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DEVELOPMENT OF A DECISION SUPPORT SYSTEM FOR EMPLOYEE SCHEDULING PROBLEM IN HOSPITALITY SECTOR: A CASE STUDY IN A TURKISH FIRM

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DEVELOPMENT OF A DECISION SUPPORT SYSTEM FOR EMPLOYEE SCHEDULING PROBLEM IN HOSPITALITY SECTOR: A CASE STUDY IN A TURKISH FIRM

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Approval of the Graduate School of Social Sciences

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ABSTRACT

DEVELOPMENT OF A DECISION SUPPORT SYSTEM
FOR EMPLOYEE SCHEDULING PROBLEM
IN HOSPITALITY SECTOR: A CASE STUDY
IN A TURKISH FIRM

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Employee scheduling problems arise in many environments where a group of employees works together. This study deals with the employee scheduling problem in hospitality sector where the employees are supposed to greet and communicate with the guests in the events. The content of the problem is assigning different skilled employees to the events which have different complexity and difficulty levels. We propose a solution method which aims to create better employee schedules in terms of cost and quality of the service. Moreover, the proposed solution method takes workload balance among employees into consideration. Sensitivity analysis is conducted and it is observed that the results of the proposed method are robust against small changes in the input parameters. This study focuses of establishment of a decision support system for a Turkish firm in hospitality sector. Specifically, a

user-friendly Microsoft Excel-based decision support system is designed to help the decision maker in composing the employee schedules. The details of the decision support system into which the mixed integer programming models are integrated are provided.

Keywords: Employee scheduling, Decision support system, Mixed integer programming, Hospitality sector

ÖZ

KARŞILAMA SEKTÖRÜNDE ÇALIŞAN ÇİZELGELEME PROBLEMİ İÇİN KARAR DESTEK SİSTEMİ GELİŞTİRİLMESİ: BİR TÜRK İŞLETMESİ ÖRNEĞİ

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Çalışan çizelgeleme problemleri birden çok çalışanın bir arada çalıştığı birçok organizasyonda ortaya çıkmaktadır. Bu çalışma çalışanların çeşitli etkinliklerde konukları karşılayıp, konuklarla iletişim kurduğu karşılama sektöründeki çalışan çizelgeleme problemini ele almaktadır. Problemin içeriği farklı yetenekteki çalışanların düzenlenen farklı zorluk ve karmaşıklık seviyesindeki etkinliklere atanmasıdır. Çalışma kapsamında maliyet ve servis kalitesi açısından daha iyi çalışan çizelgeleri üreten bir çözüm yöntemi sunulmuştur. Sunulan çözüm yöntemi maliyet ve servis kalitesine ek olarak çalışanlar arasındaki dengeli iş yükü dağılımını da dikkate almaktadır. Geliştirilen çözüm yöntemine duyarlılık analizi uygulanmış ve metodun girdi parametrelerindeki küçük değişikliklere karşı dayanıklı olduğu gözlemlenmiştir. Bu çalışma karşılama sektöründeki bir firma için karar destek sistemi tasarlanmasına odaklanmıştır. Karar vericilere çalışan çizelgelemesi

oluşturmakta yardımcı olmak için kullanıcı dostu ve Microsoft Excel tabanlı bir karar destek sistemi tasarlanmıştır. Karma tamsayılı programlama modellerini içinde barındıran karar destek sisteminin detayları sunulmuştur.

Keywords: Çalışan çizelgeleme, Karar destek sistemi, Karma tamsayılı programlama, Karşılama sektörü

This thesis is dedicated to my parents and love.

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LIST OF ABBREVIATIONS

ER	Experience Rating
FLR	Foreign Language Rating
CR	Communication Rating
TWR	Teamwork Rating
EIR	Emotional Intelligence Rating
IR	Importance Rating
DSS	Decision Support System
DM	Decision Maker
MIP	Mixed Integer Programming

CHAPTER 1

INTRODUCTION

Employee scheduling is a common problem in several practical applications in which employees work together. Although there are many studies and research about employee scheduling, most of organizations do not use a systematic scheduling model. Instead, they tend to use tentative methods. Usually, the decision maker (DM) in companies only aim to create a schedule considering the constraints of the employees. They settle for a feasible schedule. Despite the difficulty and complexity of the employee scheduling problems, the DMs can get an optimal schedule by using an optimization model instead of a feasible schedule which they create by themselves. The main reasons of difficulty and complexity of the employee scheduling problems can be listed as the constraints of employees and the probability of disparity in employee skills and job requirements. A better employee schedule reduces staff costs which can help a company to obtain a competitive advantage in marketplace. In addition to costs, a better employee schedule increases employee satisfaction and even the quality of service if the company is a service sector company.

Hospitality industry is a service industry which contains a lot of social interaction between the employees and customers. There are so many sectors which fall into hospitality industry such as accommodation, restaurants and tourism. The main purpose of hospitality industry is meeting the needs of the customers by greeting, welcoming, taking care, serving and communicating. Customer satisfaction is the basis of hospitality industry. In our study, we deal with the congress organization sector which is included in hospitality industry. Congress organization companies, organizes the congresses or events of some associations, colleges, societies and governments. Typically, an organization company determines the place which the

events or congresses will take place. During the events or congresses, the employees of the organization company try to indulge the customers who are the participants of the events or congresses by greeting, welcoming, taking care and communicating. Although we focus on the congress and event organization companies in the sector, our study guides all the companies in hospitality industry because the main facets of all hospitality industry companies are almost the same.

Although the solution approaches to employee schedule problems in literature generally focus on reducing the scheduling cost, in our study, there are conflicting objectives which are minimization of employee cost and maximization of quality. The quality of employee schedule can be described as the match between employee skills and the complexity of jobs in different dimensions. There is a tradeoff between these objectives which the DM should overcome. Two mathematical models which contain two objective functions separately are constructed by mixed integer programming method in this study. One of the objective functions is cost; the other is the match between employee skills and complexity of jobs, which can be states as quality. Two optimal solutions are obtained as a result of these mathematical models. Moreover, except from optimal solutions, alternative solutions which take both objectives into consideration are presented. The solution method is implemented in a real life organization which is a hospitality sector company. The employee schedule of the company is obtained with the mathematical model which is constructed in this study. The obtained schedule is compared with the current employee schedule of the company.

Ernst et al. (2004) stated that, a decision support system (DSS) in employee scheduling can provide enormous profits to companies. To help DM, a user friendly DSS is designed for scheduling employees. The DSS finds the optimal schedules in these two dimensions separately and then shows the tradeoff between these dimensions. Over and above DM can determine the level of workload balance which can be stated as the third conflicting objective in our study. The DSS which is created in this study can be used for any organization dealing with scheduling.

The organization of the rest of this study is as follows: Chapter 2 reviews the previous studies about employee scheduling methods and service sector quality dimensions. In Chapter 3, the mathematical models which are created by mixed integer programming are presented. In Chapter 4, the experiments with the data of a real-life company are provided. Chapter 5 presents the results of the solution methods and compares these results with the current state of the company. In this chapter, the contributions of the mathematical models are demonstrated. In Chapter 6, the DSS is explained in detail. Lastly, Chapter 7 discusses the concluding remarks and future study.

CHAPTER 2

LITERATURE REVIEW

In this chapter the review of previous studies is presented. The review consists of three main parts which are employee scheduling methods, quality dimensions of hospitality sector and weighting methods.

2.1 Employee Scheduling Methods

Ernst et al. (2004) present a wide range of review of employee scheduling studies in literature. They base their review upon three dimensions. Firstly, they classify the employee scheduling problems according to problem types. They characterize the employee scheduling problems in six modules, which are demand modelling, days off scheduling, shift scheduling, line of work construction, task assignment and staff assignment. After proposing the modules, they provide characteristics of each module to guide other studies to locate the problem in literature. Secondly, they introduce the most common application areas of employee scheduling problems. They provide important studies in each application area they mention. Lastly, they review the employee scheduling techniques and methods in literature. The most common solution techniques are mathematical programming, metaheuristics and constraint programming according to their review. Moreover, they come up with some comments about suitability of each technique for specific problem types.

Knighton (2005) present a personnel tour scheduling problem solution with a mathematical programming approach to minimize the costs. The author develops a linear program which finds the optimal schedule for employees considering some specialized side constraints. The author aims to assign the different skilled and waged employees to tours by procuring the required number of employees for each tour.

After analyzing their problem with the help of Ernst et al. (2004), Stollerz and Zamorano (2014) propose a mixed integer programming (MIP) to optimize their tour scheduling problem for employees with multiple skills. They aim to minimize the assignment cost considering the demand and labor regulations. Stollerz and Zamorano (2014) state that the complexity of the problem due to skill diversity makes it impossible for MIP to give a solution in short times. Therefore the authors develop a heuristic method to solve their problem.

Although Fırat and Hurkens (2011) deal with a production sector problem in their MIP, their study inspires the solution approaches to employee scheduling problems. Fırat and Hurkens (2011) develop a MIP to find the optimal assignment of technicians to the tasks. The authors are given a set of tasks and a group of technicians which they try to match on the purpose of reducing the employee costs. The skill requirements of each task are different from each other. Moreover, all technicians have different skills. The researchers state that the MIP they developed for their scheduling model cannot give a solution in a reasonable time because it is a NP hard problem. Afterwards, they construct a meta-heuristic method.

Sadykov and Wolsey (2003) approach a scheduling problem, which is a multi-machine assignment problem, with integer programming method. Their objective is finding the optimal assignment of jobs to the machines, which provides the minimum assignment costs, considering the release date constraints. Sadykov and Wolsey (2003) have a set of jobs and they try to assign these jobs to the machines. The logic of machine assignment problems and employee scheduling problems are parallel.

There are some similarities between the model that we develop in our study and Knighton (2005). The most important similarity is that in both problems there are different skill-sets and wage rates within employees. Secondly, the required number of employees in each shift or event is certain in both problems. The MIP that is created by Stollerz and Zamorano (2014) and the integer programming model which is developed by Sadykov and Wolsey (2003) inspire the model which is proposed in this study since the constraints, objectives and logic are similar. Lastly, the

differences between skill requirements of tasks and between technicians' skills in Fırat and Hurkens (2011) remind the difference in skill requirements in events and difference in employees' skills in our study, as a result we originate from Fırat and Hurkens (2011) in our research. The similarities are discussed detailed in Chapter 3.

2.2 Quality Dimensions in Hospitality Sector

Hughes and Rog (2008) aim to clarify talent management's importance in hospitality organizations. Although talent management has many definitions, it can be perceived as a synonymous with workforce or employee planning. Workforce planning is a general issue which contains many factors to think about. One of them is the match of employee skills and job's skill requirements. This match is an indicator of an effective workforce planning in organizations. According to Hughes and Rog (2008) an effective workforce planning increases employee engagement which means employees feel themselves important for the organizations and give their best in each task. Employee engagement boosts firms' performance in the long term.

Tourism and hospitality sectors contain so many social interactions between customers and employees. Since the product is not tangible, the quality of the service can be defined as the image in customer's mind. Spielmann et al. (2012) highlight the importance of the social interactions in hospitality organizations in order to create a good image in customers' mind. They propose a scale to measure the factors which affects the company image in customer's mind. With the help of the scale, it can be seen that the social interactions play a critical role. In addition to Spielmann et al. (2012), Baum et al. (1997) highlight that human factor must be the main focus in hospitality organizations to satisfy customers' expectations due to the social interactions in workplace.

Bhattacharya et al. (2005) discuss the relationship between firms' performance and flexibility in human resources (HR). The researchers assert that employee skill, employee behavior and HR practice flexibility are positively related to the firm's financial performance. Employee behavior flexibility means the ability of adopting the behavior of the employees to different types of demands. With the aid of the

findings of Bhattacharya et al. (2005) which state that firms' financial performance increase by the employee behavior flexibility, the employee behavior adaptation to different types of jobs is tried to get obtained by matching the employees' personality attributes with the jobs' challenging features.

Emotional intelligence, one of the popular issues of psychology, has a huge impact on personal relationships and mental health. There has been a lot of study regarding the relationship between emotional intelligence and professional relationships. In one of these researches, Nikolaou and Tsaousis (2002) have found out that there is a strong bond between EI and occupational stress. The author claim that, employees with higher EI can manage their feelings and stress better. As a result of managing their feelings and stress better, their interactions in organization are more reliable. Moreover, according to Nikolaou and Tsaousis (2002) the performance of employees with high EI can increase when they are assigned to a stressful position in the organization. Besides Nikolaou and Tsaousis (2002), Kim et al. (2012), Zeidner et al. (2004), Tischler et al. (2002), Rosete and Ciarrochi (2005) and Bracket et al. (2011) also show that EI helps the employees to be successful in hospitality workplace.

Hospitality sector is a service-intensive sector which leads people factor to come forward. The skills, qualifications and quality of employees play a critical role in firm's performance in this sector. Hai-yan and Baum (2006) determine the critical personal skills in hospitality sector with a research in hotels in China. They conducted a survey and applied it in the hotels of the most touristic cities like Beijing, Tianjin, Shanghai, Jinan, Qingdao and Weihai. After collecting and analyzing the result of the survey, they have found out that communication skill, professional and ethical standards and team work skills are the most important employee skills in hospitality sector.

According to Kusluvan et al. (2010) human resources are one of the key assets of hospitality organizations. They execute a review of human resource management issues in hospitality sector to increase employee performance which plays a significant role in service quality and customer satisfaction. In their review, the

authors emphasize the personality and EI of employees. Employee personality and emotional intelligence affect the social interactions and behaviors in hospitality sector. Kusluvan et al. (2010) compile the previous studies about employee personality and claim that conscientiousness and agreeableness are the most common personality traits that increase employee performance. Both conscientiousness and agreeableness are skills that are positive contributors of a good communication in tourism and hospitality organizations. The authors deal with another critical issue in employee performance which is emotional intelligence. As a result of their wide range review, they find out that customer satisfaction increases as the emotional intelligence of employees rises.

Employee skills issues in hospitality workplaces are main the topic of Baum (2002). Baum (2002) work on the key employee skills after highlighting the importance of hospitality sector in market although there is a prejudice that hospitality workplaces are low skill economies compared to the other fields. The author summarizes the key employee skills in hospitality sector as communication; experience, information technology and teamwork. After discussing the key skills, the researcher presents some ways to develop these skills in organizations.

As Saleh and Ryan (1991) state that, the service is perceived as qualified if the service meets the customers' expectations. To understand the customers' expectations in hospitality workplace, a wide range literature research is done. After the research, some critical dimensions are found to close the gap between customers' expectations and actual service. The dimensions and their references are shown in Table 1.

Table 1. *Quality dimensions and references*

Quality Dimension	References
Communication (conscientiousness, agreeableness, etc)	Saleh and Ryan (1991), Hai-yan and Baum (2006), Baum (2002), Kusluvan et al. (2010), Leonard et al. (2004)

Table 1. (cont'd)

Teamwork	Hai-yan and Baum (2006), Baum (2002), Leonard et al. (2004), Manzoor et al. (2011), Abdullah et al. (2012)
Emotional Intelligence	Kusluvan et al. (2010), Nikolaou and Tsaousis (2002), Kim et al. (2012), Zeidner et al. (2004), Tischler et al. (2002), Rosete and Ciarrochi (2005), Bracket et al. (2011)

2.3. Weighting Methods

The employees are assigned to different events with different importance in our study. To get a better schedule in terms of quality, it is necessary to determine the weights of events with regards to the importance. With the help of weighting the events, mathematical model allows qualified employees to get assigned to more important events. This is critical in customer satisfaction.

Wang and Luo (2010) propose some approaches in determining the weights in multiple attribute decision making fields. Basically, the researchers separate the weighting approaches into three main categories, which are subjective weighting, objective weighting and integrated approach. Direct rating method and point allocation methods are some of the most common subjective weighting methods. Bottomley et al. (2000) make a clear definition for direct rating and point allocation method. Direct rating method is rating each alternative on a scale of 0 to 100. On the other hand, point allocation method is spreading a total of 100 points to the alternatives. Although Keeney, Kelly and von Winterfeldt (2006) use point allocation method in their research which is about evaluating the academic programs in United States, Bottomley et al. (2000) present that direct rating method is more accurate than point allocation method. The reason is that, people cannot give points objectively to the alternatives when they think how many points they have left to spread.

Roszkowska (2013) reviews several weighting methods which convert the rankings between alternatives into numerical weights. The types of weighting methods that the author presents can be listed as equal weight method, rank sum weighting method, rank exponent weighting method, inverse or reciprocal weights and rank-order centroid weighting method. The equal weight method is used when the DM has too little information about the priorities about the alternatives. The weights of the alternatives are determined by the number of alternatives. For example, if there are three alternatives available, the weights of alternatives are calculated as 1/3. The rank sum weights are calculated by normalizing the ranks of alternatives by dividing each of them by sum of the ranks. The rank exponent weight method is similar with the rank sum weights method. The difference is that the DM can determine the weight of the most important alternative. The weights of other alternatives are calculated according to the most important alternative. The inverse weights method calculates the weights of the alternatives by dividing each alternative by the sum of reciprocals. The rank order centroid method minimizes the maximum error of the weights by indicating the centroids of all alternative points while conserving the rank order of importance. The formula of rank order weight calculation is presented below. N represents the total number of alternatives, w_j represents the weight of alternative j, r_k represents the rank position of alternative k. As Roszkowska (2013), Ahn (2011) also presents the concept of ROC weights.

$$w_j = \frac{1}{n} \sum_{k=j}^{n} \frac{1}{r_k}$$

Considering all of the weighting methods, we decided to use direct rating method in our study because of the effectiveness of this method as stated by Bottemley et al. (2000) present and the preference of the DM.

CHAPTER 3

THE APPROACH

In Chapter 3, the problem and the solution approach are presented. The details of the problem and the solution method are explained.

The problem we deal with in our study is included in the scope of employee scheduling problems. We want to schedule the employees of hospitality organizations by taking cost, quality and balanced workload among employees into consideration. The logic of the proposed solution method is assigning the employees to the events or organizations.

There are two main parameters in our problem. One of them is the data of events and the other is data of employees. All the events can have different concepts and requirements. Moreover, the events have different importances from the firms' eye. On the other hand, we classify the employees into four groups according to their titles. The four groups can be listed as; managers, organizers, accountants and interns which can be stated as the main employee titles in hospitality or tourism organizations. Each employee in each group has different skills and wage rates.

One of the aims in the scheduling system is to minimize the employee costs. As mentioned before, each employee has a different wage rate. This means that the amount of money which the firms pay for each employee can be different. Each employee gets a bonus of a predetermined percentage of his/her wage per event if he/she is assigned to an event. Scheduling cost is defined as the total bonuses of all employees. Quality is the second objective in our employee scheduling problem. Quality is defined as the match between employee skills and event requirements and complexity in determined dimensions.

The dimensions in Table 1 are the critical factors that affect the customer satisfaction and work success in hospitality workplaces according to the previous studies. In addition to these quality dimensions, we add two more dimensions, which are experience and foreign language skills as a result of our observation and feedback from the DM. Some of the events can be international, so the foreign language skills of the employees can affect the quality of that events. On the other hand, experienced employees can understand the needs of the guests better than inexperienced ones. As a result, experience of employees is added to the quality dimensions. At the end, the quality perception consists of five dimensions, which are communication, teamwork, emotional intelligence, experience and foreign language skills. The quality dimensions are presented in Figure 1.

