IJE TRANSACTIONS C: Aspects Vol. 32, No. 9, (September 2019) 1312-1319

International Journal of Engineering

Journal Homepage: www.ije.ir

RESEARCH NOTE

Multi-objective Solution Approaches for Employee Shift Scheduling Problems in Service Sectors

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PAPER INFO

Paper history:
Received 29 May 2019
Received in revised form 30 June 2019
Accepted 05 July 2019

Keywords:
Employee Shift Scheduling
Multiobjective Optimization
Weighted Sum Scalarization
Conic Scalarization

A B S T R A C T

Today, workforce scheduling programs are being implemented in many production and service centers. These sectors can provide better quality products and/or services to their customers, taking into account employees' desires and preferences in order to increase sector productivity. In this study, an employee shift scheduling problem in the service sector is discussed. In the problem, the aim is to minimize the total amount of workloads of the employees and to provide the preferences of the employees. Under this multi-objective structure, by taking into account the needs of employees, a multi-objective decision model has been developed. After then, a multi-criteria decision-making model has been developed to obtain the weights/priorities of the objective functions. By the help of these obtained weights, the problem is scalarized by the Weighted Sum Scalarization (WSS) and Conic Scalarization (CS) methods. When Pareto solutions are compared, it is seen that more Pareto solutions are obtained with CS method. Additionally, better schedules have been obtained in a very short time in terms of the quality of the solution according to the manually prepared schedule.

doi*: 10.5829/ije.2019.32.09c.12*

1. INTRODUCTION

Scheduling is a decision-making process in many manufacturing and service sectors, such as production, health, tourism, hospitality, and transportation. Timetabling problems are the scheduling problems in which a number of activities, persons, materials, or capital are assigned to predefined time periods under certain constraints. Different scheduling problem types such as course/exam scheduling problems encountered in educational institutions, machine scheduling problems in different configurations, train scheduling, employee scheduling, crew scheduling and scheduling of working hours of nurses have been discussed in the literature [1-3].

If we focus on one of these various scheduling problems, workforce scheduling problem enables the staff to be assigned to shifts to provide a better service to the customers. In general, workforce scheduling problem is the problem of assigning the right person to the right place at the right time. Although the business constraints vary from business to business, it is determined by the schedules which days and hours to work and to be allowed for days-off. Particularly in the service sector, personnel have a great importance in this process. Because to ensure customer satisfaction, it is necessary firstly to ensure the satisfaction of the personnel. Due to its complex structure, shift scheduling problems have been the subject of work for many years [1].

In this study, the employee shift scheduling problem of a technology store in a shopping center is considered with a multi-objective structure. The first objective is to balance the workloads of the store personnel and the second one is to meet the personnel demands for days-off as much as possible. In order to achieve the best shift schedule, a multi objective mixed integer programing model subject to the business constraints has been developed.

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Please cite this article as: M. Taghizadehalvandi, Z. Kamisli Ozturk, Multi-objective Solution Approaches for Employee Shift Scheduling Problems in Service Sectors, International Journal of Engineering (IJE), IJE TRANSACTIONS C: Aspects Vol. 32, No. 9, (September 2019) 1312-1319

In this paper we suggest an improvement to workforce scheduling by considering two objectives simultaneously. It's important to note that, the manual solution of the scheduling problem usually requires many person-days of work. Also, the manual obtained schedules may be unsatisfactory in some respect. So, it should be better to handle this problem as a multi objective optimization problem and solve the problem with an optimization software in seconds. After then, the issue of taking personnel's' time preferences (days-off) and considering balanced workloads could be helpful to eliminate the unsatisfactions. We also need to specify that, there is no doubt that employee satisfaction is critical in the service industry because of the nature of the industry. Customer satisfaction is very related to employee satisfaction.

To find a solution for this multi objective problem, firstly the objective functions have to be scalarized. The proposed mathematical model was scalarized with different weights by Weighted Sum Scalarization and Conic Scalarization methods and different Pareto solutions were obtained. To explain the eventual contribution of this study we used numerical outcomes of the model and the current system schedule performance criteria.

