yenilikçilik																		İsrafların azaltılması
																		Sürekli iyileştirme ve geliştirme
																		Kalite artışı
																		Maliyetlerin düşürülmesi
																		Veri kullanımı
İsrafların azaltılması																		Sürekli iyileştirme ve geliştirme
																		Kalite artışı
																		Maliyetlerin düşürülmesi
																		Veri kullanımı
Sürekli iyileştirme ve geliştirme																		Kalite artışı
																		Maliyetlerin düşürülmesi
																		Veri kullanımı
Kalite artışı																		Maliyetlerin düşürülmesi
																		Veri kullanımı
Maliyetlerin düşürülmesi																		Veri kullanımı

Figure A.17. Poll Form Page 17

BÖLÜM 4 : ANKETİN GELİŞTİRİLMESİ

Çalışmada belirtilen faktör veya alt faktörlerden farklı, şirket için önemli gördüğünüz ve ankette bulundurulmasının iyi olacağını düşündüğünüz önerileriniz var ise aşağıda yazılı olarak belirtmenizi rica ederiz.

Anketimiz bitmiştir. Cevaplandırdığınız için teşekkür ederiz.

Figure A.18. Poll Form Page 18