Evaluation and Scheduling of the Car Manufacturing Factory's Employers' Work Shifts

Erhan Baran*‡

*Industrial Engineering Department, Faculty of Engineering, Hitit University, 19030

(erhanbaran@hitit.edu.tr)

‡Erhan Baran,Industrial Engineering Department, Hitit University, Tel:+90 364 227 4533,

Fax: +90 364227 4535, erhanbaran@hitit.edu.tr

Received: 21.02.2017 Accepted: 04.04.2017

Abstract-This study is made an application related to the regulation of working hours of workers in car factory. This factory has thick to work 24 hour shifts need to work with the system as needed. In this study, which is open 24 hours a day and 7 days in a car factory, it has made application serving with 3 shifts. The attention of employees serving in this industry and are crucial to productivity. Mistakes will be made, which can lead to irreparable consequences. The working hours of workers at the factory scheduling process is usually carried out by personnel chief in the factory. In this study, in consultation with the chief engineer in charge of drafting the schedule and made relevant studies were identified by examining the constraints to be considered. Then it established a mathematical model that can be used in a general sense with integer linear programming techniques. Established model applies to data in a unit of a car factory and has been found to be optimal solutions with the help of LINGO software. Unlike other shift scheduling problems in the literature, this study aimed to run for a minimum of additional workers outside the factory. There is also a model that defined the mathematical model and skillful workers to shift some concessions to be assigned any number of workers in particular experience has been established.

Keywords Mathematical programming, Integer linear programming, Scheduling, Optimization.

1. Introduction

For many organizations, the ability to have the right employee on work at the right time is a critically important factor when attempting to satisfy their costumers' requirements. Computational methods for rostering and personnel scheduling has been a subject of continued research and commercial interest since thee 1950s. Personnel scheduling rostering is defined as the process of constructing optimized work timetables for staff.

Staff scheduling problems deal with the issue of assigning employees to shifts in a certain time period (usually, a week or one month) such that several regulations are satisfied, qualifications and preferences of the employees are taken into account, level of service is maximized and costs are minimized [1].

Personnel scheduling and rostering problems tackle the difficult problem of building employee rosters respecting legal and organizational constraints to satisfy personnel requirements [2]. To fit the minimum-cost shift schedule is also required [3].

To use resourcesoptimally, the structure of the work must be; shift types, holidays, hard and soft constraints to be satisfied, etc.) [4]. Feasible schedules are used if we succeed [5]. These problems involve a great deal of constraints that derive from the usual complexity of regulations on the work relationship employer/employee [6]. Personnel scheduling (PS) is defined as the process of constructing optimized work schedules for staff [7].

In this study, have been studied to find a solution with mathematical programming approach to employee scheduling problems. In literature, the limitations identified in the results of the bilateral talks held in relevant areas of the work done and expressed factory unit with a constraint equations in the model. The fact that patients or authorized personnel working, does not distribute so as to respond to the needs of any shift engineer of the existing obligation, makes it extremely difficult problem making scheduling updates.

When the inadequate number of available workers from outside is needed as the company's short-term help some workers from other units. In these cases, the workers from the another unit to run as soon as possible the work will make it more healthy.

2. Literature Review

Some studies in the literature relating to personnel shift scheduling problems over the years has been in operation in Ernst et al. (2004)[8]. Subsequent studies since 2004 are detailed in the study of Van Den Berghe et al. (2013)'s[9]. When the works are examined since 2013, heuristic approaches can be seen in work shift scheduling. In some studies, heuristic and analytical approaches are used together. Some of the most commonly used methods in mathematical programming techniques are linear programming and integer programming.

If the literature is searched, it can be seen that models and algorithms for specific situations are studied by Burke et al. [10], airline crew scheduling by Kohl and Karisch [11], staff scheduling in postal service by Bard et al. [12], and also call centers optimization by Mehrotra [13]. And also cyclic patterns is studied (cf.,e.g. Beaumont [14] or Mason et al. [15]). Shift scheduling is studied by Vakharia et al. [16] and Lauer et al. [17]. Ernst et al. also work same subjects[8] and Blöchliger [18] who gives a tutorial on modeling staff scheduling problems also work. De Causmaecker et al. [19] classified personnel scheduling problems. Meisels and Schaerf [20] considered a general employee scheduling problem with local search algorithm. Integer linear programming formulation solved by column generation of Sarin and Aggarwal [21]. And also in Baran and Erol's study [22], there has been a mathematical model to select the suppliers. It has many similarities with the scheduling problems.

In this study; the purpose of constraints and can be solved in an analytical approach is not needed to use the heuristic approach. Within this aim and constraints, optimal results were obtained. In this study, optimal results are obtained by mathematical programming techniques.