The rest of the paper is organized as follows. In section 2, the literature review of the shift scheduling problems is given; in section 3, proposed solution approaches and numerical results are discussed. Finally, the conclusion are given in section 4.

2. LITERATURE REVIEW

Over the past studies in the literature, several approaches have been developed for shift scheduling and multi-criteria shift scheduling problems. However, there are very few studies on multi-objective ones. In this section, the studies which are considered with single and multiple objective structures, the various solution approaches used for especially multi objective ones.

Shift scheduling problems are one of the topics that have been extensively considered by many researchers. Mason et al. [2] proposed an integer programming model for personnel scheduling of customs personnel at Auckland International Airport in New Zealand. Lagodimos and Leopoulos [3] formulated a workforce shift planning problem as an integer linear programming problem. Two greedy heuristic algorithms have been proposed to solve this problem, one for single and one for multiple workday shifts. There are many studies on nurse scheduling problems solved with different approaches such as integer programming, and genetic algorithm [4-7]. İpekçi Çetin et al. [8] proposed an integer programming model to solve the flight crew scheduling problems of a private airline company.

As it can be seen from the literature research, although there is a lot of study about shift scheduling problems, multi-objective shift scheduling problem studies are very few. Here we refer to some studies. Shahnazari-Shahrezaei et al. [9] proposed a multi-objective workforce scheduling model to ensure employers' goals and employee preferences. Fuzzy goal programming model has been developed for this model. Ünal and Eren [10] examined the shift scheduling problem in a government agency in the service sector. Weighted goal programming model was developed by taking into consideration the requests of the personnel. The most important feature of this proposed model is to allow staff to choose their shifts. Varli and Eren [11] developed a model for the balanced assignment of the total workforce of each chef after separating the chefs working in a factory into their seniority levels with the Analytic Hierarchy Process (AHP) technique. In order to solve the problem, integer programming and goal programming models were developed.

When the shift scheduling problem is considered with multiple objectives, it is necessary to be scalarized to be solved by exact solution methods. There are different scalarization techniques used in the literature to solve various optimization problems. In the study conducted by Mavrotas [12], ε-constraint method was applied to obtain Pareto optimal solutions in multi-objective mathematical programming problem. In the ε-constraint method, one of the objective functions is optimized by adding other purpose functions to the model as constraints. Sipahioğlu and Saraç [13] discussed the multi-objective knapsack problem. In order to solve this problem, previously unused conic scalarization method has been applied and it has been shown that concave Pareto solutions which cannot be solved by weighting method can be found with this method.

Billionnet [14] studied the objective of this problem is to find the minimal labor cost and satisfy the labor and off-days requirements. Cai and Li [15] considered multiple skills of the staff.

Bard et al. [16] presented an integrated model to meet daily staffing requirements at minimum cost for United State Postal Service. Castillo et al. [17] tried to minimize the costs and maximize the service level. Valls et al. [18] applied a hybrid genetic algorithm for solving a real-life multi-objective scheduling problem. Smet et al. [19] used a two-phase hybrid heuristic algorithm based on the principles of matheuristics for the problem of assigning tasks to multi-skilled employees. The objective is to minimize the number of employees while assigning all tasks.

Talarico and Duque [20] examined a scheduling problem for the workforce management in several supermarkets located in Southern Italy. In order to solve this problem, a hybrid heuristic algorithm based on mathematical formulation has been developed. In order to guarantee a high satisfactory service level during the check-out operations, a combination of full-time and part-time staff which are needed every week has been demanded to companies.

Ağralı et al. [21] investigated an employee scheduling problem that imposed in a special health-care organization such as care centers for children with disabilities and nursing homes for elderly. To solve this problem, a mixed-integer programming model has been proposed. The proposed model was applied and tested on a real size data sets provided by a large health-care organization in Belgium. The objectives of problem are minimizing unsatisfied service requirements, maximizing the utilization of contracted hours, maximizing employee satisfaction and maximizing fairness between employees by making balanced work assignments during holidays.

As it's seen from the literature review, in previous studies, the workload balance of the employees and their preferences for days-off were not taken into consideration, simultaneously. And for the solution of this multi objective problem, scalarization techniques have not been used intensively. In this study, both workforce balance and employee satisfaction are considered. And the conic scalarization technique is firstly used in the solution of multi objective workforce scheduling problem.

