Available online at www.sciencedirect.com

ScienceDirect

Procedia Economics and Finance 26 (2015) 827 – 832

Procedia Economics and Finance

www.elsevier.com/locate/procedia

4th World Conference on Business, Economics and Management, WCBEM

Shift scheduling with fuzzy logic: an application with an integer programming model

Muhittin Sagnak[a], Yigit Kazancoglu[a]*

[a]*Izmir University of Economics, Sakarya Cad. No:156, 35330, Balcova/IZMIR/TURKEY*

Abstract

The shift scheduling, which is one of the most crucial processes in order to increase efficiency and decrease labor costs, is a common phenomenon in both manufacturing and service organizations such as airlines, security services, fire stations, etc. In order to meet changing demand and keep responsiveness and flexibility, the shift scheduling includes the scheduling of manpower by assigning employees to shifts determined by types, length, and the number of breaks. The types of shifts may present variety such as part time and full time shifts. The breaks also show variety like lunch breaks, short rests, and compulsory reasons based on the occupational health and safety or necessities for maintenance. To overwhelm this complexity, this paper recommends an integer programming model integrated with fuzzy logic due to the vagueness inherited to the nature of decision-making process in order to provide flexibility in shift lengths, and lower the total labor costs.

Peer-review under responsibility of Academic World Research and Education Center

Keywords: Shift scheduling, integer programming model, fuzzy logic

1. Introduction

Many companies face difficulties while composing acceptable optimized schedules for employees. These difficulties include contradictory and multiple scheduling restrictions of work environment. As Dahmen and Rekik (2015) stated, schedules should allow employees to be present at needed places in different periods of planning in order to maintain admissible service quality.

* Yigit Kazancoglu. Tel.: +90-232-488-83-46; fax: +90-232-279-26-26.
E-mail address: yigit.kazancoglu@ieu.edu.tr

Peer-review under responsibility of Academic World Research and Education Center
doi:10.1016/S2212-5671(15)00888-6

Effective scheduling of manpower is one of the critical issues that a service system manager comes across daily. In an operating day, the demand for service generally might change in service systems. Shift scheduling can be developed by determining the demand which will after be converted into labor requirements with the help of queuing models. This will help to maintain the desired service level throughout the day. After this, employees are assigned to shifts in a way to meet these requirements. Understaffing might be useful for lowering the total labor cost but on the other hand it might result in degeneration of the service quality so this might also lead to higher total cost. On the other hand, in order to improve the service quality, overstaffing might be the answer but it leads to underutilization of labor and so labor costs also increases. For this reason, in order to minimize the labor cost and ensure desired service level, efficient scheduling is important for organizations (Aykin, 2000).

Efficient personnel scheduling is used by organizations, in order to be competitive among other organizations (Bard et al., 2003). Competitive advantage can be attained by achieving the best staff configuration in terms of time, demand and cost constraints. If workforce scheduling is not appropriate, it may lead to oversupply or undersupply which might result in loss of business. Nevertheless, characteristics and constraints on workforce scheduling show an alteration in different industries and organizations (Kabak et al., 2008).

There are various problems regarding the developing shift schedule. These can be counted as the determination of the employee number that are to work in various shifts, the timing of the shifts and their breaks considering the limitations allowed by legacy, unions, and company requirements. In order to improve the utilization of manpower and decrease labor costs, the flexibility in shift types, start times, duration of shifts and breaks is provided (Aykin, 2000).

The main concern of manpower scheduling is the scheduling of resources in order to meet the requirements of operations while satisfying the goals and policies enforced by the management, labor union and the government. Manpower scheduling is critical in non-stop operating service organizations in which the employees have multiple shifts. Operators in communication companies and workers in airports can be given as examples (Lau, 1996).

In order to meet changing demand and keep responsiveness and flexibility, the shift scheduling includes the scheduling of manpower by assigning employees to shifts determined by types, length, and the number of breaks. The types of shifts may present variety such as part time and full time shifts. The breaks also show variety like lunch breaks, short rests, and compulsory reasons based on the occupational health and safety or necessities for maintenance. To overwhelm this complexity, this paper recommends an integer programming model integrated with fuzzy logic due to the vagueness inherited to the nature of decision-making process in order to provide flexibility in shift lengths, and lower the total labor costs.

The remainder of the paper is structured as follows. First, in Section 2, the literature related to shift scheduling is presented. Then, in Section 3, the proposed methodology of fuzzy integer programming model explained. Section 4 is conclusion and discussion for future research.

2. Literature Review

Edie (1954) introduced the shift scheduling problem (SSP) in order to schedule toll booth operators. Then, the integer programming model was firstly introduced by Dantzig (1954) for solving SSP problems. With this precursor work, researchers are able to be done on more variations of the model and the solution methods in more realistic way.

A new integer programming model for optimal shift scheduling including various multiple brakes was proposed by Aykin (1996). In his work, a new approach was formed for introducing a set of break variables in order to assign break placements. With this approach, an improved integer programming model which needs constitutively smaller number of variables and computer memory was formed.