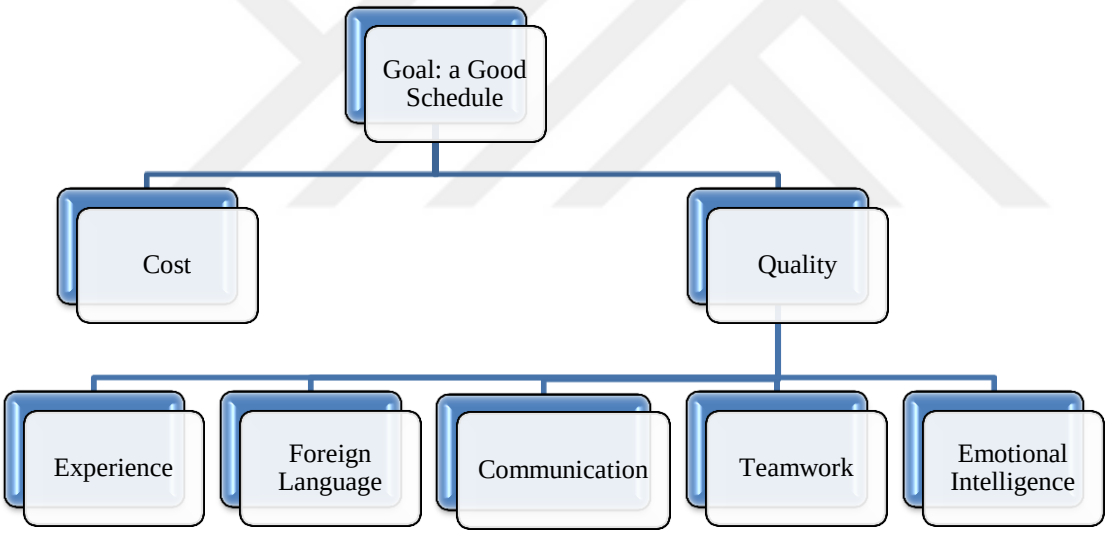


Figure 1. *Quality Dimensions*

After determining the dimensions, the DMs should rate all employees and events in the company for all the dimensions with the direct rating method stated in Chapter 2. The ratings should be given from 0 point to 10 points. The ratings of employees should be given according to their skills and abilities; on the other hand the events should be rated according to the complexity and difficulty. For example, an employee who has good communications skills will get a higher communication

rating point. In a similar manner, an event that hosts international participants will get a higher foreign language rating point compared to an event in which all of the participants are local. Each event or employee is evaluated independently. Moreover, the DM must determine importance rating (IR) for all events according to the events' importance from the point of company with direct rating method as in the way that most important job will have the highest weight.

After all the ratings are determined by the DM, the quality point is constituted. The quality contribution of an employee to an event is calculated as the summation of the multiplication of rating of employee, rating of event and IR of event for all dimensions. For example, if employee 1 is assigned to event 1, the quality contribution of employee 1 to event 1 is calculated as, (experience rating (ER) of employee 1)*(ER of event 1)*(IR of event 1) + (foreign language rating (FLR) of employee 1)*(FLR of event 1)*(IR of event 1) + (communication rating (CR) of employee 1)*(CR of event 1)*(IR of event 1) + (teamwork rating (TWR) of employee 1)*(TWR of event 1)*(IR of event 1) + (emotional intelligence (EIR) rating of employee 1)*(EIR of event 1)*(IR of event 1). The total quality point of the general schedule is calculated as the summation of the quality contribution of the attendant employees in all events. Quality point does not have a meaning by its own, but higher quality point means that the characteristics of employees match better with the requirements and complexity of events in the dimensions which are determined above.

After identifying the problem, the mathematical model is constructed by using MIP method.

3.1 Mathematical Model

Sets

T : Set of employee types in company, 1:Managers, 2:Organizers, 3:Accountants, 4:Interns

E_t : Set of available type $t \in T$ employee in company

I : Set of events that the company organizes

Parameters

P_{e_t} : Cost of assigning employee *e* of type *t* to an event

MIN_{ti} : Minimum number of type *t* employee required for event *i*

ERE_{e_t} : ER of employee *e* of type *t*

FRE_{e_t} : FLR of employee *e* of type *t*

CRE_{e_t} : CR of employee *e* of type *t*

TRE_{e_t} : TWR of employee *e* of type *t*

IRE_{e_t} : EIR of employee *e* of type *t*

ER_i : ER of event *i*

FR_i : FLR of event *i*

CR_i : CR of event *i*

TR_i : TWR of event *i*

IR_i : EIR of event *i*

IM_i : IR of event *i*

$$d_{ij} \begin{cases} 1, & if\ events\ i\ and\ j\ take\ place\ at\ the\ same\ time \\ 0, & otherwise \end{cases}$$

$e \in E_t \qquad i, j \in I \qquad t \in T$

Threshold: Workload balance parameter, the maximum difference between the most assigned employee and least assigned employee. This parameter is determined by the DM.

Decision Variable

$$x_{e_t i} = \begin{cases} 1, & \text{if employee } e \textit{ of type } t \text{ is assigned to event } i \\ 0, & \textit{otherwise}, \end{cases}$$

$t \in T \qquad e \in E_t \qquad i \in I$

Cost Minimization Model

Minimize $Z_1 = \sum_{t \in T} \sum_{e \in E_t} \sum_{i \in I} x_{e_t i} * P_{e_t}$

Subject to:

$\sum_{e \in E_t} x_{e_t i} \geq MIN_{ti}$ $\forall i \in I, \forall t \in T$ (1)

$\sum_{i \in I} x_{k_t i} - \sum_{i \in I} x_{l_t i} \leq$ Treshold $\forall k, l \in E_t \; k \neq l, \forall t \in T$ (2)

$\sum_{i \in I} x_{k_t i} - \sum_{i \in I} x_{l_t i} \geq -1 *$ Treshold $\forall k, l \in E_t \; k \neq l, \forall t \in T$ (3)

$(x_{e_t i} + x_{e_t j}) * d_{ij} \leq 1$ $\forall e \in E_t, \forall t \in T, \forall i, j \in I \; i \neq j$ (4)

$x_{e_t i} \in \{0,1\}$ $\forall e \in E_t, \forall t \in T, \forall i \in I$ (5)

- (1) is the set of requirement constraints so that minimum number of organizers, managers, accountants and interns are guaranteed to assigned to the events. The constraints are similar to those of Fırat and Hurkens (2011) and Sadykov and Wolsey (2003).
- (2) ensures the balanced workload among employees.
- (4) avoids the employees to get assigned to events which take place at the same time. The logic of these constraints is same with Stolletz and Zamorano (2014).
- (5) explains that the decision variables are binary.

Quality Maximization Problem

Maximize

$$Z_2 = \sum_{t\in T}\sum_{i\in I}\sum_{e\in E_t} x_{e_t i} * ERE_{e_t} * ER_i * IM_i + \sum_{t\in T}\sum_{i\in I}\sum_{e\in E_t} x_{e_t i} * FRE_{e_t} * FR_i * IM_i + \sum_{t\in T}\sum_{i\in I}\sum_{e\in E_t} x_{e_t i} * CRE_{e_t} * CR_i * IM_i + \sum_{t\in T}\sum_{i\in I}\sum_{e\in E_t} x_{e_t i} * TRE_{e_t} * TR_i * IM_i + \sum_{t\in T}\sum_{i\in I}\sum_{e\in E_t} x_{e_t i} * IRE_{e_t} * IR_i * IM_i$$

Subject to:

(1) - (5)

All of the constraints in the quality maximization model are same with the constraints of cost minimization model.

Lastly, a DSS is designed for this scheduling problem to help the DM in handling these conflicting purposes which are cost and quality in this scheduling process. The solution method is integrated into the DSS. The details of DSS are presented in Chapter 6.

CHAPTER 4

EXPERIMENTS

In Chapter 4, we present experiments for a Turkish firm which is operating their activities in hospitality sector.

The firm, founded in 2008, is organizing congresses, meetings, events and tours all over the world. The main focus of the firm is medicine and health sector. The firm organizes approximately 30 events per year in which the company touches 60,000 customers. The management office of the firm is located in Istanbul, Turkey. There are 29 employees in the firm.

Firstly, the necessary data is obtained from the company. The DM is the founder and the general manager of the firm and he is not taking charge in events. The DM of the company is asked to evaluate the current employees of the company. The rates are given from 0 to 10. After the evaluation each employee gets a skill set. Table 2 shows the skill ratings and wage rates of each employee in each title. According to the company policy, each employee gets 10% bonus of his/her monthly wage per event when he/she is assigned to an event. The personal information of employees such as names, surnames are not provided because of the company policy. Instead of names and surnames nicknames which consist of the title name and the sequence are used.

Table 2. *Skill ratings and wage rates of employees*

Employee	ER	FLR	CR	TWR	EIR	Wage Rate
Manager 1	10	10	10	10	10	15,000
Manager 2	10	10	10	10	10	13,000
Manager 3	10	10	10	10	10	13,000

Table 2. (cont'd)

Manager 4	8	10	10	10	10	9,000
Organizer 1	10	7	10	7	7	6,000
Organizer 2	6	8	8	9	7	4,000
Organizer 3	6	8	9	10	8	4,000
Organizer 4	6	6	8	8	7	3,800
Organizer 5	3	9	6	8	8	2,700
Organizer 6	8	8	8	9	8	4,500
Organizer 7	6	7	8	7	7	4,000
Organizer 8	6	8	7	8	9	3,800
Organizer 9	3	5	10	9	8	2,700
Organizer 10	9	9	8	10	10	5,500
Organizer 11	6	8	7	8	8	4,000
Organizer 12	6	3	8	8	8	4,000
Organizer 13	6	10	8	7	6	4,000
Organizer 14	3	7	9	8	9	3,000
Organizer 15	6	7	7	8	8	3,800
Organizer 16	3	10	8	9	8	2,700
Organizer 17	8	6	9	7	7	4,500
Organizer 18	3	8	7	8	8	3,000
Accountant 1	10	2	2	2	3	6,500
Accountant 2	3	8	7	7	8	3,000
Intern 1	0	8	5	8	6	500
Intern 2	0	9	7	8	7	500

After evaluating the employees and deciding the ratings of them, the DM evaluated the events that the company organizes in 2019. The DM rated the events in six quality dimensions which are five quality dimensions mentioned above and events' importance. The ratings are given from 0 to 10. Table 3 shows the ratings of the

events which the company organizes in 2019. Event names are not provided because of company policy.

Table 3. *Ratings of events*

Event	ER	FLR	CR	TWR	EIR	IR
Event 1	10	8	10	10	9	10
Event 2	9	8	9	9	7	8
Event 3	10	2	8	9	7	8.5
Event 4	9	6	9	9	8	6.5
Event 5	9	9	8	9	7	7
Event 6	9	8	9	8	9	7.5
Event 7	9	8	9	8	9	7.5
Event 8	8	8	8	7	7	5.5
Event 9	8	8	8	7	7	5.5
Event 10	8	4	7	8	7	3
Event 11	8	8	8	8	7	3
Event 12	5	8	6	5	5	0.5
Event 13	5	8	6	5	5	0.5
Event 14	5	8	6	5	5	0.5
Event 15	6	10	8	7	7	1.5
Event 16	6	10	8	7	7	1.5
Event 17	7	3	6	6	6	2
Event 18	6	8	7	8	7	1
Event 19	6	8	7	8	7	1
Event 20	4	9	6	6	6	0.5
Event 21	4	9	6	6	6	0.5
Event 22	4	9	6	6	6	0.5
Event 23	6	8	7	7	7	1.5

The events that the company organizes in a year are determined at the end of the previous year with a bidding system. The capacity, place and date are determined in bids. It is assumed that place is not important in our problem because the place of the events does not change the schedule. On the other hand capacity and dates are critical. Capacity of the event affects the number of employees required in that event. Dates are also important because scheduling an employee in the events that are planned in the same date intervals is not possible. In current event calendar of 2019, event 2 and event 5 take place in same time, so same employees cannot be assigned to both events. The DM determines the minimum number of employees needed in an event according to the capacity of that event. The required number of employees for the events and the dates of events are obtained. They are shown in Table 4.

Table 4. *Required employee numbers and date intervals of events*

Event	**Minimum Number of Managers**	**Minimum Number of Organizers**	**Minimum Number of Accountants**	**Date Intervals**
Event 1	3	12	1	03-06 October
Event 2	2	10	1	01-05 May
Event 3	2	10	1	07-09 February
Event 4	2	12	1	22-25 April
Event 5	2	8	1	03-04 May
Event 6	2	5	1	10 March
Event 7	2	5	1	09 April
Event 8	2	4	1	13-14 June
Event 9	2	4	1	18 April
Event 10	2	6	1	27 March
Event 11	2	5	1	29 November
Event 12	1	3	0	25 May
Event 13	1	3	0	29 June
Event 14	1	3	0	12 October

Table 4. (cont'd)

Event 15	0	3	0	13 April
Event 16	0	3	0	07 September
Event 17	0	3	0	22 June
Event 18	0	3	0	16 October
Event 19	0	3	0	25 November
Event 20	1	3	0	15 April
Event 21	1	3	0	08 June
Event 22	1	3	0	25 October
Event 23	0	3	0	20 October

The last step before the solving the mathematical model is obtaining specific constraints about the events that is going to involve in the model. The minimum numbers of employees for each event are one of the constraints. In addition to this, there is an experience constraint for each event according to the company policy. The company aims to set minimum experience year limits to some events. These limitations are given in Table 5. Experience is defined as the total experience of years of employees in the hospitality sector.

Table 5. *Experience constraints of events (maximum number of organizers who have less than 2 years of experience)*

Event	**Constraint**
Event 1	2
Event 2	3
Event 3	4
Event 4	4
Event 5	1
Event 6	1
Event 7	-

Table 5. (cont'd)

Event 8	-
Event 9	2
Event 10	2
Event 11	2
Event 12	2
Event 13	2
Event 14	2
Event 15	2
Event 16	2
Event 17	2
Event 18	2
Event 19	2
Event 20	2
Event 21	2
Event 22	2
Event 23	2

To ensure the specific experience constraints of the company, an experience constraint is added into the mathematical models. Two extra parameters are needed to construct the experience constraint. The parameters and constraint are shown below.

Parameters:

MT_i : Maximum number of organizers who have less than 2 year experience for event $i \in I$

$$TE_{e_2} = \begin{cases} 1, & \text{if organizer } e \text{ is less then 2 years experienced} \\ 0, & otherwise \end{cases}$$

Experience constraint:

$$\sum_{e \in e_2} x_{ei} * TE_{e_2} \leq \mathrm{MT_i}$$

CHAPTER 5

RESULTS AND DISCUSSIONS

In Chapter 5, the results of the mathematical models will be shown. After constructing the mathematical models and obtaining the necessary data from the company, the models are solved with optimization software CPLEX OPL v12.8. The optimal employee schedules will be presented for both cost minimization and quality maximization models. Afterwards, four other solutions will be provided except the optimal solutions. In addition, the difference in schedule costs will be shown in different workload balance threshold parameters. Lastly, the solutions will be compared with the current schedule of the company.

5.1 Cost Minimization Model Solution

The cost minimization model which is constructed in Chapter 2 is solved with the data which is provided by the company by using optimization software. The objective function value which is the schedule cost of year 2019 is founded as 84,850 TL. The quality value which is the second objective of our scheduling problem is calculated as 278,000 where the cost is minimized. The solution time is 05.92 seconds. The detailed schedule for managers, organizers, accountants and interns are shown in Table 6. If there is a “1” in a cell, it means that the corresponding employee is assigned to the corresponding event. If there is a “0” in a cell, it means that the corresponding employee will not take a role in corresponding event. Table 6 is presented below. In the detailed schedule, it can be observed that Accountant 1 and Intern 2 are assigned to only one event. These two employees can be utilized better as their current workload is below the average. This will be in line with the workload balance equity concerns of the DM.

Table 6. *2019 schedule of managers, organizers, accountants and interns in the optimal solution of cost minimization model*

	Events																						
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Man1	1	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Man2	1	0	0	1	1	0	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0
Man3	1	0	0	0	1	0	0	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0
Man4	0	1	1	0	0	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0
Org1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	1
Org2	0	1	1	1	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0
Org3	1	0	0	1	1	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1
Org4	1	0	1	1	1	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
Org5	1	0	1	1	1	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0
Org6	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Org7	1	1	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Org8	1	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1	0	0
Org9	0	1	0	1	0	0	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	0	0
Org10	1	0	1	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
Org11	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	1	0
Org12	1	0	0	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Org13	0	1	0	1	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0
Org14	0	1	0	1	0	1	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0
Org15	1	0	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Org16	1	0	1	0	1	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Org17	1	1	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Org18	0	1	1	1	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0	0	0
Acc1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acc2	1	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Int1	0	0	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Int2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

5.2 Quality Maximization Model Solution

As the cost minimization model, quality maximization model is solved with the data obtained from the company by using optimization software. The objective function value which is the quality value of the schedule of 2019 is founded as 524,423.5. The cost of this schedule is calculated as 221,280 TL. The solution time is 02.31 seconds.

The detailed schedule is shown in Table 10 which shows the schedules of managers, organizers, accountants and interns.

Table 7. *2019 schedule of managers, organizers, accountants and interns in the optimal solution of quality maximization model*

	Events																					
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Man1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Man2	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Man3	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Man4	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Org1	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Org2	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Org3	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Org4	1	0	1	1	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	1	1	0
Org5	0	0	0	0	1	0	0	1	1	0	0	1	1	1	1	0	0	1	0	1	1	1	0
Org6	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Org7	1	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	1	0	0	0
Org8	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Org9	0	1	1	1	0	0	0	1	1	1	0	1	0	0	0	0	1	1	1	0	0	0	1
Org10	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Org11	1	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	1	0	0	0	0	0
Org12	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	0	1	0	0	0	0	0	0
Org13	1	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	0	0	0	1
Org14	1	1	1	1	0	0	0	1	1	1	1	0	0	0	0	1	1	0	0	0	0	0	1
Org15	1	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	1	0	0	0	0
Org16	1	0	1	1	1	1	1	1	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0
Org17	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Org18	0	0	1	1	1	0	0	1	1	0	0	0	1	1	0	0	0	0	1	1	1	1	0
Acc1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Acc2	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Int1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Int2	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

5.3 Workload Balance – Cost Analysis

In our employee scheduling problem there are two objectives which are minimizing the cost and maximizing the quality. In addition to these two objectives, the balanced

workload among the managers and organizers is another point which is taken into consideration in the mathematical models. The workload balance is not defined as an objective, but there is a constraint which limits the difference between the maximum and minimum number of events that an employee is assigned. This constraint provides equity in workload. We use a predetermined threshold level which is defined by the DM beforehand. That is, the difference in event numbers to which managers or organizers assigned cannot exceed this workload balance threshold. For example, if an organizer is assigned to six events and the workload balance threshold is two, then other organizers can be assigned to four, five, six, seven or eight events. If the workload balance threshold is set as zero by the DM, all the managers and organizers should be assigned to the same number of events. The current workload balance threshold is decided as two by the DM. The cost minimization and quality maximization models are solved with the current workload balance threshold. To see how workload balance threshold parameter affects the scheduling costs, different solutions are obtained by using different workload balance threshold parameters and report the corresponding cost values in Table 8.

Table 8. *Minimum scheduling costs for different workload balance parameters*

Workload Balance Threshold	**Scheduling Cost(TL)**
0	93,650
1	85,500
2	84,850
3	83,800
4	82,850
5	81,900
6	81,100
7	80,200
8	79,350
9	78,500
10	77,900
11	77,350
12	76,860
13	76,570

Table 8. (cont'd)

14	76,280
15	76,020
16	76,020

The tradeoff between workload balance and scheduling costs is shown visually in Figure 1. As it can be observed from the Figure 2, the scheduling costs decreases when the workload balance threshold increases. The scheduling cost is highest when the firm decides to assign the each employee exactly the same number.

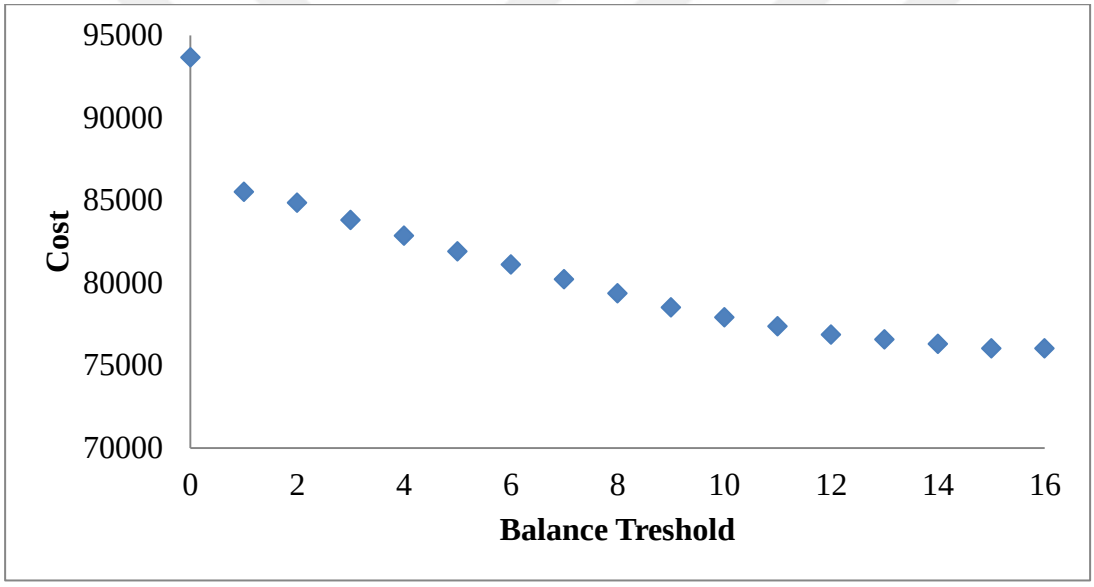


Figure 2. *Tradeoff between workload balance and minimum scheduling costs*

5.4 Alternative Solutions

Two base optimal solutions are founded by solving the cost minimization and quality maximization models. The minimum scheduling costs is founded as 84,850 TL and the quality value is 278,000 when the cost is minimum. The maximum quality value is founded as 524,423.5. The cost is 221,280 TL when quality value is maximum. The detailed schedules are provided in Table 6 and 7. It can be seen that there is a tradeoff between cost and quality. The base optimal solutions are shown together in Figure 3.