3. MATHEMATICAL SOLUTION APPROACHES FOR MULTI-OBJECTIVE SHIFT SCHEDULING PROBLEM

In this study, shift scheduling problem encountered in a technology store located in a shopping mall was discussed.

The real world problem can be defined as follows: At the store where the shift plans are prepared weekly, a total of 50 staff work and carry out 8-hour shifts between 10 a.m.-6 p.m. and 2 p.m.-10 p.m., every day. While 10 a.m.-6 p.m. shift is called "morning shift", the 2 p.m.-10 p.m. shift is called as "day shift". Each employee has the right to use one day-off on weekdays. At the weekends, no employee is allowed to use day-off. Because it's given that, the number of customers arriving at the weekend is at least 4 times the number of customers arriving on weekdays.

In addition, there are 5 different departments in the store (1-TV and TV products, 2-Notebooks, tablets and computer products, 3-Phone and telephone accessories, 4-Personal care, Small appliances and White goods, 5-Disney collection). Customers give attention to every department in the store. So, in the morning and day shifts, at least one staff must be assigned to each department, and each staff can be assigned up to 5 departments per day in the morning and day shifts. The weights of the departments are not the same due to the type of product sold and customer densities. A weight is assigned to each department by the store manager. Therefore, it is aimed to balance the total department load rather than the total number of departments to which the employees are assigned. In the current situation, as this issue is not paid attention to, the assigned unbalanced workloads cause dissatisfaction among the employees. In the current store, monthly shift schedules are prepared by the store manager in at least one day.

These conditions mentioned above are compulsory restrictions of the system. In this study, a balanced workload is obtained for all employees and the shift assignments to unwanted days-off are minimized, simultaneously.

In this section, firstly a two-objective mixed integer mathematical model has been developed for the current shift system of the application site. In addition, it is also tried to obtain Pareto solutions by Weighted Sum Scalarization and Conic Scalarization methods. Finally, the obtained Pareto solutions are also evaluated at the end of the section.

3. 1. Mathematical Model of Employee Shift Scheduling Problem

The constraints and objective functions in the proposed model are determined by interviewing with the store manager and employees.

Sets and parameters:

Set of weekdays, $H: \{i|i = 1, \dots ,5\}$
Set of weekend, $S: \{i|i = 6,7\}$
n number of days in a schedule, $(n = 1, \dots , 7)$
p number of staffs in a schedule, $(p = 1, \dots , 50)$
i index of days, $i = 1,2, \dots , n$
j index of staff, $j = 1,2, \dots , p$
k index of departments, $k = 1, \dots , 5$
$a_{\boldsymbol{k}}$ weight of department k, $k = 1, \dots , 5$
$w_{\mathbf{1}}$ weight of first objective function
$w_{\mathbf{2}}$ weight of second objective function

$$r_{i,j}: \begin{cases} 0 & if\ j^{th} staff\ is\ preffered\ day\ i\ as\ a\ day-off \\ 1 & o.w. \end{cases}$$

d_i $number\ of\ staff\ required\ for\ day\ shift\ at\ day\ i$
m_i $number\ of\ staff\ required\ for\ morning\ shift\ at\ day\ i$

Decision variables:

$$xd_{i,j} = \begin{cases} 1, & if\ staff\ j\ is\ assigned\ to\ day\ shift\ at\ day\ i \\ 0, & o.w. \end{cases}$$

$$xm_{i,j} = \begin{cases} 1, & if\ staff\ j\ is\ assigned\ to\ morning\ shift\ at\ day\ i \\ 0, & o.w. \end{cases}$$

$$xr_{i,j} = \begin{cases} 1, & if\ staff\ j\ is\ off\ at\ day\ i \\ 0, & o.w. \end{cases}$$

$$yd_{i,j,k} = \begin{cases} 1, & if\ staff\ j\ is\ assigned\ to\ k.department\ in\ day\ shift\ at\ day\ i \\ 0, & o.w. \end{cases}$$

$$ym_{i,j,k} = \begin{cases} 1, & if\ staff\ j\ is\ assigned\ to\ k.department\ in\ morning\ shift\ at\ day\ i \\ 0, & o.w. \end{cases}$$

t_j: $maximum\ total\ workload\ amount\ of\ staff\ j$

q_j: $maximum\ total\ number\ of\ unwanted\ day-off\ assignments\ of\ staff\ j$

$$minz = w_1.(\textstyle\sum_{j=1}^{50} t_j)/780 + w_2.(\sum_{j=1}^{50} q_j)/50 \tag{1}$$