In Al-Yakoob and Sherali's (2007) work, a new approach was proposed and this approach's main concern was multiple shifts and work centers included scheduling problems of employees who belong to an organization which has downward substitutability of hierarchies. For example, an employee at a lower-position might not perform the duties of an employee at a higher-position, but vice versa is possible. After all, employees at higher-position get more wage than the ones in lower-position. Demand is constant in weekdays; however, it shows some fluctuations in weekends. There are two objectives which are 1) to schedule workforce with minimum cost to satisfy demand requirements, and 2) to consider the employees' preferences while assigning them to shifts. A mixed-integer programming model is introduced for the problem.

Sabar et al. (2008) proposed a mathematical model for scheduling of manpower. Like Al-Yakoob and Sherali's (2007) work, the model considers the preferences and abilities of each employee. The case study examines the performance of the proposed model.

Rekik et al. (2008) made a study about shift scheduling problems in which shift start times and durations of shifts show some variations. In order to find solutions over a multiple-day planning horizon, two approaches are proposed. Local branching strategy initiates the first approach and temporal decomposition initiates the second one. To find feasible solutions, local branching is more efficient comparing to a classical branch-and-bound procedure. Nonetheless, the decomposition approach leads to income-generating applicable solutions both in difficult phases and short computing times.

3. Proposed Methodology

Fuzzy set theory was first established by Zadeh (1965) in order to consider the vague nature of human thought. The major contribution of fuzzy set theory is the ability to describe vague data. According to this theory, "A fuzzy set is a class of objects with a continuum of grades of membership. Such a set is characterized by a membership (characteristic) function, which assigns to each object a grade of membership ranging between zero and one. A tilde "~" is placed above a symbol if the symbol represents a fuzzy set" (Zadeh, 1965).

The general formulation of a fuzzy mathematical programming model is:

$$\text{Maximize } Z = \sum_{j=1}^{n} \tilde{c}_j x_j$$

$$\sum_{j=1}^{n} \tilde{a}_{ij} x_j \le \tilde{d}_i \quad i = 1,...,m$$

$$x_j \ge 0.$$

where c_j is the profit coefficient of objective function, d_i is the amount of scarce resources, and a_{ij} is the technical coefficient.

In this study, we will present an approach in which only the right hand side values of model are fuzzy values.

The fuzzy membership $\mu_{i(x)}$ function for right hand side of constraints of fuzzy mathematical programming is defined as (Zimmermann, 1985):

$$\mu_{i(x)} = \begin{pmatrix} 1, if \quad (Ax)_i > d_i \\ 1 - \dfrac{d_i - (Ax)_i}{p_i}, if \quad d_i - p_i \le (Ax)_i \le d_i \\ 0, if \quad (Ax)_i < d_i - p_i \end{pmatrix}$$

The membership function of the objective function is (Zimmermann, 1985):

$$\mu_{i(x)} = \begin{pmatrix} 1, if \quad c(x) < z_0 \\ 1 - \dfrac{c(x) - z_0}{z_1 - z_0}, if \quad z_1 \le c(x) \le z_0 \\ 0, if \quad c(x) > z_1 \end{pmatrix}$$

The value of z_0 is the best solution when the right hand side values are crisp. $z1$ is the best solution when the right hand side values are fuzzy.

One new variable, λ, is introduced to substitute the objective function in fuzzy environment. The model can be written as:

Max λ

$$\lambda \le 1 - \frac{(c_j x_j) - z_0}{z_1 - z_0}$$

$$\lambda \le 1 - \frac{d_i - (Ax)_i}{p_i}$$

$0 \le \lambda \le 1$

$X \ge 0$

The parameters of proposed integer programming model are as follows:

C_j = Unit cost of labor working in j^th shift, j = number of shifts, j = 1, 2, …, m

A_{ij} = 1, if j^th shift works in i^th period; 0, otherwise, i = number of periods, i = 1, 2, …, n

D_i = number of workers needed in period i

T_i, TL_i, T_M = Rest break, lunch break, and maintenance break for period i

R_j, RL_j, R_M = set of periods for labor working in j^th shift to start rest break, lunch break, and maintenance break

The variables of proposed integer programming model are as follows:

X_j = number of workers assigned to work in j^th shift

U_{ji} = number of workers assigned to j^th shift who give rest break in period i

W_{ji} = number of workers assigned to j^th shift who give lunch break in period i

M_{ji} = number of workers assigned to j^th shift who give maintenance break in period i

The integer programming model that minimizes total labor cost is as follows:

Min Z = $\sum c_j x_j$

subject to

$$\sum_{j=1}^{m} A_{ij} x_j - \sum_{j \varepsilon T_i} U_{ji} - \sum_{j \varepsilon TL_{(i-1)}} W_{j(i-1)} - \sum_{j \varepsilon TL_i} W_{ji} - \sum_{j \varepsilon T_M} M_{ji} \ge D_i$$

$$X_j - \sum_{i \varepsilon R_j} U_{ji} = 0$$

$$X_j - \sum_{i \varepsilon RL_j} W_{ji} = 0$$

$$X_j - \sum_{i \varepsilon R_M} M_{ji} = 0$$

$X_j, U_{ji}, W_{ji}, M_{ji} \geq 0$ *and integer*

In this model, the objective function minimizes the total labor cost. First constraint ensures that number of workers assigned to period i are equal or greater than number of workers needed in period i after subtracting the number of workers who give the rest break, lunch break, and maintenance break. Second, third, and fourth constraints, respectively, explains that number of workers assigned to j^{th} shift are equal to number of workers who give rest break, lunch break, and maintenance break in j^{th} shift. Those three constraints ensure that each worker gives their rest break, lunch break, and maintenance break.

When fuzzifying that model, only the right hand side values will be fuzzified, however, in second, third, and fourth constraints, right hand side values are equal to zero. Therefore, only the first constraint and objective function will be fuzzified with the help of λ variable.

The fuzzy integer programming model for shift scheduling is set as follows:

Max λ

$$\lambda \leq 1 - \frac{(\sum c_j x_j) - z_0}{z_1 - z_0}$$

$$\lambda \leq 1 - \frac{D_i - (\sum_{j=1}^{m} A_{ij} x_j - \sum_{j \varepsilon T_i} U_{ji} - \sum_{j \varepsilon TL_{(i-1)}} W_{j(i-1)} - \sum_{j \varepsilon TL_i} W_{ji} - \sum_{j \varepsilon T_M} M_{ji})}{p_i}$$

$$X_j - \sum_{i \varepsilon R_j} U_{ji} = 0$$

$$X_j - \sum_{i \varepsilon RL_j} W_{ji} = 0$$

$$X_j - \sum_{i \varepsilon R_M} M_{ji} = 0$$

$X_j, U_{ji}, W_{ji}, M_{ji} \geq 0$ *and integer*

4. Conclusion

The shift scheduling includes the scheduling of manpower by assigning employees to shifts determined by types, length, and the number of breaks. The types of shifts may present variety such as part time and full time shifts. The breaks also show variety like lunch breaks, short rests, and compulsory reasons based on the occupational health and safety or necessities for maintenance. To overwhelm this complexity, this paper recommends an integer programming model integrated with fuzzy logic due to the vagueness inherited to the nature of decision-making process in order to provide flexibility in shift lengths, and lower the total labor costs.

The proposed method, fuzzy integer programming model, ensures that each worker gives their rest break, lunch break, and maintenance break with minimum cost.

Further studies should be made with a numerical example, or a representative case study. Also, we may focus on to fuzzify not only the right hand side values, but also the whole model.

References

Al-Yakoob, S. M., Sherali, H. D., 2007. Multiple Shift Scheduling of Hierarchical Workforce with Multiple Work Centers. *Informatica* 18 (3), 325–342.

Aykin, T., 1996. Optimal Shift Scheduling with Multiple Break Windows. *Management Science* 42 (4), 591-602.

Aykin, T., 2000. A comparative evaluation of modeling approaches to the labor shift scheduling problem. *European Journal of Operational Research* 125, 381-397.

Bard, J., Binici, C., de Silva, A.H., 2003. Staff scheduling at the United States Postal Service. Computers & Operations Research 30 (5), 745–771.

Dahmen, S., Rekik, M., 2015. Solving multi-activity multi-day shift scheduling problems with a hybrid heuristic. Journal of Scheduling 18, 207–223.

Dantzig, G.B., 1954. A comment on Edie’s traffic delays at toll booths. *Journal of the Operations Research Society of America* 2, 339–341.

Edie, L.C., 1954. Traffic delays at toll booths. *Journal of the Operations Research Society of America* 2, 107–138.

Kabak, O., Ulengin, F., Aktas, E., Onsel, S., Topcu, Y. I., 2008. Efficient shift scheduling in the retail sector through two-stage optimization. *European Journal of Operational Research* 184, 76–90.

Lau, H. C., 1996. On the Complexity of Manpower Shift Scheduling. *Computers & Operations Research* 23 (1), 93-102.

Rekik, M., Cordeau, J-F., and Soumis F., 2008. Solution Approaches to Large Shift Scheduling Problems. *RAIRO-Operations Research* 42, 229–258.

Sabar, M., Montreuil, B., Frayret, J-M., 2008. Competency and preference based personnel scheduling in large assembly lines. International *Journal of Computer Integrated Manufacturing* 21 (4), 468 – 479.

Zadeh, L.A., 1965. Fuzzy sets. Information Control 8, 338 – 353.

Zimmermann, H.J., 1985. Applications of Fuzzy Set Theory to Mathematical Programming. Information Sciences 36, 29-58.