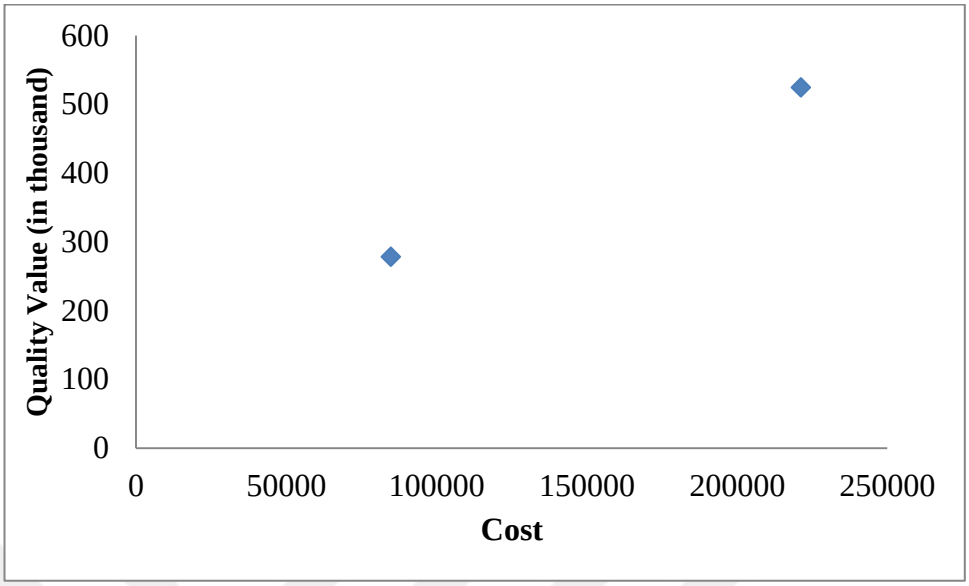


Figure 3. *Optimal solutions of cost minimization and quality maximization models*

In our study, we seek to present alternative solutions besides to the two base optimal solutions. We intended to find four alternative solutions. To obtain these alternative solutions we divided the range between the maximum and minimum cost into five equal pieces. The maximum cost is 221,280 TL and the minimum cost is 84,850 TL. The difference between them is 136,430. If this difference is divided into five equal, one piece corresponds to 27,286. The equal pieces are shown in Figure 4.

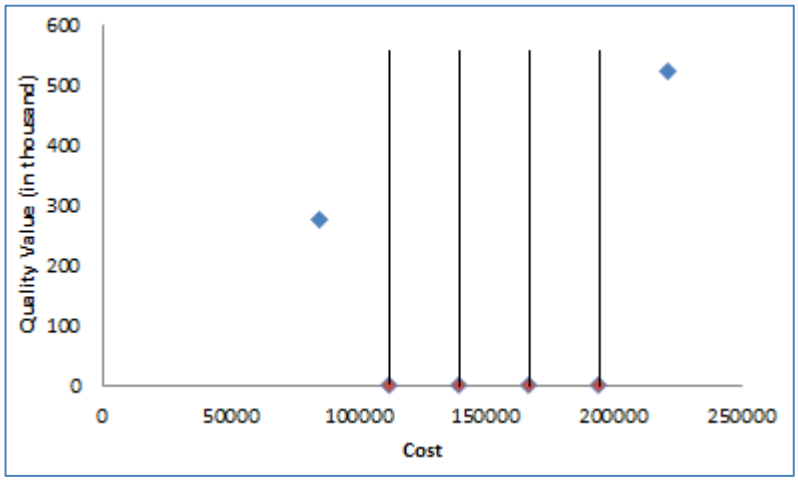


Figure 4. *Equal pieces between the base optimal solutions*

After dividing the range into five pieces, we wanted to find the maximum quality value in each line in Figure 4. To find the maximum quality value, we added a constraint in quality maximization model which limits the scheduling cost. The cost is defined as $\sum_{t\in T}\sum_{e=1}^{E_t}\sum_{i=1}^{I} x_{e_t i} * P_{e_t}$. We defined this cost function as "SchedulingCost" and the constraint which is shown below is added into the quality maximization model.

SchedulingCost <=…;

Afterwards, the right-hand side of the constraint is set as the cost value of the lines one by one which are described in Figure 4 and the quality maximization model is solved four times. The corresponding values that are used in the constraints are 112,136, 139,422, 166,708 and 193,994. The constraints which are added to the quality maximization model are shown below with the right-hand side values.

SchedulingCost <=112,136;

SchedulingCost <=139,422;

SchedulingCost <=166,708;

SchedulingCost <=193,994;

These constraints are added one by one and the model is solved four times. The solutions are shown in Table 9.

Table 9. *Alternative Solutions*

Cost	Quality
112,120	436,536.5
139,410	490,492.5
166,680	511,702.5
193,880	521,336

These solutions show the maximum quality values in limited costs to the DM. These solutions are presented with the original optimal solutions in Figure 5 where the circles show the optimal solutions and the squares show the alternative solutions. The detailed schedules are presented in Appendix A.

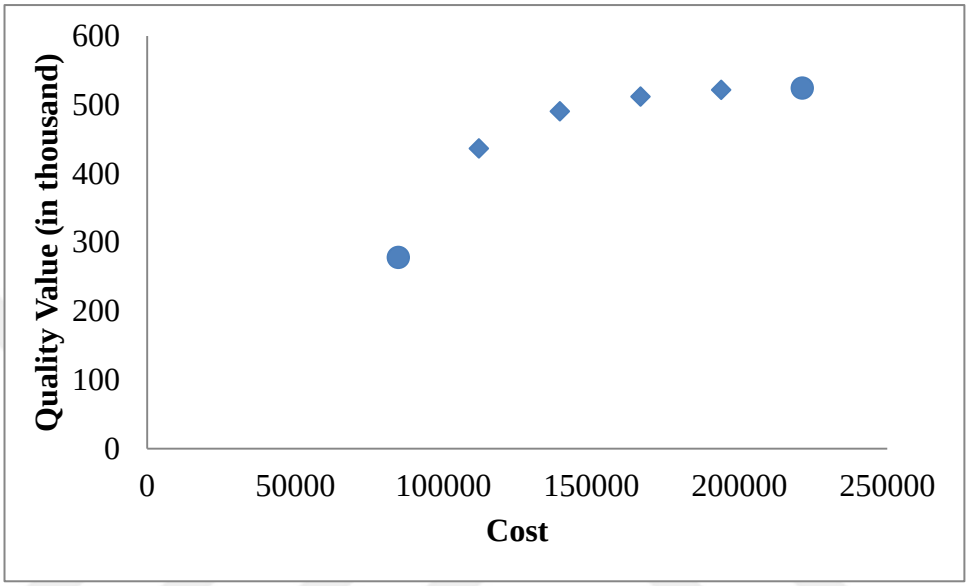


Figure 5. *Alternative Solutions and Optimal Solutions*

5.5 Comparison of Existing Schedule in the Firm and Proposed Solutions

In this section, the firm's current employee schedule and the results of mathematical models is compared. To make the comparison, firstly the company's current schedule is obtained. Table 10 shows the existing schedule of managers, organizers, accountants and interns.

Table 10. *Existing Schedule of Managers, Organizers, Accountants and Interns*

	Events																						
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Man1	1	1	0	1	1	1	1	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	0
Man2	1	1	0	0	0	1	1	1	1	1	0	1	0	0	0	0	0	1	0	0	0	1	0
Man3	1	0	1	1	0	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1
Man4	0	1	1	0	1	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0
Org1	1	1	0	1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
Org2	1	0	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	0	0	0	0

Table 10. (cont'd)

Org3	1	1	0	1	0	1	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1
Org4	1	0	1	1	1	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	1	0
Org5	1	0	1	1	1	1	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
Org6	1	1	0	0	0	0	0	1	1	0	0	0	0	1	1	0	1	0	0	0	0	0	0
Org7	0	1	1	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0	0
Org8	0	1	1	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0
Org9	1	0	0	1	1	0	0	0	1	0	1	0	0	1	0	0	0	0	1	0	0	0	0
Org10	0	1	1	1	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Org11	1	0	1	0	1	0	1	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0
Org12	1	1	0	1	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0
Org13	1	0	1	1	1	0	0	0	1	0	1	0	0	0	1	0	0	1	0	0	0	0	0
Org14	0	1	1	1	0	0	0	1	0	1	0	0	0	0	0	1	0	0	1	0	0	0	1
Org15	1	1	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	1	0	1	0	0
Org16	0	0	1	1	1	0	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	1	0
Org17	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
Org18	0	0	1	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0
Acc1	1	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acc2	0	0	1	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Int1	0	1	0	0	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
Int2	0	0	1	0	0	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1

After obtaining the existing employee schedule of 2019 from the company, the scheduling cost and quality point are calculated. Scheduling cost is 106,690 TL and quality value is 311,118.5. The existing schedule's cost and quality value are added to the Figure 3 and Figure 4 is obtained. Figure 6 shows the company's current schedule and the six schedules which is created by the mathematical models in previous chapters. The circles show the optimal solutions, the squares show the alternative solutions and the triangles shows the current schedule.

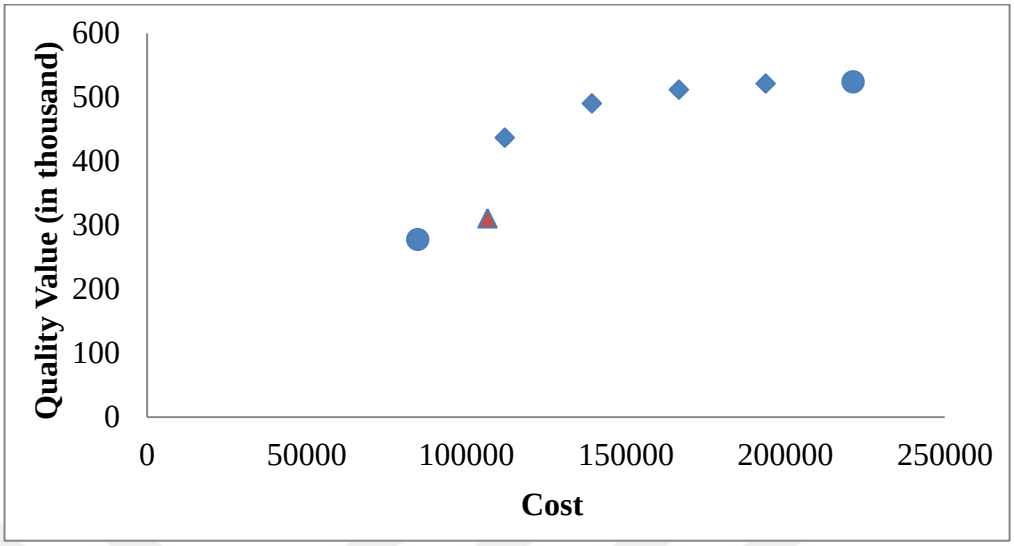


Figure 6. *Existing Schedule, Optimal Solutions and Alternative Solutions*

It is not possible to make a comparison between the current schedule and six solutions which are obtained from the mathematical models because the alternative solutions and extreme optimal solutions do not dominate the existing schedule of the company. To make a comparison, we intended to find two solutions which are at the same cost with the current schedule and at the same quality value with the current schedule separately. Firstly, we updated the cost constraint in quality maximization model and we changed the right-hand side of the constraint as the current scheduling cost which is 106,690 TL. The cost of this new schedule is 106,690 TL and quality value is 417,875. After solving the quality maximization model, the objective function in quality maximization model is defined as quality function and this function is added as a constraint in cost minimization model. The current schedule's quality value is set as the right-hand side of the quality constraint in cost minimization model and the new cost minimization model is solved. The cost of the solution is 86,050 TL and the quality value of the solution is 311,410. These solutions are shown with the previous solutions and current schedule in Figure 7. The points which are marked with a cross and a square are the new two solutions which are obtained in this section.

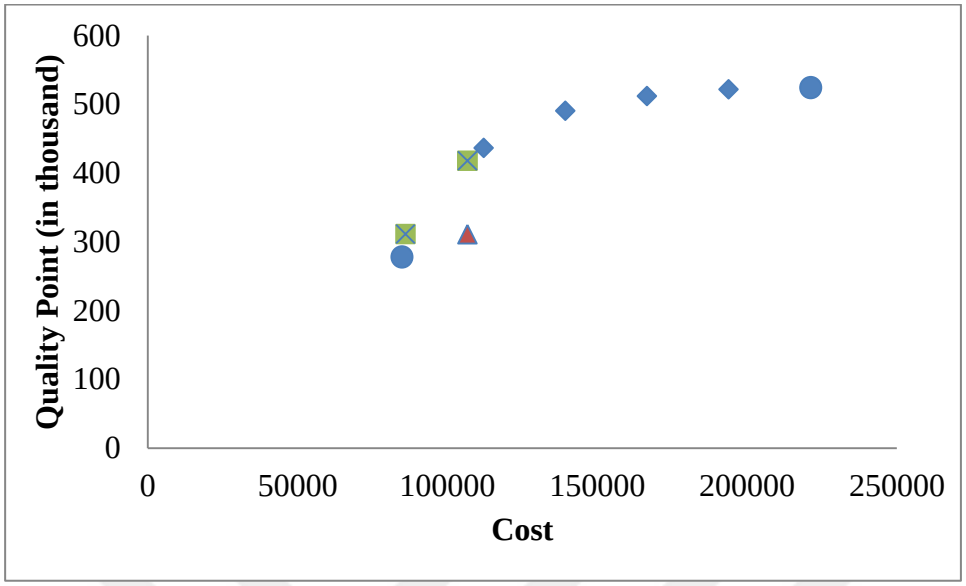


Figure 7. *Current Schedule, Optimal Solutions, Alternative Solutions and Dominating Solutions*

It is shown that, the new two solutions dominate the current schedule. This means, a solution at almost same quality point with a lower cost or a solution at same cost with a higher quality point is possible with the mathematical models which are constructed in our study.

5.6 Sensitivity Analysis

In this section, we further investigate the sensitivity of the proposed mixed integer programming model through detailed analysis. We intended to capture if the proposed model is robust to small changes of parameters which are determined by the DM. For this analysis, we evaluate the effect of quality ratings of the employees and events to the scheduling decision by changing their values within the range of ±5% of current values. We generated 10 random ratings within the range of ±5% of each employee and event rating for each employee and event in each dimension which are explained in Chapter 3. The generated random values are presented in Appendix B. After the generation of random ratings, we design 50 test problems with the random ratings and solve them. We found out that the schedule do not change in

these 50 test problems. As a result, it can be stated that the proposed mixed integer programming model is not sensitive to small changes in the parameters.

CHAPTER 6

DECISION SUPPORT SYSTEM

In this chapter, the DSS for the employee scheduling problem is presented.

A user-friendly DSS is designed for the hospitality organizations to schedule their employees by using our proposed solution approach. The parameters used in the employee scheduling problem which are event number, employee number, event's characteristics, employee's characteristics, event dates and employee's wage rates can vary in time. The DSS can handle this change. The DSS is based on Microsoft Excel and Microsoft Visual Basic. We incorporated our models into the designed DSS. The mathematical models are solved in Excel Solver Add-In. DSS is designed to create the employee schedules at the beginning of the year because event calendar is set yearly. DM can change every parameter in the problem and get the new solutions. The details of designed DSS are shown below.

There is a main page of the DSS which contains 4 buttons. The main page is shown in Figure 8.

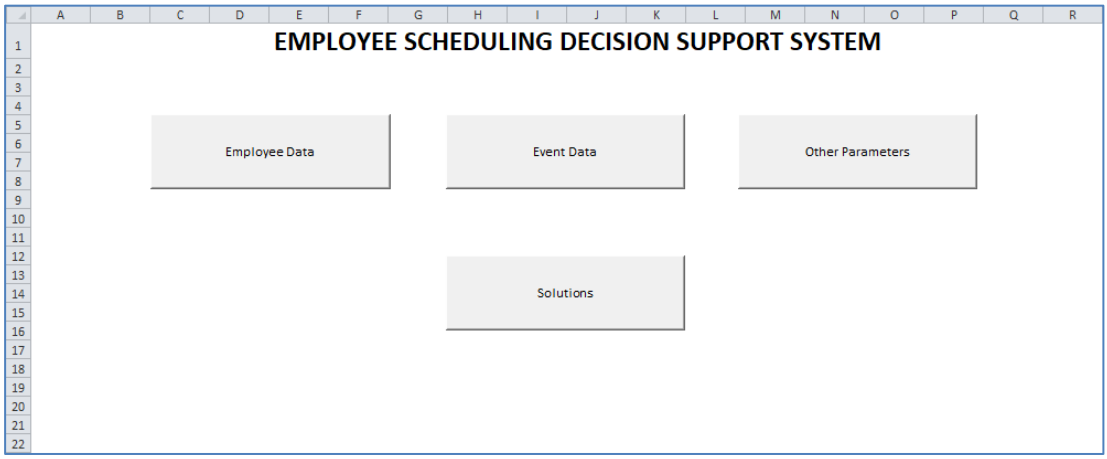


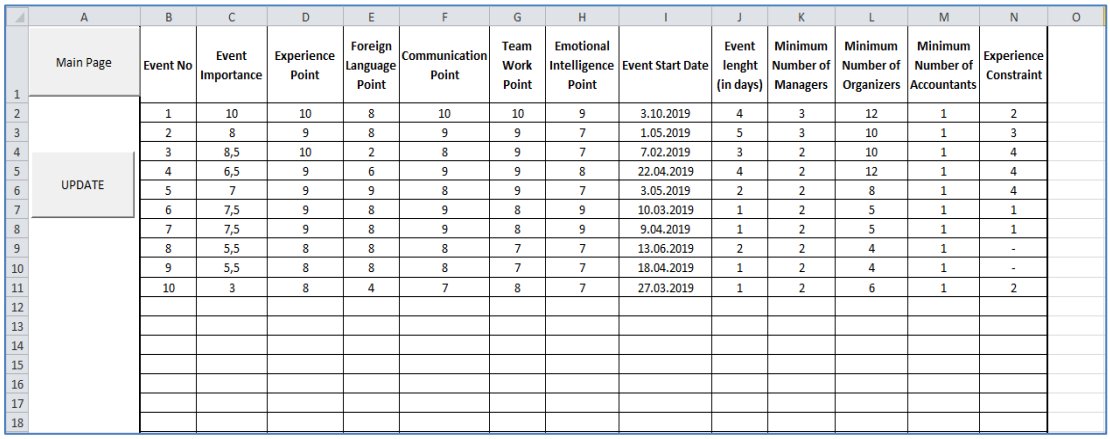
Figure 8. *Main Page of DSS*

DM can click on these 4 buttons. If DM clicks on “Employee Data” button, a new page appears. DM can change all parameters about employees on this page. Employee title parameter is limited. DM can set the title as “Manager”, “Organizer”, “Accountant” or “Intern”. The points should be given from 0 to 10. After changing the data, DM should click on “UPDATE” button. DM can add more employees to the system or delete some of the employees. If DM renounces changing, “Main Page” button should be clicked. Figure 9 shows the employee data page.