$s.t.$

$$xd_{i,j} + xm_{i,j} + xr_{i,j} = 1 \quad \forall (i \in H), \forall j \tag{2}$$

$$xd_{i,j} + xm_{i,j} = 1 \quad \forall (i \in S), \forall j \tag{3}$$

$$\textstyle\sum_{i=1}^{5} xr_{i,j} = 1 \quad \forall j \tag{4}$$

$$\textstyle\sum_{j=1}^{50} yd_{i,j,k} \geq 1 \quad \forall i \in S \cup H, \forall k \tag{5}$$

$$\textstyle\sum_{j=1}^{50} ym_{i,j,k} \geq 1 \quad \forall i \in S \cup H, \forall k \tag{6}$$

$$xd_{i,j} \leq \textstyle\sum_{k=1}^{5} yd_{i,j,k} \quad \forall i \in S \cup H, \forall j \tag{7}$$

$$\textstyle\sum_{k=1}^{5} yd_{i,j,k} \leq M.xd_{i,j} \quad \forall i \in S \cup H, \forall j \tag{8}$$

$$xm_{i,j} \leq \textstyle\sum_{k=1}^{5} ym_{i,j,k} \quad \forall i \in S \cup H, \forall j \tag{9}$$

$$\textstyle\sum_{k=1}^{5} ym_{i,j,k} \leq M.xm_{i,j} \quad \forall i \in S \cup H, \forall j \tag{10}$$

$$\textstyle\sum_{i=1}^{7} \sum_{k=1}^{5} (a_k.yd_{i,j,k} + a_k.ym_{i,j,k}) \leq t_j \quad \forall j \tag{11}$$

$$\textstyle\sum_{i=1}^{5} (xd_{i,j} + xm_{i,j}).r_{i,j} \leq q_j \quad \forall j \tag{12}$$

Constraint (2) ensures that a person will be off on a weekday; if he is not off so either work in the morning or afternoon shift. Constraint (3) ensures that a person to work either in the morning or in the afternoon shift at the weekend. With constraints (4), each person is allowed to use only one day-off per week. With constraint (5) and (6), in the morning and day shift, at least one person is assigned to each department. In constraints (7), (8), (9) and (10) the assignment of up to 5 departments in the morning and day shifts per person in per day is protected by $xd_{i,j}, yd_{ijk}$ and $xm_{i,j}, ym_{ijk}$ decision variables. The constraint (11) is the constraint that required to provide a balanced workload. The maximum workload per person can be t_j.

In the objective function, the total t_j is minimized for all persons and balanced load assignment is performed. Constraint (12) is the constraint that required to ensure that the staff are assigned to the unwanted day-off. Assignments to unwanted days-off will take maximum q_j for each person. In another objective function, by minimizing the total q_j, the assignments to unwanted days-off are minimized. In the above-mentioned model, Equation (1) is the minimization of the equal weighted sum of two objectives. Thus, it is aimed to increase the level of satisfaction of all employees.

3. 3. Solution by Weighted Sum Scalarization Method Weighted Sum Scalarization (WSS) method was developed by Gass and Saaty in 1955 and is the most widely used scalarization method for the solution of multi-objective optimization problems.

The WSS method correlates the weight coefficients determined by the decision maker with each objective and optimizes the total weighted function of the objectives. $w'= (w_1, w_2,..., w_n)$ including weight vector, each w_i value is associated with a $f_{i(x)}$, i=1,…,n purpose function. The scalar problem written for the given weight vector is given in the WSS (w) problem (13).

$$\min_{x \in X} \textstyle\sum_{i=1}^{n} w_i f_i(x) \qquad (WSS(w)) \tag{13}$$

The mathematical model developed in Section 3.1 is solved by GAMS software. With a total of 50 weights w_1 and w_2 have been valued from 1 to 50 and different Pareto solutions with WSS were obtained. The objective function values of this bi-objective problem with WSS method are given in Figure 1. The objective functions $f_1(x) = \sum t_j$ represented by (t) and $f_2(x) = \sum q_j$ (q) is represented by q.

Pareto surfaces were obtained by WSS method. However, the obtained results will be interpreted in comparison with the results obtained with Conic Scalarization method.

3. 4. Solution by Conic Scalarization Method The use of the Conic Scalarization (CS) approach, which was developed by Gasimov in 2001, is characterized by the possibility to investigate solutions close to a reference point. This method can be applied to a wide range of problems and, most importantly, to find the solutions that cannot be supported with hyperplanes [22]. The solution space that can be obtained by Conic Scalarization is given in Figure 2.

The CS method does not require convexity conditions on the problem. The CS method always yields efficient, weakly efficient, or properly efficient solutions if the corresponding scalar problem has a finite solution. By choosing a suitable scalarizing parameter set consisting of a weighting vector, an augmentation parameter, and a reference point, the decision maker may guarantee a most preferred efficient or properly efficient solution. The method provides conditions for obtaining (solely) properly efficient solutions, and all properly efficient solutions can be detected in this method [23].

The preference and reference point information of decision maker is taken into consideration by the CS method. The CS method does not use neither additional constraints, nor additional decision variables.

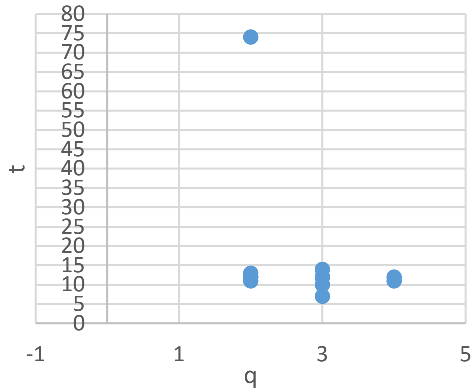

Figure 1. Pareto solution with WSS

The conic scalarization method is a generalization of the weighted sum, the Benson's and the Pascoletti–Serafini scalarization methods. There're also some other scalarization techniques like $\varepsilon - constraint$ (EC) method. However, the EC method generates weakly efficient solutions and does not provide conditions for generating properly efficient solutions. And, decision maker's preferences such as weights of objectives and reference point information are not considered in this method. So, in this section, Conic Scalarization Method is used to find Pareto points for our problem.

When the problem of shift scheduling is solved by CS method, scalar objective function is given by function (14).

$$min \sum_{j=1}^{50} w_1 (t_j - r_1) + \sum_{j=1}^{50} w_2 (q_j - r_2) + \alpha \sum_{j=1}^{50} |t_j - r_1| + \alpha \sum_{j=1}^{50} |q_j - r_2| \quad (14)$$

Here, w_i's are taken between 1 and 50 as in the WSS method. Reference point $r = (r_1, \ldots, r_n)$. Such a point may be identified by a decision maker in cases when he or she desires to calculate minimal elements that are close to some point. The conic scalarization method does not impose any restrictions on the ways for determining reference points. These points can be chosen arbitrarily.

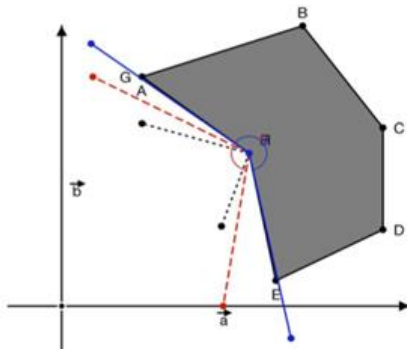

Figure 2. Graphical representation of Conic Scalarization method [23]

In this study, r_1 and r_2 are determined by taking the average values of objective functions 1 and 2, obtained by WSS method. α is defined as a variable determined by the decision maker. It is clear that in the case α=0, the objective function of the scalar optimization problem becomes an objective function of the well-known weighted sum scalarization method.