	A	B	C	D	E	F	G	H	I	J	K
1	Main Page	Employee Title	Employee No	Years of Experience	Experience Point	Foreign Language Point	Communication Point	Team Work Point	Emotional Intelligence Point	Wage Rate	
2		Manager	1	10	10	10	10	10	10	15000	
3		Manager	2	8	10	10	10	10	10	13000	
4		Manager	3	6	10	10	10	10	10	13000	
5		Manager	4	3	8	10	10	10	10	9000	
6	UPDATE	Organizer	1	5	10	7	10	7	7	6000	
7		Organizer	2	2	6	8	8	9	7	4000	
8		Organizer	3	2	6	8	9	10	8	4000	
9		Organizer	4	2	6	6	8	8	7	3800	
10		Organizer	5	1	3	9	6	8	8	2700	
11		Organizer	6	3	8	8	8	9	8	4500	
12		Organizer	7	2	6	7	8	7	7	4000	
13		Organizer	8	2	6	8	7	8	9	3800	
14		Organizer	9	1	3	5	10	9	8	2700	
15		Organizer	10	4	9	9	8	10	10	5500	
16		Accountant	1	6	10	2	2	2	3	6500	
17		Accountant	2	1	3	8	7	7	8	3000	
18		Intern	1	0	0	8	5	8	6	500	
19		Intern	2	0	0	9	7	8	7	500	
20		Manager									
21		Organizer									
22		Accountant									
		Intern									

Figure 9. *Employee Data Page*

After clicking the “UPDATE” button, the main page appears again. If the DM clicks on “Event Data” button, a page about event data opens. Similar with employee data page, the DM change each parameter about the events in this page. Also, the DM can add more events to schedule or delete some events from the schedule. There is an “Experience Constraint” column in this page. This column indicates the maximum number of employees which have less than 2 years of experience allowed for that event. Same with employee data page, “UPDATE” button should be clicked after a change. The page which contains the event data is presented in Figure 10.



	Event No	Event Importance	Experience Point	Foreign Language Point	Communication Point	Team Work Point	Emotional Intelligence Point	Event Start Date	Event lenght (in days)	Minimum Number of Managers	Minimum Number of Organizers	Minimum Number of Accountants	Experience Constraint
Main Page													
	1	10	10	8	10	10	9	3.10.2019	4	3	12	1	2
	2	8	9	8	9	9	7	1.05.2019	5	3	10	1	3
	3	8,5	10	2	8	9	7	7.02.2019	3	2	10	1	4
UPDATE	4	6,5	9	6	9	9	8	22.04.2019	4	2	12	1	4
	5	7	9	9	8	9	7	3.05.2019	2	2	8	1	4
	6	7,5	9	8	9	8	9	10.03.2019	1	2	5	1	1
	7	7,5	9	8	9	8	9	9.04.2019	1	2	5	1	1
	8	5,5	8	8	8	7	7	13.06.2019	2	2	4	1	-
	9	5,5	8	8	8	7	7	18.04.2019	1	2	4	1	-
	10	3	8	4	7	8	7	27.03.2019	1	2	6	1	2

Figure 10. *Event Data Page*

The last button about the parameters is the “Other Parameters” button. A user form appears when this button is clicked. The DM can change 3 parameters in this user form which are workload balance threshold, percentage of wage rate gain for each event and number of solutions except extreme optimal solutions. Workload balance threshold is set as “2” in existing situation. DM can change this parameter in this form and obtain a new solution. The second parameter is percentage of wage rate gain for each event. In current system, an employee gets 10% of his/her annual wage rate if he/she is assigned to any event. This percentage can be changed by DM in this form. Last parameter is the number of solutions except extreme optimal solutions. In Section 5.4 we presented 4 alternative solutions except the optimal solutions. DM can select the number of alternative solutions. The alternative solutions are composed in same way as described in Section 5.4. The user form which appears after clicking “Other Parameters” button is shown in Figure 11.

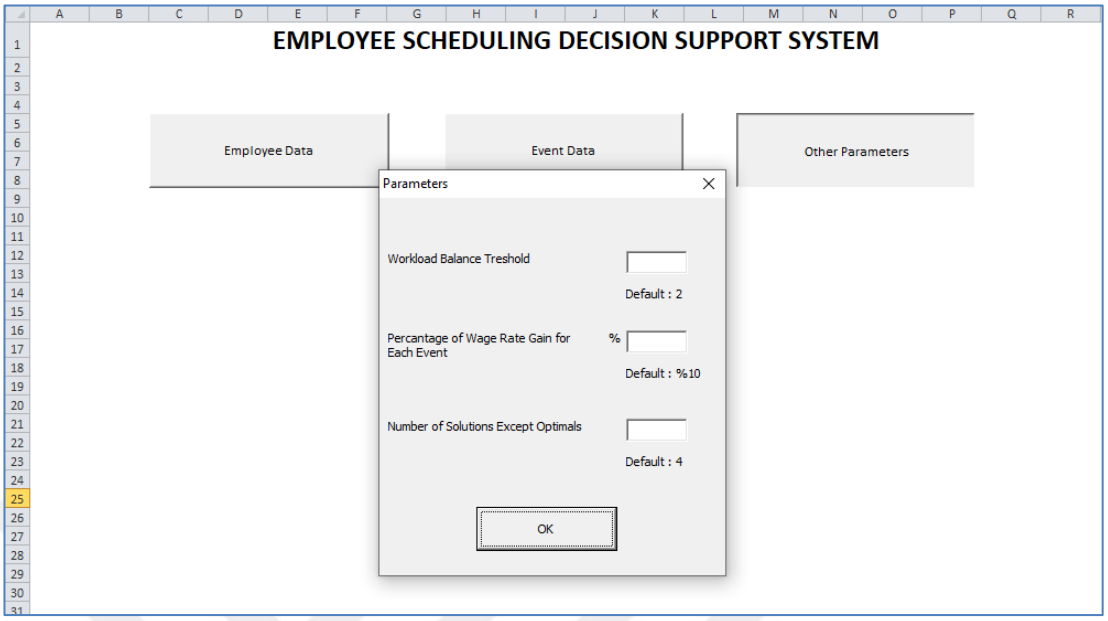


Figure 11. *Other Parameters User Form*

The last button in the main page of DSS is “Solutions” button. After providing the necessary data to the system, the results can be seen in the solution page which appears as the button is clicked. The solutions page is shown in Figure 12.

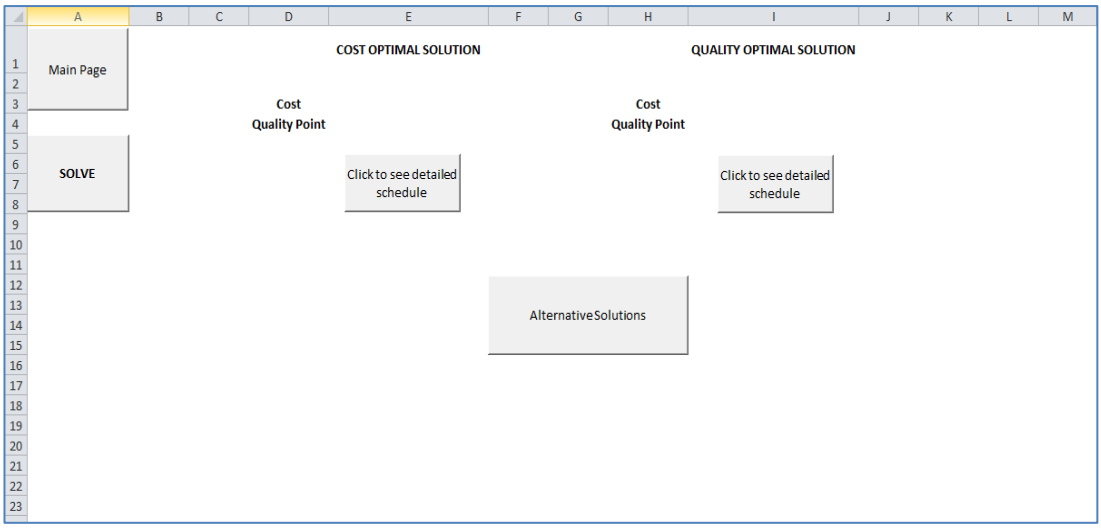


Figure 12. *Solutions Page*

The page is empty when it is opened. There is a “SOLVE” button on the left side of the page. If this button is clicked, the mathematical models are solved by Excel Solver Add-In and the objective function results are displayed in this page. In the column “E” objective function values of cost minimization model, in the column “I” objective function values of quality maximization values are shown. There are two buttons under these values. To see detailed schedules, which means to see which employee is assigned to which event, these buttons should be clicked. The last button on this page is “Alternative Solutions” button. The number of alternative solutions is determined by the DM in the main page of DSS. If this button is clicked, the alternative solutions are shown.

To clarify these buttons and pages, a small scale problem is solved by the DSS. The reason why a small scale problem is used is Standard Excel Solver Add-In’s number of decision variable and constraint limits. Standard Excel Solver Add-In allows a maximum number of 200 decision variables and 100 constraints. Premium Solver Products can be used if the problem size is bigger.

As mentioned above, a small scale problem is constituted and solved in DSS. The problem contains 3 managers, 5 organizers, 2 accountants, 2 interns and 10 events. The employee and event data is shown in Tables 11 and 12 respectively.

Table 11. *Employee Data of Small Scale Problem*

Employee Title	Employee No	Years of Experience	ER	FLR	CR	TWR	EIR	Wage Rate
Manager	1	10	10	10	10	10	10	15,000
Manager	2	6	10	10	10	10	10	13,000
Manager	3	3	8	10	10	10	10	9,000
Organizer	1	5	10	7	10	7	7	6,000
Organizer	2	2	6	8	8	9	7	4,000
Organizer	3	1	3	9	6	8	8	2,700
Organizer	4	1	3	5	10	9	8	2,700
Organizer	5	4	9	9	8	10	10	5,500
Accountant	1	6	10	2	2	2	3	6,500

Table 11. (cont'd)

Accountant	2	1	3	8	7	7	8	3,000
Intern	1	0	0	8	5	8	6	500
Intern	2	0	0	9	7	8	7	500

Table 12. *Event Data of Small Scale Problem(ratings,dates)*

Event No	IR	ER	FLR	CR	TWR	EIR	Event Start Date	Event lenght (in days)
1	10	10	8	10	10	9	3.10.2019	4
2	8	9	8	9	9	7	1.05.2019	5
3	8.5	10	2	8	9	7	7.02.2019	3
4	6.5	9	6	9	9	8	22.04.2019	4
5	7	9	9	8	9	7	3.05.2019	2
6	7.5	9	8	9	8	9	10.03.2019	1
7	7.5	9	8	9	8	9	9.04.2019	1
8	5.5	8	8	8	7	7	13.06.2019	2
9	5.5	8	8	8	7	7	18.04.2019	1
10	3	8	4	7	8	7	27.03.2019	1

Required employee numbers and experience constraints of events are shown in Table 13. Experience constraint represents the maximum number of employees who have less than 2 years of experience.

Table 13. *Event Data of Small Scale Problem(minimum number of employees and experience constraints)*

Event No	Minimum Number of Managers	Minimum Number of Organizers	Minimum Number of Accountants	Experience Constraint
1	2	4	1	2
2	2	3	1	3
3	1	3	1	4

Table 13. (cont'd)

4	1	4	1	4
5	1	2	1	4
6	1	1	1	1
7	2	2	1	1
8	1	1	1	-
9	2	1	1	-
10	1	1	1	2

The solutions are obtained with the small scale problem's data. The objective function values are presented in the solution page when the "SOLVE" button is clicked on this page. The objective function values of the sample problem are shown in Figure 13.

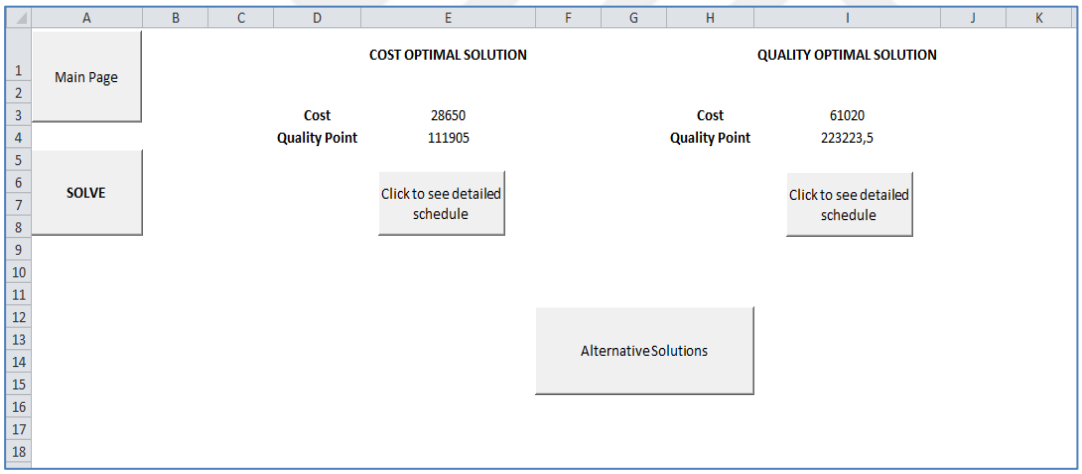
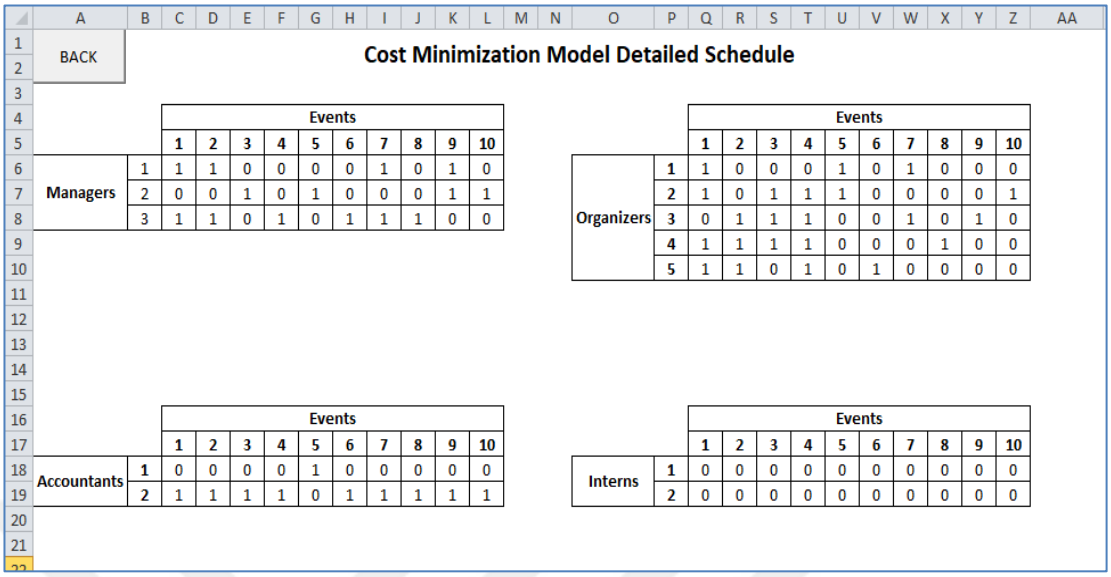


Figure 13. *Objective Function Values of Sample Problem*

If the DM clicks on the buttons under the objective function values, the detailed schedules are presented. Figures 14 and 15 show the detailed schedules of cost optimal and quality optimal solutions respectively.



BACK

Cost Minimization Model Detailed Schedule

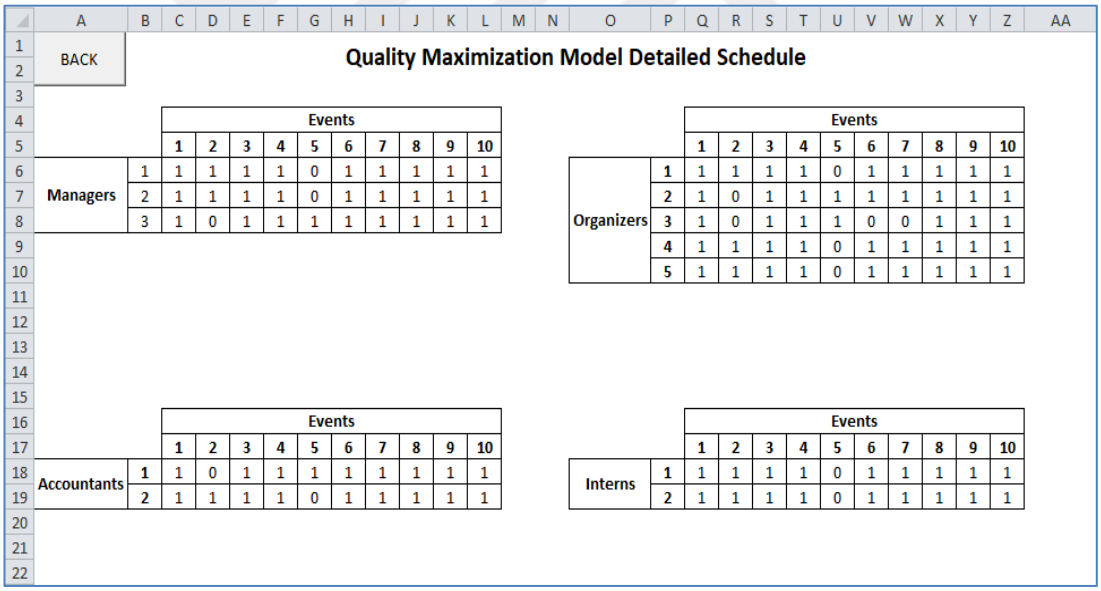
		Events									
		1	2	3	4	5	6	7	8	9	10
Managers	1	1	1	0	0	0	0	1	0	1	0
	2	0	0	1	0	1	0	0	0	1	1
	3	1	1	0	1	0	1	1	1	0	0

		Events									
		1	2	3	4	5	6	7	8	9	10
Organizers	1	1	0	0	0	1	0	1	0	0	0
	2	1	0	1	1	1	0	0	0	0	1
	3	0	1	1	1	0	0	1	0	1	0
	4	1	1	1	1	0	0	0	1	0	0
	5	1	1	0	1	0	1	0	0	0	0

		Events									
		1	2	3	4	5	6	7	8	9	10
Accountants	1	0	0	0	0	1	0	0	0	0	0
	2	1	1	1	1	0	1	1	1	1	1

		Events									
		1	2	3	4	5	6	7	8	9	10
Interns	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0

Figure 14. *Detailed Schedule of Cost Optimal Solution*



BACK

Quality Maximization Model Detailed Schedule

		Events									
		1	2	3	4	5	6	7	8	9	10
Managers	1	1	1	1	1	0	1	1	1	1	1
	2	1	1	1	1	0	1	1	1	1	1
	3	1	0	1	1	1	1	1	1	1	1

		Events									
		1	2	3	4	5	6	7	8	9	10
Organizers	1	1	1	1	1	0	1	1	1	1	1
	2	1	0	1	1	1	1	1	1	1	1
	3	1	0	1	1	1	0	0	1	1	1
	4	1	1	1	1	0	1	1	1	1	1
	5	1	1	1	1	0	1	1	1	1	1

		Events									
		1	2	3	4	5	6	7	8	9	10
Accountants	1	1	0	1	1	1	1	1	1	1	1
	2	1	1	1	1	0	1	1	1	1	1

		Events									
		1	2	3	4	5	6	7	8	9	10
Interns	1	1	1	1	1	0	1	1	1	1	1
	2	1	1	1	1	0	1	1	1	1	1

Figure 15. *Detailed Schedule of Quality Optimal Solution*

Except from the optimal solutions, DM can see the alternative solutions by clicking the “Alternative Solutions” button in the solutions page. The page which appears when the “Alternative Solutions” button is clicked is shown in Figure 16.