The results obtained by CS were compared with the results obtained by WSS method. The comparison graph is given in Figure 3.

The objective functions (q and t) are minimization functions. So, in Figure 3 it can be easily seen that CS method has reached more Pareto solutions. This figure gives solutions corresponding to different weights, but not all of these solutions are Pareto solutions. As both of the objective functions are minimization functions, better solutions could not be achieved with WSS.

3. 5. Numerical Results As an example, the current weekly schedule of 13 personnel is given in Table 1. As a result of the comparison of the current schedule and the proposed schedule, 5 personnel were assigned to one of the days they prefer for days-off, while 9 personnel were assigned to the days according to their demands with proposed model. The results are compared in Table 1.

In addition to the determination of days-off, the proposed model is used to determine the staffs' working days' morning and day shifts. Also, the departments of each staff to responsible are determined. By this way, we can easily calculate the total workload of each staff based on the assigned departments. In Table 2 the current and proposed workloads of the staff are given for 13 employees. It can be easily seen that, the prosed solutions are in balance.

The given outcomes are the results of a Pareto solution. With CS method, we have obtained a Pareto front (Figure 3). These are the Pareto points that we have obtained according to WS method. The two objectives are about minimization.

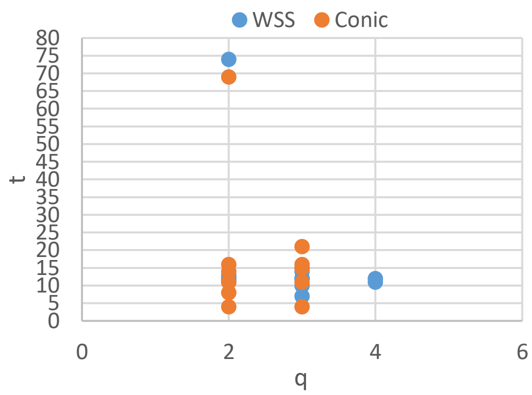

Figure 3. Solutions obtained by CS and WSS

In Table 3, some Pareto solutions are given. For instance, while in *t* value is 8 in solution 1, it's decreased to 4 in solution 2. However, while *q* value is 2 in solution 1, it's increased to 3 in solution 2. It means that, solution1 and solution 2 obtained by CS method, are not dominating each other. So, they're Pareto points. The same nondomination relation can be seen on the solutions 5, 6 and 10-13. They're all Pareto points obtained by CS method.

To make a comparison of obtained objective function values by WSS and CS, Table 3 gives a clear result that,

TABLE 1. Current and proposed days-off assignments for 13 staff

Personel	Demands for days-off	Current assignment days-off	Proposed assignment days-off
Onur	Tuesday/Friday	Tuesday	Tuesday
Doğukan	Tuesday/Thursday	Friday	Friday
Remziye	Monday/Wednesday	Wednesday	Wednesday
Yunus	Wednesday/Friday	Friday	Friday
Akın	Monday/Thursday	Wednesday	Wednesday
İlker	Monday/Thursday	Thursday	Thursday
Sedat	Wednesday/Friday	Tuesday	Tuesday
Didem	Monday/Thursday	Tuesday	Monday
Yalçın	Tuesday/Wednesday	Thursday	Thursday
Mehmet	Thursday/Friday	Friday	Friday
Ahmet	Tuesday/Friday	Monday	Tuesday
Mustafa	Wednesday/Friday	Thursday	Wednesday
Hüseyin	Monday/Thursday	Wednesday	Thursday

TABLE 2. Proposed days-off assignments for 13 staff

Personel	Current workload	Proposed workload
Onur	7	12
Doğukan	14	12
Remziye	14	11
Yunus	11	7
Akın	12	10
İlker	9	14
Sedat	16	12
Didem	7	12
Yalçın	14	12
Mehmet	12	12
Ahmet	9	13
Mustafa	13	11
Hüseyin	14	12

TABLE 3. Obtained objective function values

Solution	WSS		Conic	
	t	q	t	q
1	74	2	8	2
2	12	3	4	3
3	11	4	15	3
4	7	3	8	2
5	10	3	15	3
6	14	3	16	2
7	12	3	21	3
8	12	2	4	2
9	12	3	16	3
10	13	2	14	2
11	12	4	11	3
12	11	2	69	2
13	12	2	11	2

CS method finds more Pareto points than WWS method. Because, both of the objective functions are tried to be minimized. The minimum value of *t* and *q* means better solutions.