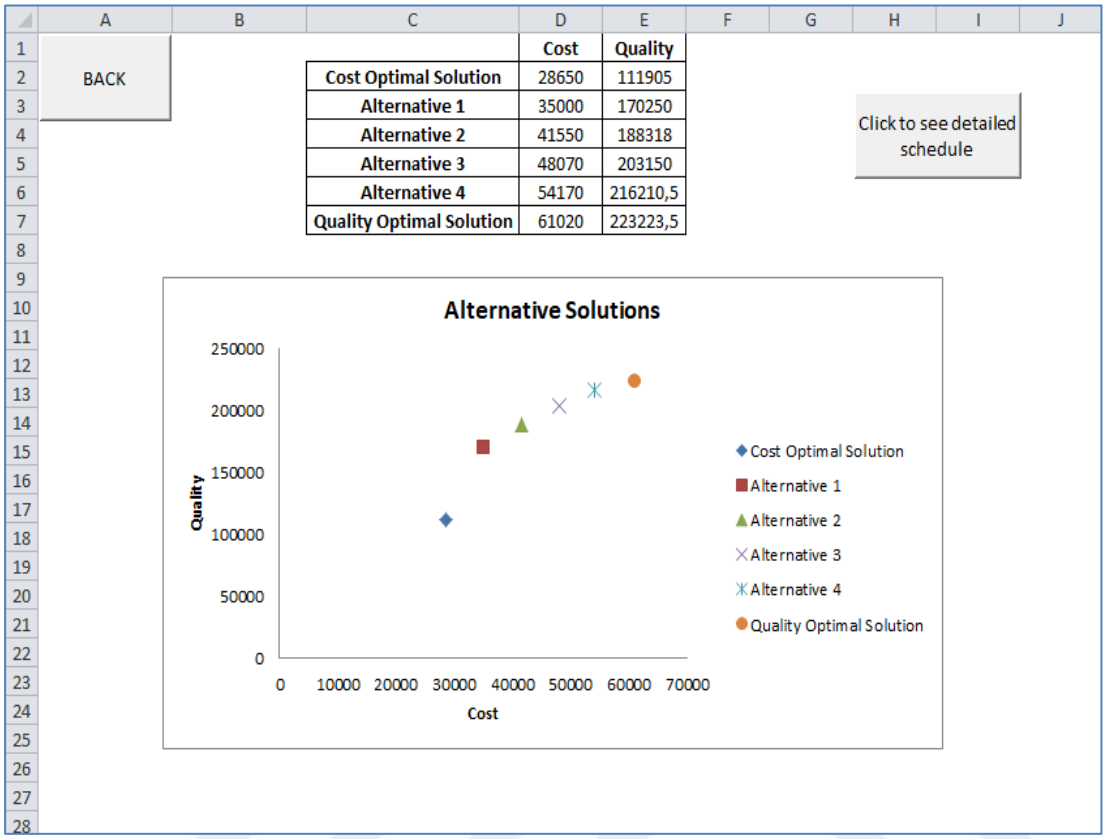


Figure 16. *Alternative Solutions Page*

Figure 16 shows the alternative solutions page. A graph of all solutions is provided so DM can interpret all the solutions and trade-offs between them.

There is a button next to the objective function values or alternative solution in this page. This button is used for getting the detailed schedule of the alternative solutions. When this button is clicked, a user form appears. DM can select the alternative solution of which he/she wants to see the detailed schedule. This user form is presented in Figure 17.

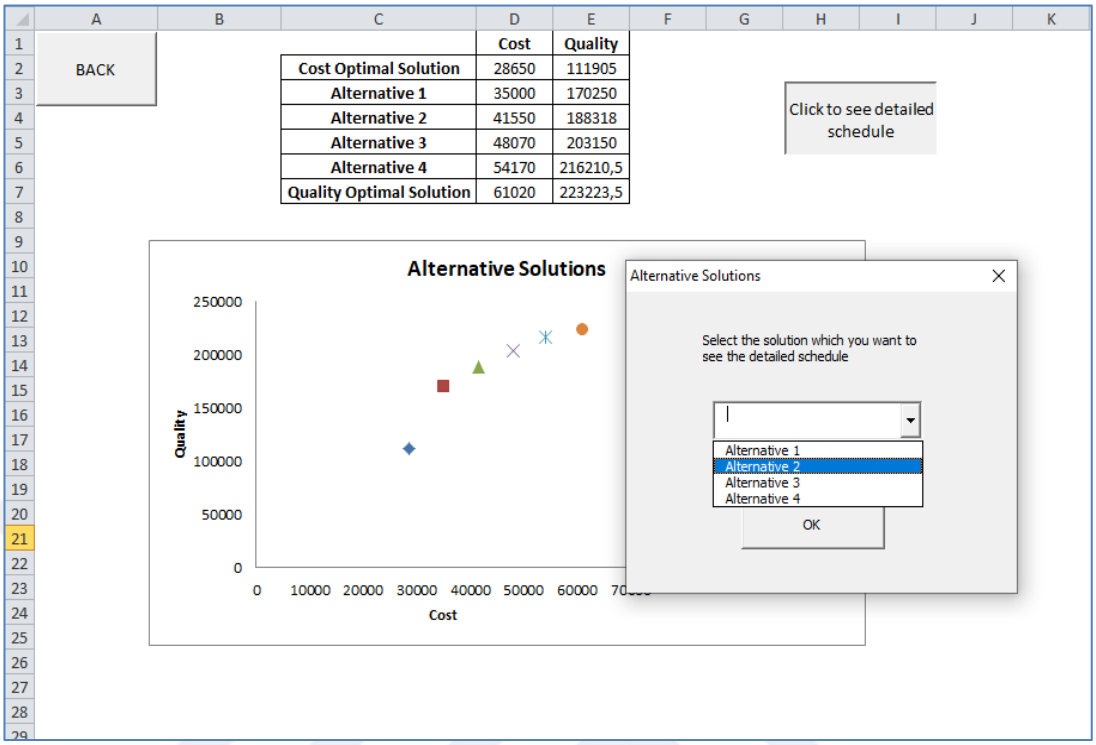


Figure 17. *Alternative Solutions Selection User Form*

After the selection of alternative solution, the detailed schedule of the selected solution is presented in a new page. In the example above, Alternative 2 is selected. Figure 18 shows the detailed employee schedule of the Alternative 2 solution.

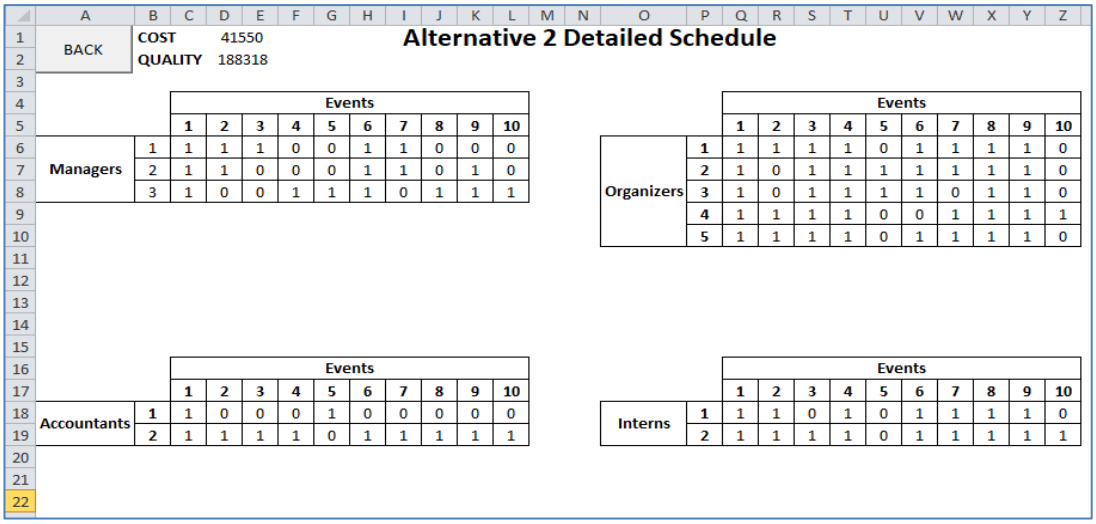


Figure 18. *Detailed Schedule of Alternative 2*

CHAPTER 7

CONCLUSIONS

Employee scheduling is a common problem in all sectors where several employees work together. It has so many popular application areas such as flight crew scheduling, nurse scheduling, shift scheduling and public transport driver scheduling. Generally, employee scheduling problems are difficult and complex problems, as a result it takes long time to create even a basic and feasible schedule for DMs. Staff costs are one of the basic costs of the organizations so it is important to reduce these costs in order to increase the profitability and gain competitive advantage in the market In our study, we deal with the optimization of an employee scheduling problem. Moreover, not only we concern with the cost of the schedule but also the quality measures and balanced workload among the employees.

Firstly, we identified the key skills and attributes of employees in hospitality sector which ensure the quality in this sector from the previous studies. We came up with five critical attributes which are experience, foreign language, communication skills, team work ability and emotional intelligence. After introducing these five dimensions, we presented optimization models by using mixed integer programming. As we treat the employee scheduling considering two objectives, we suggested two separate models which are cost minimization and quality maximization models. We defined quality as the match of employee skills and event difficulty and complexity in the five dimensions which stated above. Two optimal solutions are obtained from the two mathematical models. The solution of cost minimization model provides the lowest cost; whereas, the solution of quality maximization model provides the best quality.

The workload balance, another concern of employee scheduling problem, is defined as a constraint in our mathematical models. The maximum event difference between the most assigned employee and least assigned employee is set as a parameter and this parameter prevents the inequitable workload among employees. Unfair workload can pull the motivation down in organizations. By securing the balanced workload among employees, the motivation and performance of the employees are aimed to rise.

The method in our study is implemented on an organization company which organizes congress events. The employee and event data are obtained from the DM in the company. The mathematical models are solved with the obtained data. Two optimal solutions are provided to the company. After obtaining the optimal solutions of two mathematical models, we suggest four additional alternative solutions which take both objectives into consideration at the same time. As a result, six schedules are provided to the company. Afterwards, the company's current employee schedule is analyzed. The cost of the current schedule and the quality point of current schedule are calculated. The cost of the current schedule is set as a constraint in our quality maximization model and the quality point of the current schedule is set as a constraint in our cost minimization model. The models are solved with these constraints and two new solutions are obtained. These solutions dominate the company's current schedule. It means that, our method offers a schedule which has same quality with the current schedule with a lower cost or a schedule which has same cost with the current schedule with a better quality.

We review three quality dimensions from the previous studies which are communication, teamwork and emotional intelligence skills. During the application of our proposed approach, we find out two more quality dimensions which are experience and foreign language ability. These two dimensions are included in quality of the service to cover more dimensions and reflect the real-life situations in hospitality sector better.

We also establish a DSS into which the developed models are incorporated. The DM can change every parameter in the problem and get the new solution. DMs can get the employee schedule in a short time. The DSS is designed user friendly; each organization in hospitality sector can use this DSS to generate their employee schedule easily. The DSS which is designed in our study is the most critic managerial impact to hospitality companies.

Our study has some limitations which should be considered in the future studies. One of them is Excel Solver's decision variable and constraint capacity. Premium Excel Solver Add-In must be bought in order to solve large problems. Secondly, we assume that the DMs in organizations are rational and consistent while rating the employees and events. The rating is the main point in quality maximization model. If the DMs rate the employees and events biasedly, the maximization model will not give a meaningful solution. In our approach, there is not any difference between employees' genders. Gender factor in hospitality industry cannot be underestimated, so it should be included in future studies. Lastly, employee fatigue is not considered in our study. Apart from the balanced workload among employees, employee fatigue factor plays a critical role in employee satisfaction and motivation. If an employee works in several events in a short time, he/she can lose his/her motivation and energy.

There is a constraint which ensures that the employees cannot work in different events in the same time in our method but employee fatigue is not discussed in our study. The mathematical models can be rearranged by taking the fatigue factor into the consideration.

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APPENDICES

A. DETAILED SCHEDULES OF ALTERNATIVE SOLUTIONS

Alternative 1

	Events																						
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Man1	1	1	0	1	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Man2	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Man3	1	1	1	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Man4	1	0	0	0	1	0	0	0	0	1	0	1	1	1	0	0	0	0	0	1	1	1	0
Org1	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Org2	1	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Org3	1	1	1	1	0	1	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0
Org4	1	0	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Org5	0	0	0	0	1	0	0	1	1	0	0	1	1	0	0	1	0	1	1	1	1	1	0
Org6	1	1	1	1	0	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Org7	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Org8	1	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1
Org9	0	1	1	1	0	0	0	1	1	1	0	0	0	1	0	0	1	1	1	0	0	0	1
Org10	1	1	1	1	0	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Org11	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Org12	1	1	1	1	0	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Org13	1	0	1	1	1	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Org14	1	1	1	1	0	0	0	1	1	1	1	0	0	0	1	0	1	0	0	0	0	0	1
Org15	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	0	1	1	0
Org16	1	0	1	1	1	1	1	1	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0
Org17	1	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Org18	0	0	1	1	1	0	0	1	1	0	0	1	1	1	0	0	0	0	0	1	1	1	0
Acc1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acc2	1	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Int1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1
Int2	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Alternative 2

	Events																						
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Man1	1	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Man2	1	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Man3	1	1	1	1	0	1	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Man4	1	0	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0	1	1	1	0
Org1	1	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Org2	1	1	1	1	0	1	1	1	1	1	1	0	0	0	0	1	0	1	0	0	0	0	0
Org3	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	0	1	0	0	0	0	0	0
Org4	1	0	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0
Org5	0	0	0	0	1	0	0	1	1	0	0	0	1	1	1	0	0	1	1	1	1	1	0
Org6	1	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Org7	1	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Org8	1	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0	0	1
Org9	0	1	1	1	0	0	0	1	1	1	0	0	0	1	0	0	1	1	1	0	0	0	1
Org10	1	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Org11	1	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Org12	1	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Org13	1	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	0
Org14	1	1	1	1	0	0	0	1	1	1	1	1	0	0	0	1	1	0	0	0	0	0	0
Org15	1	0	1	1	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	1	0	0	0
Org16	1	0	1	1	1	1	1	1	1	0	1	0	0	0	1	1	0	0	0	0	0	0	1
Org17	1	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Org18	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	0	0	0	0	1	1	1	0
Acc1	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acc2	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	1
Int1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
Int2	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Alternative 3

	Events																						
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Man1	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	0	0	0	0	0	0	0
Man2	1	0	1	1	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0	0	0	0	0
Man3	1	1	1	1	0	1	1	1	1	1	1	0	0	1	1	1	0	0	0	0	0	0	0
Man4	1	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	0
Org1	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0

Org2	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Org3	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Org4	1	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	0
Org5	0	0	0	0	1	0	0	1	1	0	0	1	1	0	0	1	0	1	1	1	1	1	0
Org6	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Org7	1	0	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0	0	0	0	0	0	0
Org8	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Org9	0	1	1	1	0	0	0	1	1	1	0	0	0	1	0	0	1	1	1	0	0	0	1
Org10	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Org11	1	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	1	0	0	0	0	0
Org12	1	1	1	1	0	1	1	1	1	1	1	1	1	0	0	0	1	0	0	0	0	0	0
Org13	1	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	0	0	0	1
Org14	1	1	1	1	0	0	0	1	1	1	1	0	0	0	1	0	1	0	0	0	0	0	1
Org15	1	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	1	0	0	0	0
Org16	1	0	1	1	1	1	1	1	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0
Org17	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Org18	0	0	1	1	1	0	0	1	1	0	0	1	1	1	0	0	0	0	0	1	1	1	0
Acc1	1	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Acc2	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	1	1	0	1	1	1
Int1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Int2	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Alternative 4

	Events																						
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Man1	1	1	1	1	0	1	1	1	1	1	1	1	0	0	1	1	1	1	1	0	0	0	1
Man2	1	1	1	1	0	1	1	1	1	1	1	0	1	0	1	1	1	1	1	0	0	0	1
Man3	1	0	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	0	0	0	1
Man4	1	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1
Org1	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Org2	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Org3	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Org4	1	0	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	0	0	1	1	0	0
Org5	0	0	0	0	1	0	0	1	1	0	0	1	1	1	0	1	0	1	0	1	1	1	0
Org6	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Org7	1	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	0	0	1	0
Org8	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Org9	0	1	1	1	0	0	0	1	1	1	0	0	0	1	0	0	1	1	1	0	0	0	1
Org10	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0

Org11	1	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	1	0	0	0	0	0
Org12	1	1	1	1	0	1	1	1	1	1	1	1	1	0	0	0	1	0	0	0	0	0	0
Org13	1	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	0	0	0	1
Org14	1	1	1	1	0	0	0	1	1	1	1	0	0	0	1	0	1	0	0	0	0	0	1
Org15	1	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	1	0	0	0	0
Org16	1	0	1	1	1	1	1	1	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0
Org17	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Org18	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	0	0	0	1	1	1	1	0
Acc1	1	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	0	0	0	1
Acc2	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
Int1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Int2	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

B. RANDOM VALUES IN SENSITIVITY ANALYSIS

Random Values of ERs

	Ran1	Ran2	Ran3	Ran4	Ran5	Ran6	Ran7	Ran8	Ran9	Ran10
Man1	9.59	9.93	9.65	9.86	9.63	9.53	10	9.57	9.71	9.98
Man2	9.96	9.92	9.76	9.54	10	9.89	9.65	9.6	10	9.64
Man3	9.82	9.88	9.57	9.94	9.71	10	9.8	10	9.68	9.62
Man4	8	7.6	7.63	7.96	7.65	7.8	8.04	7.93	7.87	7.78
Org1	9.70	10	10	9.57	9.67	9.59	9.77	9.76	9.7	10
Org2	5.72	5.81	5.94	5.75	5.98	5.89	5.91	5.9	6.02	6
Org3	5.92	5.89	5.78	5.74	5.83	5.81	6	5.8	5.9	6.05
Org4	5.97	5.77	5.72	5.76	5.93	5.89	5.83	5.74	5.76	5.94
Org5	3	2.89	2.86	2.95	2.87	2.97	2.92	2.95	2.91	3
Org6	7.93	7.89	7.99	7.66	7.63	7.77	7.89	7.70	7.82	7.92
Org7	5.94	5.76	5.77	5.91	5.89	5.94	5.8	5.75	5.78	6.05
Org8	5.84	5.86	5.74	5.72	5.78	5.75	5.88	5.93	5.97	6.06
Org 9	2.99	2.97	2.89	2.87	2.91	2.86	3	2.97	2.89	2.99
Org10	8.95	8.77	8.83	8.88	8.74	8.68	8.98	8.64	8.87	9.01
Org11	5.75	5.81	5.81	5.95	5.94	5.76	5.99	5.86	5.83	6.01
Org 12	5.92	5.77	5.83	5.72	5.9	5.78	5.96	5.96	5.92	5.96
Org13	5.81	5.97	5.85	5.71	5.92	5.83	5.92	5.85	5.79	6.06
Org 14	2.94	2.86	2.99	2.88	2.94	2.96	2.92	2.88	2.9	3
Org15	5.98	5.74	5.83	5.94	5.73	5.85	5.8	5.86	5.79	5.81
Org16	2.92	2.91	2.98	2.94	2.89	2.88	2.92	2.92	2.94	2.96
Org17	7.90	7.72	7.64	7.99	7.9	7.74	7.69	7.76	7.98	7.85
Org18	2.95	3	2.98	2.95	2.92	2.98	3	2.91	2.95	2.92
Acc1	10.00	9.52	9.96	9.74	9.63	9.56	9.78	9.93	9.92	9.98
Acc2	2.95	2.86	2.87	2.97	2.89	2.97	2.99	2.95	2.9	2.92
Int1	0.00	0	0	0	0	0	0	0	0	0
Int2	0.00	0	0	0	0	0	0	0	0	0
Event 1	9.89	9.68	9.86	10	9.63	9.75	9.95	9.85	9.79	9.63
Event 2	8.99	8.98	8.93	8.74	8.64	8.78	8.95	9.03	8.64	9.02
Event 3	9.91	9.85	9.68	9.92	9.83	9.64	9.84	9.8	9.96	9.75
Event 4	8.85	9	8.97	8.98	8.56	8.6	8.97	8.81	8.79	9
Event 5	8.70	8.55	8.72	8.94	8.7	8.58	8.86	8.74	8.74	8.85
Event 6	8.74	8.78	8.6	8.83	8.98	8.71	8.88	8.71	8.65	8.9

Event 7	8.82	8.9	8.9	8.74	8.57	8.79	8.91	8.92	8.93	8.78
Event 8	7.70	7.78	8.03	7.91	7.75	7.63	8.03	7.83	8	7.73
Event 9	7.88	7.76	7.94	7.79	7.9	7.83	7.9	7.93	8.01	7.91
Event 10	7.69	7.76	7.98	7.6	7.85	7.66	7.86	7.88	7.85	7.8
Event 11	7.62	7.85	7.71	7.95	7.9	7.76	7.86	7.79	7.68	7.89
Event 12	4.96	4.91	4.85	4.95	4.92	4.94	5.02	4.93	4.93	4.75
Event 13	4.87	4.96	4.83	4.87	4.96	4.89	4.93	4.95	4.99	4.76
Event 14	4.96	4.84	4.89	4.95	4.91	4.91	4.97	5.01	4.95	4.82
Event 15	5.92	5.94	5.7	5.91	5.88	5.98	5.93	5.88	5.93	5.93
Event 16	5.94	5.87	5.72	5.71	5.75	6	6.03	5.78	5.81	5.83
Event 17	6.83	6.83	6.71	6.73	6.85	7	6.81	6.7	6.78	6.99
Event 18	5.83	5.99	5.84	5.71	5.91	5.96	5.81	5.78	5.83	6
Event 19	5.70	5.85	5.95	5.78	5.76	5.93	6.02	5.83	5.75	5.89
Event 20	3.89	3.9	3.94	3.86	3.98	3.85	3.89	3.83	3.88	4.02
Event 21	3.93	3.85	3.94	3.96	3.94	3.85	3.92	3.87	3.9	3.99
Event 22	3.93	3.92	3.92	3.86	3.8	3.81	3.89	3.83	3.84	3.92
Event 23	5.95	5.94	5.7	5.84	5.87	5.79	5.79	5.81	5.79	5.98

Random Values of FLRs

	Ran1	**Ran2**	**Ran3**	**Ran4**	**Ran5**	**Ran6**	**Ran7**	**Ran8**	**Ran9**	**Ran10**
Man1	9.53	9.74	10	9.76	10	9.62	9.99	10	9.92	9.78
Man2	9.59	9.62	9.72	9.6	9.9	9.85	9.67	9.61	9.74	9.92
Man3	9.51	9.82	9.99	9.75	9.84	9.71	9.77	9.84	9.88	10
Man4	9.56	9.8	9.72	9.65	9.89	9.75	9.93	9.9	9.92	9.73
Org1	6.75	6.88	6.84	6.94	6.71	6.86	7.02	6.69	6.94	6.76
Org2	7.85	7.94	7.78	7.97	7.77	7.85	7.75	7.86	7.67	7.98
Org3	7.98	7.8	7.68	7.83	7.7	7.92	7.66	7.98	7.67	7.99
Org4	5.93	5.96	5.86	5.79	5.82	5.88	5.81	5.85	5.72	5.75
Org5	8.63	8.68	8.88	8.72	8.61	8.8	8.89	8.59	8.87	8.65
Org6	7.86	7.9	7.9	7.91	7.85	7.88	8	7.91	7.94	7.97
Org7	6.97	6.73	6.97	6.97	6.78	6.92	6.82	6.69	6.7	6.71
Org8	7.88	7.66	7.97	7.63	7.72	7.9	7.92	7.98	7.78	7.67
Org9	4.86	4.84	4.96	4.84	4.91	4.82	4.94	4.78	5	4.79
Org10	8.81	8.95	8.8	8.68	8.97	8.77	8.71	8.99	8.69	8.83
Org11	7.8	7.97	7.81	7.89	7.88	7.89	7.81	7.7	7.89	7.97
Org12	2.9	2.98	2.97	2.88	2.96	2.95	2.9	2.86	2.95	2.95
Org13	9.73	10	9.87	9.64	9.86	9.85	10	9.84	9.84	9.83
Org14	6.66	6.88	7	6.82	6.81	6.93	6.86	6.76	6.98	6.75

Org15	6.97	6.79	6.7	6.83	6.95	6.71	6.77	6.92	6.68	6.82
Org16	9.62	9.68	9.71	9.68	9.53	9.65	9.91	9.99	10	9.75
Org17	5.76	5.94	5.82	5.82	5.78	5.99	5.99	5.97	5.92	5.81
Org18	7.81	7.85	7.7	7.92	7.69	7.68	7.95	7.9	7.74	7.71
Acc1	1.94	1.94	1.96	1.92	1.92	1.98	1.92	1.99	1.99	1.97
Acc2	7.69	7.84	7.89	7.78	7.79	7.85	7.83	7.67	7.87	7.78
Int1	7.99	7.89	7.78	7.89	7.92	7.85	7.99	7.87	7.99	7.73
Int2	8.85	8.84	8.79	8.7	8.88	8.64	8.86	8.59	8.72	8.67
Event 1	7.79	7.78	7.97	7.62	8	7.83	7.78	7.89	7.75	7.85
Event 2	7.77	7.65	7.8	7.91	7.76	7.94	7.67	7.75	7.76	7.8
Event 3	1.94	2	1.96	1.98	1.99	1.92	2	1.91	1.95	1.99
Event 4	5.98	5.97	5.97	5.89	5.91	6.03	5.98	5.94	5.78	5.93
Event 5	8.65	8.71	8.72	8.66	8.8	8.96	8.89	8.71	8.87	8.89
Event 6	7.83	7.73	7.86	7.89	7.88	7.91	7.71	7.88	7.75	7.76
Event 7	7.61	7.97	7.63	7.85	7.89	7.95	7.85	7.75	7.82	7.7
Event 8	7.93	7.74	7.92	7.67	7.92	7.95	7.88	7.75	7.89	7.98
Event 9	7.97	7.96	7.82	7.65	7.63	8	7.98	7.63	7.89	8.02
Event 10	3.97	3.93	3.9	3.98	3.82	3.89	4	3.9	3.95	3.87
Event 11	7.91	7.74	7.87	7.76	7.84	7.93	7.79	7.76	7.99	7.78
Event 12	7.77	7.88	7.63	7.7	7.78	7.69	7.94	7.63	7.9	7.96
Event 13	7.66	7.96	7.93	7.88	7.73	7.77	7.7	7.9	7.65	7.73
Event 14	7.99	7.73	7.74	7.63	7.88	7.67	7.82	7.82	7.75	7.92
Event 15	9.9	9.5	9.58	9.6	9.69	10	9.8	9.61	9.64	9.88
Event 16	9.77	9.77	9.7	10	9.67	9.87	10	9.77	9.73	9.68
Event 17	2.9	2.93	2.91	2.88	2.97	2.97	2.99	2.89	2.98	3
Event 18	7.82	7.63	7.85	7.86	7.74	7.69	7.83	7.93	7.63	7.73
Event 19	7.88	7.95	7.89	7.76	7.72	8.03	7.7	7.64	7.88	8.03
Event 20	8.86	8.63	8.66	8.63	8.83	9.01	8.68	9	8.62	8.86
Event 21	8.72	8.55	8.66	8.69	8.67	8.99	8.77	8.75	8.62	8.95
Event 22	8.57	8.85	8.66	8.71	8.64	8.85	8.75	8.86	8.58	9.03
Event 23	7.96	7.97	7.72	7.68	7.78	7.75	8	7.96	7.71	7.7

Random Values of CRs

	Ran1	**Ran2**	**Ran3**	**Ran4**	**Ran5**	**Ran6**	**Ran7**	**Ran8**	**Ran9**	**Ran10**
Man1	9.57	9.99	9.56	9.57	9.52	10	9.64	10	9.65	9.6
Man2	9.86	9.52	9.7	9.86	9.75	9.67	9.65	9.86	9.77	9.76
Man3	9.75	9.98	10	10	9.61	9.98	9.99	9.88	10	9.93

Man4	10	9.67	9.93	9.79	9.8	9.97	10	9.92	9.89	9.84
Org1	9.82	10	9.57	9.94	9.66	9.79	9.96	9.97	9.8	9.83
Org2	7.84	7.74	7.68	7.61	7.6	7.84	7.71	7.78	7.82	7.96
Org3	8.81	8.69	8.55	8.73	8.8	8.9	9	8.83	8.72	8.95
Org4	7.96	7.98	7.9	7.99	7.63	7.81	7.95	7.88	8.03	7.72
Org5	5.95	5.93	5.92	5.72	6	5.79	5.82	5.92	5.84	5.78
Org6	7.71	8	7.97	7.73	7.82	7.7	7.84	7.78	7.95	7.85
Org7	7.82	7.95	7.67	7.71	7.86	7.85	7.74	7.84	7.78	7.89
Org8	6.97	6.84	6.9	6.78	6.97	6.98	6.75	6.93	7.06	6.84
Org9	9.65	9.51	9.73	9.52	9.72	9.8	9.51	9.82	9.66	9.55
Org10	7.93	7.94	7.63	7.89	7.73	8.03	7.69	7.81	7.83	7.63
Org11	6.97	6.66	6.82	6.92	6.89	7.01	6.69	6.95	7.07	6.91
Org12	8.01	7.88	7.93	7.67	7.98	7.75	7.95	7.93	7.71	7.88
Org13	7.88	7.93	7.91	7.66	7.91	7.93	7.71	7.76	7.75	7.97
Org14	8.99	8.58	8.88	8.82	8.61	8.8	8.99	8.81	9.06	8.82
Org15	6.9	6.94	6.92	6.84	6.8	6.93	6.73	6.99	7.07	6.89
Org16	7.75	7.63	7.65	7.63	7.73	7.91	7.75	7.76	8.05	7.81
Org17	8.89	8.98	8.74	8.78	8.77	9.04	8.88	8.88	8.91	8.8
Org18	6.95	6.88	6.7	6.76	6.7	6.93	6.74	6.95	7.05	6.82
Acc1	1.97	1.99	1.99	1.92	1.93	1.94	1.92	2.02	1.96	1.92
Acc2	6.87	6.99	6.95	6.87	6.94	6.87	7.02	6.9	6.65	6.71
Int1	4.79	4.91	4.88	4.78	4.87	4.94	5.02	4.98	4.91	4.93
Int2	6.97	6.82	7	6.93	6.8	6.91	7	6.79	6.83	6.82
Event 1	9.68	9.64	9.95	9.9	10	9.85	9.8	9.72	9.82	10
Event 2	8.95	8.65	8.85	8.9	8.82	8.82	8.69	9.14	8.94	8.85
Event 3	7.71	7.67	8.01	7.65	7.62	7.94	8	8.1	7.79	7.67
Event 4	8.62	8.61	8.69	8.77	8.78	8.88	8.65	8.74	8.69	8.82
Event 5	7.82	7.69	7.8	7.78	7.86	8.02	7.99	8.09	7.86	7.79
Event 6	8.84	8.88	8.99	8.77	8.79	8.68	8.97	8.9	8.65	8.81
Event 7	8.93	8.65	8.58	8.65	8.7	8.98	9.06	8.89	8.91	8.83
Event 8	7.94	7.9	7.82	7.88	7.65	7.84	7.72	7.77	8.01	7.81
Event 9	7.93	7.81	7.97	7.61	7.73	7.93	7.69	7.95	7.86	7.85
Event 10	6.88	6.67	6.68	6.79	6.78	6.8	6.94	7.02	7.07	6.91
Event 11	7.88	7.88	7.62	7.8	7.96	7.92	8.04	7.88	7.95	7.69
Event 12	5.72	5.76	5.78	5.94	5.96	5.87	5.89	5.98	5.89	5.78
Event 13	5.8	5.79	5.7	5.93	5.73	5.86	6.05	5.88	5.97	5.77
Event 14	5.87	5.78	5.82	5.92	5.89	5.81	5.82	5.97	5.83	5.89
Event 15	7.99	7.88	7.91	7.8	7.73	8.08	7.98	8.12	7.98	7.85
Event 16	7.99	7.98	7.71	7.81	7.98	7.87	7.82	7.88	7.76	7.91
Event 17	5.99	5.71	5.86	5.77	5.81	6.02	5.78	5.97	6.05	5.97

Event 18	6.71	6.73	7	6.89	6.95	6.79	6.91	7.02	7.03	6.67
Event 19	6.69	6.86	6.84	6.87	7	7.07	6.88	6.89	6.92	6.86
Event 20	5.84	5.85	5.77	5.89	5.78	5.83	5.99	6.08	5.81	5.99
Event 21	5.82	5.87	5.97	5.71	5.85	5.96	5.9	6.06	5.81	5.73
Event 22	5.91	5.76	5.81	5.98	5.79	6	5.98	6.1	6.01	5.81
Event 23	6.87	6.75	6.93	6.97	6.97	6.9	7.04	7.1	7.04	6.89

Random Values of TWRs

	Ran1	**Ran2**	**Ran3**	**Ran4**	**Ran5**	**Ran6**	**Ran7**	**Ran8**	**Ran9**	**Ran10**
Man1	9.66	9.83	9.86	9.83	9.86	9.9	9.7	10	9.7	9.53
Man2	9.8	9.61	9.81	9.5	9.74	9.66	9.97	9.64	10	9.76
Man3	9.93	9.77	9.85	10	10	10	9.61	9.75	10	9.7
Man4	10	9.73	9.61	9.81	9.58	9.89	10	9.98	9.86	9.72
Org1	6.76	6.69	6.68	6.77	6.69	6.78	7	6.75	7	6.92
Org2	8.8	8.59	8.67	8.75	8.67	9.01	8.84	8.99	8.85	8.98
Org3	9.51	10	9.64	9.81	9.64	9.85	9.59	9.99	9.81	9.89
Org4	7.65	7.84	7.62	7.61	7.73	7.79	7.95	7.88	7.86	7.84
Org5	7.63	7.6	7.8	7.89	7.67	7.97	7.89	7.86	7.75	7.69
Org6	8.74	8.67	8.84	8.86	8.87	8.68	8.81	9.03	8.98	8.78
Org7	6.84	6.8	6.72	6.99	6.9	7.02	6.87	6.94	6.97	6.75
Org8	7.74	7.67	7.86	7.88	7.87	7.85	8	8.02	8	8.03
Org9	8.59	8.81	8.75	8.83	8.78	8.61	8.87	8.76	8.82	8.77
Org10	9.99	9.53	9.88	9.93	9.86	9.81	9.72	9.83	9.82	9.64
Org11	7.85	7.92	7.8	7.71	7.85	7.92	7.63	7.76	7.72	7.89
Org12	7.76	7.81	7.72	7.93	7.69	7.65	7.63	7.83	7.74	7.94
Org13	6.78	6.98	6.98	6.88	6.88	6.73	6.87	6.7	6.75	6.96
Org14	7.65	7.69	7.81	7.75	7.86	7.66	7.78	7.87	7.64	7.89
Org15	7.68	7.88	7.87	7.7	7.8	7.73	7.84	7.78	7.83	7.82
Org16	8.81	8.83	8.9	8.85	8.96	8.91	8.68	8.81	8.67	8.72
Org17	6.84	6.7	6.65	6.78	6.82	6.87	6.67	6.81	6.7	7.05
Org18	7.69	7.67	7.7	7.66	7.73	7.86	7.67	7.92	7.62	7.91
Acc1	1.94	1.98	1.95	1.99	1.98	1.96	1.94	1.99	1.99	1.94
Acc2	6.99	6.87	6.86	6.89	6.96	6.76	6.8	6.99	6.66	6.86
Int1	7.73	7.88	8	7.63	7.81	7.74	8	7.81	7.82	7.9
Int2	7.91	7.81	7.78	7.84	7.77	8.02	7.83	7.93	7.95	7.8
Event 1	9.89	9.54	10	9.7	9.59	9.97	9.53	9.93	9.81	10
Event 2	8.92	8.85	8.98	8.95	8.68	8.82	8.88	9.02	8.63	8.81

Event 3	8.67	8.64	8.92	8.96	8.58	8.79	8.69	8.72	8.7	8.78
Event 4	8.8	8.85	8.64	8.92	8.68	8.97	8.62	8.86	8.98	8.68
Event 5	8.73	8.68	8.87	8.74	8.6	8.94	8.66	8.77	8.99	9.04
Event 6	7.78	7.86	7.72	7.75	7.65	7.77	7.97	7.96	7.98	7.74
Event 7	7.77	7.97	7.64	7.73	7.62	7.99	7.83	7.85	7.9	7.94
Event 8	6.98	6.89	6.74	6.9	6.9	6.9	6.67	6.9	6.96	6.81
Event 9	6.84	6.83	6.92	6.79	6.7	6.91	6.75	6.83	6.77	7.06
Event 10	7.97	7.76	7.61	8	7.71	7.76	7.63	8.02	7.96	7.9
Event 11	7.85	7.85	7.86	7.95	7.9	7.72	7.65	7.69	7.62	7.95
Event 12	4.93	4.85	4.8	4.93	4.95	4.83	4.77	4.81	4.77	4.95
Event 13	4.86	4.86	4.76	4.98	4.79	4.87	4.94	4.91	4.99	4.83
Event 14	4.84	4.85	4.82	4.82	4.93	4.78	4.84	5.02	4.9	4.87
Event 15	6.94	6.89	6.71	6.75	6.87	6.97	6.79	6.95	6.97	6.82
Event 16	6.72	6.94	6.69	6.99	6.78	6.76	6.83	6.77	6.9	6.77
Event 17	5.94	5.9	5.92	5.91	5.86	5.75	5.75	5.86	5.95	6
Event 18	7.92	7.67	7.87	7.84	7.74	7.84	7.97	7.86	8.01	7.96
Event 19	7.93	7.87	7.73	7.74	7.66	7.85	7.77	7.99	7.74	8.02
Event 20	5.97	5.75	5.75	5.75	5.96	5.78	5.9	6.01	5.77	5.94
Event 21	5.99	5.85	5.96	5.87	5.99	5.86	5.83	5.95	5.8	6.03
Event 22	5.81	5.89	5.92	5.77	5.97	5.89	5.85	5.99	5.95	6
Event 23	6.69	6.82	6.67	6.95	6.8	6.8	6.85	6.84	6.83	6.95

Random Values of EIRs

	Ran1	**Ran2**	**Ran3**	**Ran4**	**Ran5**	**Ran6**	**Ran7**	**Ran8**	**Ran9**	**Ran10**
Man1	9.56	10	10	9.71	10	9.9	9.9	9.9	10	9.9
Man2	9.56	9.54	9.85	10	9.69	9.7	9.7	9.7	9.88	9.77
Man3	9.72	9.83	9.84	9.63	9.68	10	10	10	9.79	9.85
Man4	9.69	9.55	9.84	9.88	9.72	9.99	9.99	9.99	9.75	10
Org1	6.88	6.8	6.78	6.8	6.91	6.84	6.84	6.84	6.77	6.99
Org2	7	6.75	6.9	6.71	6.73	6.72	6.72	6.72	6.79	7.04
Org3	7.62	7.86	7.73	7.88	7.92	7.88	7.88	7.88	7.76	7.87
Org4	6.79	6.69	6.73	6.85	6.95	6.91	6.91	6.91	6.84	6.82
Org5	7.69	7.68	7.95	7.85	7.6	7.68	7.68	7.68	7.99	7.86
Org6	7.64	7.65	7.93	7.8	7.89	7.79	7.79	7.79	7.79	8.03
Org7	6.73	6.71	6.7	6.78	6.93	6.91	6.91	6.91	6.67	6.79
Org8	8.81	8.73	8.87	8.89	8.74	9.06	9.06	9.06	8.9	9.09
Org9	7.91	7.83	7.73	7.71	7.95	7.92	7.92	7.92	7.83	7.91
Org10	10	9.76	9.97	9.64	9.66	9.78	9.78	9.78	9.53	9.87

Org11	7.86	7.64	7.77	7.66	7.69	8.04	8.04	8.04	8	8.09
Org12	7.63	7.6	7.9	7.83	7.71	7.71	7.71	7.71	7.95	7.99
Org13	5.91	5.73	5.77	5.83	5.7	6.02	6.02	6.02	5.91	5.95
Org14	8.74	8.59	8.81	8.87	8.74	9.06	9.06	9.06	8.91	9.12
Org15	7.71	7.62	7.65	7.94	7.62	7.86	7.86	7.86	7.8	8.12
Org16	7.73	7.61	7.76	7.62	7.75	7.77	7.77	7.77	7.86	7.77
Org17	6.9	6.69	6.92	6.67	6.99	6.9	6.9	6.9	6.8	6.99
Org18	7.75	7.7	7.84	7.74	7.68	7.8	7.8	7.8	7.97	8.01
Acc1	2.93	2.99	2.95	3	2.87	2.98	2.98	2.98	2.94	3.03
Acc2	7.63	7.81	7.99	7.64	7.83	7.8	7.8	7.8	7.84	7.8
Int1	6	5.93	5.91	5.87	5.8	5.81	5.81	5.81	5.79	5.83
Int2	6.91	6.7	6.68	6.71	6.66	6.9	6.9	6.9	6.7	6.8
Event 1	8.83	8.91	8.73	8.72	8.71	8.93	8.93	8.93	8.82	8.81
Event 2	6.85	6.72	6.92	6.99	6.96	6.93	6.93	6.93	6.88	7.08
Event 3	6.75	6.89	6.98	6.92	6.94	6.88	6.88	6.88	6.78	6.98
Event 4	7.67	7.77	7.71	7.64	7.93	7.7	7.7	7.7	7.66	7.87
Event 5	6.68	6.91	6.9	6.95	6.7	6.91	6.91	6.91	6.87	7.11
Event 6	8.92	8.68	8.99	8.9	8.8	8.75	8.75	8.75	8.69	8.89
Event 7	8.82	8.78	8.77	8.75	8.75	8.67	8.67	8.67	8.98	9.01
Event 8	6.95	6.89	6.96	6.99	6.85	6.77	6.77	6.77	6.9	6.78
Event 9	6.8	6.79	6.87	6.67	6.73	6.98	6.98	6.98	6.91	7.09
Event 10	6.94	6.72	6.98	6.75	6.69	7	7	7	6.83	6.78
Event 11	6.82	6.82	6.7	6.85	6.66	6.93	6.93	6.93	6.94	6.95
Event 12	4.94	4.84	4.91	4.8	4.76	4.81	4.81	4.81	4.85	4.86
Event 13	4.88	4.82	4.8	4.8	4.88	4.9	4.9	4.9	4.91	4.88
Event 14	4.94	4.97	4.81	4.8	4.79	4.93	4.93	4.93	4.96	5.08
Event 15	6.97	6.99	6.7	6.85	6.98	6.75	6.75	6.75	6.89	6.85
Event 16	6.87	6.82	6.71	6.78	6.68	6.97	6.97	6.97	6.84	6.96
Event 17	5.79	5.93	5.8	5.84	5.72	5.92	5.92	5.92	5.83	6.09
Event 18	6.69	6.71	6.77	6.73	6.93	6.73	6.73	6.73	6.72	7.02
Event 19	6.96	6.82	6.69	6.74	6.93	6.84	6.84	6.84	6.99	6.85
Event 20	5.81	5.98	5.89	5.96	5.83	6.02	6.02	6.02	5.97	6.03
Event 21	5.76	5.77	5.82	5.88	5.87	6.04	6.04	6.04	5.98	5.86
Event 22	5.9	5.88	5.84	5.87	5.88	5.78	5.78	5.78	5.96	5.97
Event 23	6.89	6.73	7	6.79	6.79	6.76	6.76	6.76	6.78	7.04