In fact, it is shown by numerous studies there is a positive relationship between employee satisfaction and customer satisfaction defined by Wangenheim et al., [24].

4. CONCLUSION

In this study, we demonstrated how mathematical modeling can be combined with self-scheduling to result in a technology store. A unique aspect of our model is that it is aimed to increase employee satisfaction by providing a balanced work load and to provide better quality services and to increase the efficiency of the enterprise by means of shift work schedule.

Through using this staffing approach, the store we worked with improved its employee staffing, increased staff morale and satisfaction, and reduced the total time to prepare the monthly schedule manually. Because of this assumed positive relationship, employee satisfaction has become important for the service sector.

In this multi-objective problem, a multi-objective mixed integer programming decision model has been developed by taking into consideration the demands of the personnel. The problem' objective functions were scalarized by Weighted Sum Scalarization (WSS) method. The problem was scalarized again by Conic Scalarization (CS) method to obtain more Pareto solutions. Compared with Pareto points, it was seen that Pareto points were obtained mostly with CS method.

Previously many studies have been done on shift scheduling in the literature. However, there isn't so many studies considering the demands and preferences of the employees, simultaneously. In this study, the preferences of the employees were taken into consideration and the balanced assignment of the employees in terms of workload was taken into consideration as the workload of each department was different. In the present case, assignment appointments were made only by looking at the number of people working while with the recommended system of appointments were made by department employees' requirements. In addition, with this study, it has been offered a convenience to the firms for an optimal solution. Because, under this kind of multiple objective structure, it is always hard and almost impossible to reach the optimum assignment by solving the problem manually.

In this study, workforce shift scheduling has been performed for a company operating in the service sector. Although the model has its own constraints like the required number of staffs for each department, number of departments etc., it is applicable to a wide variety of service sectors and shiftwork.

In subsequent studies, employees' preferences can be collected via an online system and assignments can be made automatically via this system.

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Multi-objective Solution Approaches for Employee Shift Scheduling Problems in Service Sectors

RESEARCH NOTE

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PAPER INFO

Paper history:
Received 29 May 2019
Received in revised form 30 June 2019
Accepted 05 July 2019

Keywords:
Employee Shift Scheduling
Multiobjective Optimization
Weighted Sum Scalarization

چکیده

امروزه در بسیاری از مراکز تولیدی و خدماتی، برنامه هایی برای شیفت بندی و تنظیم زمان نیروی کار اجرا می‌گردد. این مراکز با در نظر گرفتن تمایلات و خواسته های کارکنان، می‌توانند در راستای ارتقاء سطح بهره وری خود، تولیدات و خدمات بهتری به مشتریان خود ارائه دهند. در این تحقیق، مسئله ای در خصوص زمان بندی شیفت کارکنان مورد بررسی قرار گرفته است. هدف از طرح این مسئله، به حداقل رساندن میزان کار کارکنان و در عین حال برآورده ساختن تمایلات آنهاست. برای رسیدن به این ساختار چند منظوره و با در نظر گرفتن نیاز کارکنان، از یک الگوی تصمیم گیری چند منظوره استفاده شده است. سپس به منظور دستیابی به وزن و اولویت های توابع هدف، یک الگوی تصمیم گیری با بیش از یک معیار به کار گرفته شده است. با کمک اوزان به دست آمده، مسئله مورد نظر با استفاده از روش‌های (WSS) و (CS) اسکالاریزه می‌شود. با مقایسه راه حل های پارتو می‌توان فهمید که با روش (CS) می‌توان به راه حل های پارتو بیشتری دست یافت. علاوه بر این، با استفاده از این روش، در مدت زمان کوتاه می‌توان به برنامه های زمان بندی بهتری بر حسب کیفیت راه حل ها دست یافت که منطبق با برنامه های تهیه شده به صورت دستی باشند.

***doi**: 10.5829/ije.2019.32.09c.12*