C. TURKISH SUMMARY / TÜRKÇE ÖZET

GİRİŞ

Çalışan çizelgeleme problemleri karar verme biliminin en popüler konularından biridir. Bu konuda çok sayıda çalışma ve araştırma olmasına rağmen gerçek hayattaki organizasyonlar sistematik bir çalışan çizelgelemesi modeli kullanmamaktadır. Bunun yerine geçici metotlar kullanma eğilimindedirler. Genellikle şirketlerdeki karar vericiler sadece çalışan kısıtlarını göz önünde bulunduran bir planlama oluşturmayı hedeflerler ve olurlu bir çalışan çizelgelemesini kabul ederler. Çalışan çizelgelemesinin zorluğu ve karmaşasına rağmen karar vericiler kendi oluşturdukları olurlu çizelgeleme yerine bir en iyileme modeli kullanarak en iyi bir çizelge elde edebilirler. Zorluk ve karmaşıklık nedeniyle en iyi çizelgelemeyi elde edemeseler bile bir çalışan çizelgeleme modeli kullanarak daha kötü bir plan elde etmeyecekleri kesindir. Daha iyi işçi programlaması personel maliyetlerini azaltmaktadır ki bu da şirketin pazar yerinde rekabet üstünlüğü kazanmasını sağlar. Daha iyi bir çalışan çizelgelemesi giderlere ek olarak çalışanların memnuniyetlerini ve hatta servis şirketlerinin servis kalitesini artırmaktadır.

Karşılama sektörü, çalışanlar ve müşteriler arasında bir hayli sosyal etkileşim içeren bir hizmet sektörüdür. Karşılama sektörü altında konaklama, restoranlar ve turizm gibi birçok sektör bulunmaktadır. Karşılama sektörünü temel amacı; karşılama, ilgilenme, hizmet ve iletişimle müşterilerin ihtiyaçlarını karşılamaktır. Müşteri memnuniyeti, karşılama sektörünün temelini oluşturmaktadır. Kongre organizasyon şirketleri; bazı derneklerin, kolejlerin, derneklerin veya toplulukların kongrelerini veya etkinliklerini organize etmektedirler. Genellikle, bir organizasyon şirketi etkinliklerin veya kongrelerin nerede yer alacağını belirlemektedir. Etkinlikler veya kongreler boyunca organizasyon şirketlerinin çalışanları, katılımcıları karşılayarak, onlarla ilgilenerek ve iletişim kurarak memnun etmeye çalışmaktadırlar. Sektördeki

kongre ve etkinlik organizasyonu şirketlerine odaklanmamıza rağmen çalışmamız, karşılama sektöründeki bütün şirketlere yol göstermektedir.

Literatürdeki çalışan çizelgeleme sorununa yaklaşım genelde maliyet azaltmaya odaklansa da, bizim çalışmamız çalışan maliyetinin yanı sıra çalışan becerileri ile işlerin karmaşıklığı arasındaki eşleşmeyi sağlamayı da hedeflemektedir. İki amaç için ayrı ayrı iki matematiksel model bu çalışmada karma tamsayılı programlama metoduyla oluşturulmuştur. Amaç fonksiyonlarından bir tanesi maliyetken diğeri çalışanların becerisi ile işlerin karmaşıklığı arasındaki eşleşme olup kalite olarak tanımlanabilir. İki en iyi çözüm bu matematiksel modellerin sonucu olarak elde edilmiştir. Ayrıca, en iyi çözümlerin haricinde iki amacı aynı anda göz önünde bulunduran alternatif çözümler sunulmaktadır. Çözüm metodu, bir konaklama sektörü şirketinde uygulanmıştır. Şirketin çalışan çizelgesi bu çalışmada oluşturulan matematiksel model ile elde edilmiştir. Elde edilen çizelge, firmanın mevcut çizelgesiyle karşılaştırılmıştır.

Ernst ve diğerleri (2004); çalışan çizelgeleme için tasarlanan bir karar destek sisteminin şirketlere büyük fayda sağlayabileceğini belirtmiştir. Çalışmamızda karar vericiye çalışan çizelgelemesi oluşturulmasında yardımcı olan bir karar destek sistemi tasarlanmıştır. Karar destek sistemi iki amaç için en iyi çizelgeleri ayrı ayrı bulmakta ve sonrasında bu çizelgeleri karşılaştırmaktadır**.** Bunun ötesinde_karar verici, çalışmamızda üçüncü amaç olarak ifade edilebilen çalışanlar arasındaki iş yükü dengesi seviyesini de belirleyebilmektedir. Karar destek sistemi maliyet ve kalite amaçları doğrultusunda en iyi çözümleri bulmasının yanı sıra, karar vericiye iki amacı aynı anda göz önünde bulunduran alternatif çözümler sunmaktadır.

LİTERATÜR TARAMASI

Bu bölümde geçmiş çalışmalar gözden geçirilmiştir. Bu tarama üç bölüme ayrılmıştır. Bu bölümler çalışan çizelgeleme metotları, karşılama sektöründeki kalite kriterleri ve ağırlıklandırma metotlarıdır.

Çalışan Çizelgeleme Metotları

Ernst ve diğerleri (2004) literatürde büyük çaplı bir çalışan çizelgeleme problemleri incelemesi sunmaktadır. İncelemelerini üç boyuta dayandırmışlardır. İlk olarak, çalışan çizelgeleme problemlerini problem türlerine göre sınıflandırmaktadırlar. Çalışan çizelgeleme problemlerini; talep modellemesi, izinli günler çizelgelemesi, vardiya çizelgelemesi, iş yapılandırması, görev ataması ve personel ataması olmak üzere altı modülde karakterize etmişlerdir. İkinci olarak, çalışan çizelgeleme yöntemlerinin en yaygın uygulama alanlarını tanıtırlar. Bahsettikleri her uygulama alanında önemli çalışmalar sağlarlar. Son olarak, Ernst ve diğerleri (2004) literatürde çalışan çizelgeleme teknik ve metotlarını gözden geçirmişlerdir. İncelemelerine göre en çok yaygın olan çözüm teknikleri matematiksel programlama, sezgisel ve kısıt programlamadır. Bu tekniklerin hangi problem tiplerinde kullanılabileceğini yorumlamışlardır.

Knighton (2005), maliyetleri en aza indirgemek için matematiksel bir programlama yaklaşımı ile bir personel turu çizelgeleme problemi çözümü sunmaktadır. Yazar özelleştirilmiş kısıtları göz önünde bulundurarak en iyi çalışan çizelgesini bulmak amacıyla doğrusal programlama modeli geliştirmiştir. Yazar farklı yetenekteki ve farklı ücretlere sahip çalışanları turlara atamaya çalışmaktadır.

Problemlerini Ernst ve diğerleri (2004) yardımıyla analiz ettikten sonra Stollerz ve Zamorano(2014) çoklu becerilere sahip çalışanlar için tur çizelgeleme problemini en iyilemek için bir karma tamsayılı programlama modeli önermektedir. Talep ve iş düzenlemelerini göz önünde bulundurarak atama maliyetlerini en aza indirgemeyi amaçlamaktadırlar. Stollerz ve Zamorano(2014) beceri çeşitliliği nedeniyle sorunun karmaşıklığının karma tamsayılı programlama modelinin makul sürede bir çözüm vermesini imkânsız kıldığını belirtmektedir. Bu sebeple araştırmacılar problemlerini çözmek için sezgisel bir metot geliştirmişlerdir.

Fırat ve Hurkens (2011) karma tamsayılı programlarında bir üretim sektörü sorunu üzerinde durmalarına rağmen araştırmaları çalışan çizelgeleme problemleri

çözümüne ilham vermektedir. Fırat ve Hurkens (2011) teknisyenlerin görevlere en uygun şekilde atanmasını sağlamak için bir karma tamsayı programı geliştirmiştir. Araştırmacılar kendilerine verilen bir dizi görev ve bir grup teknisyeni kendi aralarında eşleştirirken çalışan maliyetlerini azaltmayı hedeflemektedirler. Her görevin beceri gereksinimi birbirinden farklılık göstermektedir. Dahası, bütün teknisyenler farklı becerilere sahiptir. Araştırmacılar, çizelgeleme modelleri için geliştirdikleri karma tamsayı programlamasının makul bir zamanda çözüm sağlayamamasını problemin NP-zor olmasına bağlamaktadırlar. Daha sonrasında, meta-sezgisel bir yöntem geliştirmişlerdir.

Sadykov ve Wolsey (2003) çok makineli atama problemine tam sayılı programla yöntemiyle yaklaşmaktadırlar. Amaçları, serbest bırakılma tarihleri kısıtlarını göz önünde bulundurarak işleri makinelere maliyeti en aza indirgeyecek şekilde atamaktır. Sadykov ve Wolsey (2003) bir dizi işi makinelere atamaya çalışmaktadırlar. Makine atama problemleri ile çalışan çizelgeleme problemleri birbirlerine mantıksal olarak benzemektedir.

Knighton (2005) ile çalışmamız arasında bazı benzerlikler bulunmaktadır. En önemli benzerlik, problemlerdeki çalışanların farklı yeteneklere ve farklı ücretlere sahip olmasıdır. İkinci olarak, her iki çalışmada da her bir etkinlik veya vardiya için gerekli olan çalışan sayısı önceden belirlenmiştir. Son benzerlik ise iki çalışmada da çalışan çizelgelerinin yıllık olarak oluşturulmasıdır. Stollerz ve Zamorano (2014) nun oluşturmuş olduğu karma tamsayılı programlama modeli ve Sadykov ve Wolsey (2003) ün oluşturmuş olduğu tamsayılı programlama modeli, çalışmamızda önerdiğimiz modele ilham vermektedir. Bu modeller kısıtlar, amaçlar ve mantıksal açıdan birbirlerine benzemektedir. Son olarak çalışmamızda göz önünde bulundurduğumuz etkinliklerin yetenek gereksinimleri farklılıkları ve çalışanların yetenek farklılıkları, Fırat ve Hurkens (2011) deki farklılıkları anımsatmaktadır. Çalışmamızda Fırat ve Hurkens (2011) den esinlenilmiştir.

Karşılama Sektöründeki Kalite Kriterleri

Hughes ve Rog (2008) beceri yönetiminin konaklama şirketleri için önemini açıklamayı amaçlamaktadır. Beceri yönetiminin birçok tanımı olsa da basitçe işin veya çalışanların planlanması olarak algılanabilir. İş planlaması yapmak, üzerinde düşünülesi birçok faktörü barındıran bir konudur. Çalışanın yeteneklerinin işin gerektirdiği özelliklerle örtüşmesi bu faktörlerden biridir. Bu örtüşme, şirketlerde başarılı bir iş planlaması yapıldığını işaret etmektedir. Hughes ve Rog'a göre etkili bir iş planlaması, çalışanların kendini önemli hissetmesine ve işe kendilerini vermelerine ön ayak olmaktadır. Aynı zamanda işini severek yapan çalışanlar uzun vadede firmaların performansını artırmaktadır.

Turizm ve konaklama sektörü, çalışanlar ve müşteriler arasında yoğun bir sosyal etkileşim yaratmaktadır. Somut bir ürün olmadığından dolayı servis kalitesi müşterilerin kafasında oluşan imaj ile değerlendirilebilir. Spielmann ve diğerleri (2012) müşterilerde iyi bir izlenim bırakma açısından konaklama servislerindeki sosyal etkileşimin önemine vurgu yapmaktadır. Müşterilerde oluşabilecek kötü imajlara sebep olan faktörleri engellemek amacıyla bir ölçek öne sürmektedirler. Bu ölçeğin yardımıyla sosyal etkileşimin kritik bir rol oynadığı görülebilmektedir. Spielmann ve diğerlerine (2012) ek olarak Baum ve diğerleri (1997) de konaklama şirketlerinde iş alanındaki sosyal etkileşim sayesinde müşterilerin beklentilerini karşılama konusunda insan faktörünün ana odak olması gerektiğini vurgulamaktadır.

Bhattacharya ve diğerleri (2005) firmaların performansları ve insan kaynaklarındaki esnekliği tartışmaktadır. Araştırmacılar, çalışan becerilerinin, çalışan davranışlarının ve insan kaynakları uygulamaları esnekliğinin firmanın finansal performansıyla pozitif ilişkili olduğunu iddia etmektedir. Çalışan davranış esnekliği, çalışan davranışlarını farklı tip isteklere göre değiştirebilme yeteneği anlamına gelmektedir. Firmaların finansal performansının çalışanların davranış esnekliğiyle arttığını belirten Bhattacharya ve diğerleri (2005) çalışanların işlere adaptasyonunun çalışanların kişisel özellikleri ile işlerin gereksinimlerinin eşleşmesiyle başarılabileceğini savunmaktadır.

Duygusal zekâ, zihinsel sağlık ve kişisel ilişkiler üzerinde büyük etkisi olan psikolojinin en popüler konularından biridir. Duygusal zekâ ve mesleki ilişkiler arasındaki bağlantı ile ilgili birçok çalışma yapılmıştır. Bu çalışmaların birinde, Nikolaou ve Tsaousis (2002) duygusal zekâ ile mesleki stres arasında güçlü bir bağ olduğunu bulmuşlardır. Çalışanların duygularını ve stres seviyelerini daha iyi yönetmelerinin sonucunda organizasyondaki etkileşimleri daha güvenilir hale gelmiştir. Dahası, Nikolaou ve Tsaousis (2002) çalışmasına göre yüksel duygusal zekâya sahip çalışanların performansları organizasyonda stresli bir pozisyona atandıklarında artabilmektedir. Nikolaou ve Tsaousis (2002) gibi Kim ve diğerleri (2012) de duygusal zekânın çalışanların ağırlama ve karşılama işyerinde başarılı olmalarına yardımcı olduğunu göstermektedir.

Konaklama sektörü, insan faktörünün öne çıkmasına yol açan servis ağırlıklı bir sektördür. Bu sektörde; çalışanların beceri, nitelik ve kalitesi firmaların performanslarında büyük rol oynamaktadır. Hai-yan ve Baum (2006) konaklama sektöründe kritik kişisel becerilerin Çin'deki otellerde yapılan bir araştırma ile belirlenmesini amaçlamaktadırlar. Pekin, Tianjin, Şangay, Jinan, Qingdao ve Weihai gibi turistik şehirlerdeki otellerde oluşturdukları anketi uygulamışlardır. Anket sonuçlarını topladıktan ve analiz ettikten sonra, Hai-yan ve Baum (2006), iletişim becerilerinin, mesleki ve etik standartların ve ekip çalışması becerilerinin konaklama sektöründe en önemli çalışan becerileri olduğunu bulmuşlardır.

Kusluvan ve diğerlerine (2010) göre insan kaynakları, konaklama sektörünün en önemli varlıklarından biridir. Hizmet kalitesi ve müşteri memnuniyetinde önemli rol oynayan, çalışan performansını artırmak için konaklama sektöründe insan kaynakları yönetimi konularının bir incelemesini yürütmektedirler. İncelemelerinde, araştırmacılar çalışanların kişilik özelliklerini ve duygusal zekâsını vurgulamaktadırlar. Çalışanların kişiliği ve duygusal zekâsı konaklama sektöründeki sosyal etkileşimi ve davranışları etkilemektedir. Kusluvan ve diğerleri (2010) çalışanların kişilikleri hakkındaki önceki çalışmaları derlemekte ve dürüstlük ile uzlaşmacılığın çalışan performansını artıran en yaygın özellikler olduğunu iddia

etmektedirler. Hem dürüstlük hem de uzlaşmacılık, turizm ve konaklama sektöründe iyi bir iletişime katkı sağlayan özelliklerdir. Araştırmacılar, çalışan performansında bir diğer kritik olan duygusal zekâ ile ilgilenmektedirler. Kapsamlı incelemelerinin sonucu olarak, çalışanları duygusal zekâsı arttıkça müşteri memnuniyetinin arttığını bulmuşlardır.

Konaklama işyerlerinde çalışanların becerileri sorunları Baum (2002) çalışmasında ele alınmıştır. Araştırmacı, ağırlama işyerlerinin diğer alanlara nazaran daha dar ekonomiler olduğuna dair bir önyargıya rağmen, konaklama sektörünün pazardaki önemini belirttikten sonra önde gelen çalışan becerilerini bulmaya çalışmaktadır. Baum (2002), konaklama sektöründeki başta gelen çalışan özelliklerini şöyle özetlemektedir: iletişim becerileri, deneyim bilgi teknolojisi, takım çalışması ve öğrenme ve performans geliştirme. Temel becerileri ele aldıktan sonra, araştırmacı organizasyonlarda bu becerileri geliştirmek için bazı yollar sunmaktadır.

Saleh ve Ryan (1991) çalışmasında belirtildiği gibi, servis sektöründeki müşterilerin beklentilerinin karşılanması sayesinde kaliteli olarak algılanır. Karşılama sektöründe müşterilerin beklentilerini tespit edebilmek için geniş bir literatür araştırması yapılmıştır. Bu araştırma sonucunda tespit edilen en önemli kalite faktörleri iletişim becerisi, takım çalışması ve duygusal zeka olarak tespit edilmiştir.

Ağırlıklama Metotları

Kalite anlamında daha iyi bir program oluşturmak için önemine bağlı olarak görevlerin ağırlığını belirlemek çok önemlidir. Görev ağırlığını doğru belirlemenin yardımıyla matematiksel model, nitelikli çalışanların daha önemli görevleri üstlenmesine olanak sağlamaktadır. Bu, müşteri memnuniyetinde kritik bir önem taşımaktadır. Öncelikle, Wang ve Luo (2010) çoklu ve nitelikli karar alma alanında yoğunluk belirlemesi için bazı yaklaşımlar öne sürmektedir. Araştırmacılar iş yoğunluğu konusunu basitçe üç ana kategoriye ayırmıştır: sübjektif yoğunluk, objektif yoğunluk ve çok yönlü yaklaşım. Doğrudan derecelendirme ve puan dağıtma en yaygın sübjektif yoğunluk belirleme metotlarından bazılarıdır. Bottomley ve

diğerleri (2000) doğrudan derecelendirme ve puan dağıtma metotları için net bir tanım belirlemiştir. Doğrudan derecelendirme, her alternatifi sıfırdan yüze bir ölçek üzerinden derecelendirmektir. Öte yandan puan dağıtma, toplam yüz puanı alternatiflere paylaştırmaktır. Wang ve Luo'ya (2000) göre, karar vericiye ulaşmanın zorluğundan dolayı her zaman sübjektif yoğunluk belirleme metotlarını uygulamak imkânsızdır. Araştırmamızda, karar vericiyle iletişime geçmek ve karar vericinin fikirlerini almak kolay olduğundan sübjektif yoğunluk belirleme metodu kullanılmaktadır. Keeney ve diğerleri (2006) Amerika'daki akademik programları değerlendirme araştırmalarında puan dağıtma metodunu kullansa da; Bottomley ve diğerlerinin (2000) doğrudan derecelendirme metodunun daha kesin sonuçlar verdiğini belirtmesi nedeniyle çalışmamızda doğrudan derecelendirme metodu kullanılmaktadır. İnsanlar dağıtılacak kaç puan kaldığını düşündüğünde puanları objektif dağıtamadığı için böyle bir yaklaşım sergilenmiştir.

Roszkowska (2013), alternatifler arasındaki sıralamayı sayısal ağırlıklara dönüştüren birkaç ağırlıklandırma metodunu gözden geçirmektedir. Yazarın sunduğu ağırlıklandırma metotları; eşit ağırlık metodu, sıra toplam ağırlıklandırma metodu, sıra üs ağırlıklandırma metodu, ters veya karşılıklı ağılıklandırma ve ROC ağırlıklandırma olarak sıralanabilmektedir. Eşit ağırlık metodu, karar verici alternatiflerle ilgili öncelikler hakkında çok az bilgiye sahip olduğu zaman kullanılmaktadır. Alternatiflerin ağırlığı, alternatiflerin sayısına göre belirlenmektedir. Örneğin; uygun üç alternatif varsa, alternatiflerin ağırlıkları 1/3 olarak hesaplanmaktadır. Sıra toplamı ağırlıkları, alternatiflerin sıraların her birini sıra toplamına bölerek normalleştirme ile hesaplanmaktadır. Sıra üs ağırlıklandırma metodu, sıra toplamı ağırlıklandırma metoduyla aynıdır. Fark, karar vericinin en önemli alternatiflerin ağırlığını belirleyebilmesidir. Diğer alternatiflerin ağırlığı, en önemli alternatife göre hesaplanmaktadır. ROC metodu, önem sırasını koruyarak tüm alternatif noktaların kütle merkezini belirterek ağırlıkların maksimum hatasını en aza indirmektedir. Roszkowska (2013) gibi Ahn (2011) de ROC metodunu sunmaktadır.

Çalışmamızda doğrudan derecelendirme metodu kullanılmıştır. Bunun nedeni karar vericinin tercihi ve bu yöntemin Bottemley ve diğerleri (2000) çalışmasında belirtilen avantajlarıdır.

YAKLAŞIM

Çalışmamızda karşılama ve ağırlama sektörü için, maliyet, kalite ve dengeli iş yükü dağılımını göz önünde bulundurarak çalışan atama problemini ele aldık. Çalışmamızın kapsamı çeşitli yeteneklerdeki çalışanların, çeşitli özelliklerdeki etkinliklere atanmasıdır.

Ele aldığımız problemde temel olarak iki parametre bulunmaktadır. Bunlar çalışanların ve etkinliklerin özellikleridir. Etkinliklerin içerikleri, gereksinimleri ve firmalar açısından önemleri birbirinden farklı olabilir. Çalışmamızda bu farklılıklar göz önünde bulundurulmaktadır. Çalışanlar görev tanımlarına göre dört kategoriye ayrılmıştır. Bunlar, yöneticiler, organizatörler, muhasebeciler ve stajyerler olarak sıralanabilir. Bu kategoriler belirlenirken sektördeki firmaların genel olarak hangi görev tanımlarını kullandıkları öğrenilmiştir. Çalışanların yetkinlikleri ve maaşları da birbirinden farklı olabilir, çalışmamızda bu farklılıklara imkân tanınmıştır.

Çalışmamızın üç amacından ikisi maliyet ve kalite, karma tamsayılı programlama yönetimi kullanarak oluşturduğumuz matematiksel modellerin amaçlarıdır. Dengeli iş yükü dağılımı ise modellere kısıt olarak eklenmiştir. Çizelge maliyeti her bir etkinliğe katılan çalışanlara ödenecek ücret olarak tanımlanmıştır. Kaliteyi amaç fonksiyonu olarak tanımlamak için karşılama ve ağırlama sektöründe kaliteyi etkileyen faktörler literatürde taranmıştır. Yapılan taramalar sonucunda tecrübe, yabancı dil bilgisi, iletişim becerisi, takım çalışması becerisi ve duygusal zekâ karşılama ve ağırlama sektöründe hizmet kalitesini belirleyen ana faktörler olarak belirlenmiştir. Bu faktörler belirlendikten sonra oluşturulacak çizelgenin kalitesini simgeleyen bir kalite puanı hesaplanması tanımlanmıştır. Bu kalite puanının hesaplanması için öncelikle çalışanların ve etkinliklerin belirlenen kalite faktörleri açısından 0 ile 10 arasında puanlanması gerekmektedir. Daha sonra etkinliklere

atanan çalışanların yetenek puanlarıyla atandıkları etkinliklerin karmaşıklık puanları çarpılarak bir puan elde edilmektedir. Bu puan tek başına bir ifade etmese de bu puanın yüksek olması, daha zor ve karmaşık işlere daha yetenekli ve becerili çalışanların atanması anlamına gelmektedir. Tanımlanan kalite puanını en büyükleyecek ve maliyeti en küçükleyecek iki adet matematiksel model oluşturulmuştur. En son olarak, karar vericiye yardım etmek amacıyla bir karar destek sistemi tasarlanmış ve önerilen çözüm yönetimi bu karar destek sistemi ile bütünleştirilmiştir.

DENEYLER

Bu bölümde önerilen çözüm yöntemi karşılama ve ağırlama sektöründe yer alan bir Türk firmasında uygulanmıştır. Firmanın 2019 yılı çalışan çizelgesi oluşturulmak hedeflenmiştir. Bu doğrultuda firmadaki karar vericiden firmaya ait çalışanların belirlenen kalite faktörleri puanları, maaşları, görev tanımları, etkinliklere ait kalite faktörleri puanları, etkinlik tarihleri, etkinlikler için gerekli minimum personel sayıları ve etkinliklerin firma için önemleri temin edilmiştir. Etkinliklerin firma için önemleri, kalite faktörleri puanlaması gibi 0 ile 10 arasında doğrudan puanlama metodu ile yapılmıştır.

Elde edilen veriler ile çözümler alınmadan önce firmanın firma politikası olarak benimsediği ek bir kısıt modele eklenmiştir. Bu politikaya göre firma bazı etkinliklere tecrübe kısıtlaması getirmek istemektedir. Firma bazı etkinlikler için iki yıldan daha az tecrübeli organizatör atamalarını kısıtlamak istemektedir. Firmanın bu özel kısıtı kalite en büyüklemesi ve maliyet en küçüklemesi modellerine eklendikten sonra modeller çözülmüştür.

SONUÇLAR VE TARTIŞMA

Bu kısımda firmadan alınan verilerle CPLEX OPL v12.8 yazılımında çözülen matematiksel modellerin sonuçları sunulmaktadır. İlk olarak maliyet en küçükleme ve kalite en büyükleme modellerinin optimal sonuçları detaylarıyla birlikte gösterilecektir. Daha sonra, iki modelin optimal sonuçlarına ek olarak bu iki amacı

aynı anda gözeten dört adet alternatif çözüm sunulacaktır. Problemimizdeki üçüncü amacımız olan çalışanlar arasındaki eşit iş yükü dağılımının maliyet üzerindeki etkisi analiz edilerek iki parametre arasındaki ödünleşim tartışılacaktır. Son olarak, firmanın kullandığı mevcut çalışan çizelgesi ile çalışmamızda önerdiğimiz çözüm yöntemi aracılığıyla ürettiğimiz çalışan çizelgeleri karşılaştırılacaktır.

Maliyet En Küçükleme Modeli Çözümü

2. kısımda oluşturulan maliyet en küçükleme matematiksel modeli çözdürülmüş ve optimal bir çözüm bulunmuştur. Optimal çözümün amaç fonksiyon değeri yani firmanın 2019 yılı çalışan çizelgesinin en küçük maliyeti 84.850 TL olarak bulunmuştur. Bu çözümde çalışmamızdaki diğer amacımız kalite değeri ise 278.000 olarak hesaplanmıştır. Optimizasyon yazılımı oluşturduğumuz matematiksel modeli 5,92 saniye gibi makul bir sürede çözebilmiştir.

Kalite En Büyükleme Modeli Çözümü

Oluşturduğumuz kalite en büyükleme modeli de, maliyet en küçükleme modeli gibi firmadan aldığımız veriler çözdürülmüş ve optimal bir çözüm bulunmuştur. Bulunan çözümün amaç fonksiyonu değeri, yani kalite değeri 524.423,5 olarak hesaplanmıştır. Bu çözümdeki çizelge maliyeti ise 221.280 TL olarak hesaplanmıştır. Optimizasyon yazılımı kalite en büyükleme modelini 2,31 saniyede çözmüştür.

Dengeli İş Yükü Dağılımı – Maliyet Analizi

Ele aldığımız çalışan çizelgeme problemine çözüm yaklaşımımızda maliyeti en küçükleme, kaliteyi en büyükleme ve çalışanlar arasındaki iş yükünü dengeleme belirlediğimiz üç amacımızdır. Bu amaçlarımızdan maliyet en küçükleme ve kalite en büyükleme oluşturulan matematiksel modellerin amaç fonksiyonlarını oluşturmaktadır. İş yükü dengesi ise bir parametre olarak tanımlanmış ve modellere bir kısıt olarak eklenmiştir. İş yükü dengesini sağlamak amacıyla karar vericiden bir değer belirlenmesi istenip, bu değer çalışanlar arasındaki en çok çalışan ile en az çalışan arasındaki farkı kısıtlayacak şekilde bir matematiksel kısıt tanımlanmıştır.

Beraber çalışılan firmadaki karar verici bu farkı 2 olarak atamış, elde edilen çözümlerde en çok etkinliğe atanan organizatör ile en az atanan arasındaki fark en fazla 2 olarak gözlemlenmiştir. Bu bölümde, karar vericinin belirlediği bu parametrenin çizelge maliyetine nasıl etki ettiği gözlemlenmiştir. Bu parametre 0 dan başlayarak birer birer arttırılarak maliyet en küçükleme modeli çözdürülmüş ve parametrenin arttıkça maliyetin azaldığı gözlemlenmiştir.

Alternatif Çözümler

Çalışmamızda iki ana optimal değer bulunduktan sonra bu bölümde iki temel amacı aynı anda gözeten çözümler sunulacaktır. Ana optimal çözümlere bakılarak açıkça görülmektedir ki kalite ve maliyet arasında bir ödünleşim vardır. İki ana optimal değerin arasında çözümler bulmak için, en küçük maliyet çözümündeki maliyet değeri ile, en büyük kalite çözümündeki maliyet değeri arasındaki fark 5 eşit aralığa bölünmüştür. Bu 5 aralığın sınırlarındaki maliyet değerleri kalite en büyükleme modelinde teker teker maliyet kısıtı olarak tanımlanmıştır. Kalite en büyükleme modeli bu kısıtlarla birlikte ayrı ayrı çözdürülerek 4 adet alternatif çözüm üretilmiştir. Bu çözümler iki optimal çözüm arasında bulunan iki amacı da aynı anda göz önünde bulunduran çözümlerdir.

Firmanın Mevcut Çizelgesi ile Matematiksel Modellerle Elde Edilen Sonuçların Karşılaştırılması

Bu kısımda firmanın kullandığı mevcut çizelge ile çözüm yöntemimizde önerdiğimiz matematiksel modellerin sonuçları karşılaştırılacaktır. Bu doğrultuda ilk önce firmanın mevcut durumda kullandığı çizelge elde edilmiş ve maliyet ile kalite puanı hesaplanmıştır. Firmanın mevcut çizelgesinin firmaya maliyeti 106.690 TL, kalite değeri ise 311.118,5 olarak hesaplanmıştır. Matematiksel modellerle mevcut çizelgeyi daha iyi karşılaştırabilmek için, firmanın mevcut çizelge maliyeti oluşturduğumuz kalite en büyükleme modeline; firmanın mevcut kalite puanı ise oluşturduğumuz maliyet en küçükleme modeline kısıt olarak eklenmiş ve modeller çözdürülmüştür. Elde ettiğimiz sonuçlara göre, oluşturduğumuz modeller sayesinde

firmanın mevcut durumdaki maliyetiyle hemen hemen aynı maliyette fakat kalite puanı daha yüksek ve firmanın mevcut kalite puanıyla hemen hemen aynı seviyede fakat maliyet olarak daha düşük çözümler elde edilmiştir. Özet olarak matematiksel modeller sonucunda elde edilen çözümler firmanın mevcut çizelgesinden daha iyidir.

Duyarlılık Analizi

Bu bölümde önerdiğimiz karma tamsayılı programlama modeline duyarlılık analizi uygulanmıştır. Önerdiğimiz modelin karar vericinin belirlediği girdi parametrelerindeki ufak değişikliklere karşı güçlü olup olmadığı araştırılmıştır. Bu doğrultuda çalışanların ve etkinliklerin puanlamaları kendi değerlerinin ±5% aralığında rastgele değerlerle değiştirilmiştir. Önerdiğimiz model bu rastgele değişkenler ile 50 kere çözdürülmüştür. 50 çözümün hiç birinde çizelge değişmemiştir. Sonuç olarak, önerilen karma tamsayılı programlama modelinin parametrelerdeki küçük değişikliklere karşı duyarlı olmadığı tespit edilmiştir.

KARAR DESTEK SİSTEMİ

Çalışmamızda Microsoft Excel tabanlı bir karar destek sistemi tasarlanarak, önerdiğimiz çözüm yöntemi bu karar destek sisteme entegre edilmiştir. Bu karar destek sistemini kullanarak karar verici problemdeki her bir parametreyi değiştirerek yeni çözümler elde edebilmektedir. Karar destek sistemi çözücü olarak Excel Solver eklentisini kullanmaktadır. Bu bölümde karar destek sisteminin nasıl kullanılacağı görsellerle detaylı bir şekilde anlatılmaktadır.

KAPANIŞ

Çalışan çizelgeleme, birçok çalışanın birlikte çalıştığı sektörlerde yaygın bir problemdir. Uçuş elemanı çizelgelemesi, hemşire çizelgeleme, vardiya çizelgeleme, toplu taşıma aracı çizelgeleme gibi birçok popüler uygulama alanı vardır. Genelde çalışan çizelgeleme problemleri zor ve kompleks problemler olduğundan karar verici için uygulanabilir ve basit bir çizelge ortaya koymak bile uzun zaman almaktadır. Personel maliyetleri, organizasyonların temel maliyetlerinden biridir, bu nedenle

pazarda rekabetçi bir avantaj kazanmak ve karlılığı azaltmak için bu maliyetleri azaltmak önem arz etmektedir. Optimizasyon modelleri veya bir yazılım kullanarak çalışan maliyetlerini düşürmek mümkündür. Çalışmamızda, bir çalışan çizelgeleme probleminin optimizasyonu ile uğraşmaktayız. Dahası, sadece çizelgenin maliyeti değil aynı zamanda kalite ölçüleri ve çalışanlar arasındaki dengelenmiş iş yükü ile ilgilenmekteyiz.

İlk olarak, önceki çalışmalardan ağırlama sektöründe kaliteyi sağlayan çalışanların temel beceri ve niteliklerini tanımladık. Tecrübe, yabancı dil, iletişim becerileri, takım çalışması kabiliyeti ve duygusal zekâ olmak üzere beş kritik belirleyici özelliği ele aldık. Bu beş boyutu tanıttıktan sonra karma tamsayı programlamayı kullanarak optimizasyon modellerini sunduk. Çalışan çizelgelemesine iki amaç doğrultusunda yaklaşırken maliyet minimizasyonu ve kalite maksimizasyonu modelleri olmak üzere iki ayrı model önerdik. Kaliteyi yukarıda belirtilen beş boyutta çalışan becerilerini etkinlik zorluğu ve karmaşıklığıyla eşleşmesi olarak tanımladık. İki optimal çözüm iki matematiksel modelden elde edilebilmektedir. Maliyet minimizasyon modelinin çözümü en düşük maliyeti sağlarken kalite maksimizasyon modelinin sonucu en yüksek kaliteyi sağlamaktadır.

Çalışan çizelgeleme problemimizin üçüncü hedefi olan işi yükü dengesi, matematiksel modellerimizde kısıt olarak tanımlanmaktadır. En fazla atanmış çalışan ile en az atanmış çalışan arasındaki maksimum etkinlik farkı bir parametre olarak belirlenmekte ve bu parametre çalışanlar arasında eşit olmayan iş yükünü önlemektedir. Adaletsiz iş yükü organizasyonlardaki motivasyonu düşürebilmektedir. Çalışanlar arasındaki dengelenmiş iş yükü muhafaza edilerek çalışanların motivasyonları ve performanslarının artırılması hedeflenmektedir.

Çalışmamızdaki yöntem, kongre etkinlikleri düzenleyen bir organizasyon şirketinde uygulanmaktadır. Çalışan ve etkinlik verileri şirketteki karar vericiden elde edilmektedir. Matematiksel modeller elde edilen verilerle çözülmektedir. Şirkete iki uygun çözüm sağlanmaktadır. İki matematiksel modelin optimal çözümlerini elde ettikten sonra her iki hedefi aynı zamanda dikkate alan uygun çözümlere dört farklı

alternatif çözüm önermekteyiz. Sonuç olarak, şirkete altı çizelge sağlanmıştır. Bunu takiben, şirketin mevcut çalışan çizelgesi analiz edilmiştir. Mevcut çizelge maliyeti ve mevcut çalışan çizelgesinin kalite puanı hesaplanmaktadır. Mevcut çizelge maliyeti kalite maksimizasyon modelimizde bir kısıt olarak tanımlanırken kalite puanı, maliyet minimizasyon modelimizde bir kısıt olarak tanımlanmaktadır. Modeller bu kısıtlarla çözülmekte ve iki yeni çözüm elde edilmektedir. Bu çözümler şirketin mevcut çizelgesini domine etmektedir. Bu, yöntemimizin mevcut çizelgeyle aynı kalitede olan bir çizelgeyi daha düşük maliyetle ya da mevcut çizelgeyle aynı maliyette, daha iyi bir kaliteye sahip olan çizelge sunması anlamına gelmektedir.

Yöntemi bir şirkete uyguladıktan sonra, aynı yöntemi kullanan bir karar destek sistemi tasarladık. Karar verici problemdeki bütün parametreleri değiştirebilmekte ve yeni çözüm elde edebilmektedir. Dahası, karar destek sistemi Microsoft Excel' e dayalı olduğundan kullanımı ücretsizdir. Karar vericiler, çalışan çizelgesini kısa bir zaman içerisinde ve ücretsiz olarak alabilirler. Karar destek sistemi kullanıcı dostu olarak tasarlanmıştır; ağırlama sektöründeki her kuruluş çalışanlarının çizelgelerini oluşturmak için kolaylıkla bu sistemi kullanabilmektedir.

Çalışmamızda bazı kısıtlamalar bulunmaktadır. Bunlardan ilki Excel Solver'ın karar değişkeni ve kısıt kapasitesidir. Daha büyük problemlerin çözümü için Premium Excel Solver eklentisi kullanılmalıdır. İkinci olarak, çalışmamızda karar vericinin etkinlikleri ve çalışanları mantıksal, objektif ve tutarlı olarak değerlendirdiğini farz ettik. Karar vericinin bu değerlendirmeyi yaparken taraflı olması kalite en büyükleme modelinin anlamlı bir çözüm vermesini engeller. Çalışmamızda çalışanların cinsiyeti göz önünde bulundurulmamıştır. Karşılama sektöründe cinsiyet faktörü göz ardı edilemez, bu nedenle cinsiyet faktörü gelecek çalışmaların kapsamına dâhil edilecektir. Son olarak, çalışan yorgunlukları çalışmamızda yer almamaktadır. Dengeli iş yükü dağılımının yanı sıra, çalışan yorgunluk faktörü çalışanların motivasyonu ve iş tatmini konusunda çok önemli bir yere sahiptir. Bir çalışan kısa bir süre içerisinde çok fazla etkinliğe atanırsa motivasyonunu ve enerjisini kaybedebilir.

Yöntemimizde, çalışanların aynı zaman içerisinde farklı etkinliklerde çalışamamalarını sağlayan bir kısıt bulunmaktadır fakat çalışan yorgunluğu çalışmamızda ele alınmamıştır. Yorgunluk faktörünü hesaba katarak matematiksel modellerimiz yeniden düzenlenebilir.

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