This study has a very different character from other studies in the literature. For example, in this study, the hours of operation on a volume edited workers, workers are also taken into account in another section. There are no studies in the literature in this direction.

Also a constraint is added to the model skillful workers. Some concessions to the working master is provided with this constraint. This is provided to be different from other models in the model of the literature.

3. Application

In this study, will benefit in the event of insufficient number of workers assigned to each shift is intended to operate with a minimum duration of 8 workers considered in other units. In the study, interviews with responsible personnel unit prepares years in the factory scheduling, scheduling is performed using the data concerning the unit. In consultation with other scientists and engineers working on the issue, opinions and findings are taken. The basis of this assessment, the objective function of the mathematical model and constraints are identified.

Information from workers in the motor car manufacturing unit and analyzing the studies in the literature, the information necessary for regulation model is organized as follows:

i) The weekly working time is taken as 40 hours.

ii) The working hours are organized as three 8-hour shifts.

   1st shift; daily shift between 08:00-16:00,

   2nd shift; evening shift between 16:00-24:00,

   3rd shift; night shift between 24:00-08:00.

iii) When the desired number of first, second and third shift workers can be changed by the workload, the number of workers who will work in shifts are taken as separate constraints.

iv) At the weekend, the number of workers in the first and third shifts, taken separately to run different according to the different workload and the number of workers of different assumptions in this study, charts were prepared by running a different number of workers.

v) They are not able to work at the same time the existing employee (reports, such as annual leave) are set out in interviews that facilitates application changed the number of workers able to work in the model.

vi) These findings and the results of the evaluations taking into account the review of studies in the literature, the purpose of the established model functions and constraints are identified.

4. Mathematical Model

When studies in scheduling field workers examined were found to be the most widely used method of mathematical programming. Thus, mathematical programming approach has been applied to employee scheduling problems in this study.

In this study, according to the motor unit usually applied study system, skillful workers are working on the day shift on weekdays. According to the density of the number of workers to be working the night shift during the week to be changed, the number of shifts in generated mathematical models were taken as separate constraints.

In this study, the additional workers work outside of working hours will be needed if service is intended to be minimized. In some periods of increased work intensity, the number of available workers if insufficient number of workers with insufficient service or other reasons, this model will be very useful. In addition, according to the experience of assignment status, unlike other studies in the literature is limited to restrictions.

Mathematical representation of the mathematical model of the objective function and constraints are as follows:

Indices:

i=1,2,…..,8 (The total number of workers)

j=1,...….,3 (Number of shifts)

k=1,……7 (The number of working days)

e=1,…...,8 (The number of additional workers)

a=1,….,3 (Skillful group of workers)

i=1 (The foreman worker)

Parameters and Variables:

DS_I: The number of workers who must work in first shift,

DS_II: The number of workers who must work in second shift,

DS_III: The number of workers who must work in third shift,

DS_I_hs: The number of workers who must work in first shift at weekends,

DTCSi: The total weekly working time of the worker i.

$$X_{ijk} = \begin{cases} 1, & \textit{if worker i works at shift j in day k} \\ 0, & \textit{otherwise} \end{cases}$$

$$XK_{ajk} = \begin{cases} 1, & \textit{if worker a works at shift j in day k} \\ 0, & \textit{otherwise} \end{cases}$$

$$YK_{aj} = \begin{cases} 1, & \textit{if worker a works at shift j} \\ 0, & \textit{otherwise} \end{cases}$$

$$Y_{ij} = \begin{cases} 1, & \textit{if worker i works at shift j} \\ 0, & \textit{otherwise} \end{cases}$$

$$Z_{ejk} = \begin{cases} 1, & \textit{if worker e works at shift j in day k} \\ 0, & \textit{otherwise} \end{cases}$$

S_i: The maximum idle time during the scheduling period of worker I,

Sa: During a scheduling period, the worker a, how is that working less than 40 hours,

M: A large number.

Assumptions:

In case of need, it was assumed additional workers can be operated externally as required. In the literature, it is not working in this manner. In addition, different constraints are taken into account seniority. Accordingly, it will work day shifts and are assigned to each shift of workers in particular experience is limited to certain constraints. Specific experience of workers in the same day, desired to study the same shift case was also taken into consideration. There are three different groups of the mathematical model. These are: skillful working group, working group in relevant departments and in an additional group of freelance workers.

Objective Function Model:

The aim of this study is to do the minimum work time availability roll scheduling of additional workers will be used outside. In this case, the objective function is a mathematical model will be as follows;

$$Max\ 8\sum_{e=1}^{8}\sum_{j=1}^{3}\sum_{k=1}^{7} Z_{ejk} \qquad (1)$$

Constraints of the Mathematical Model:

Factory benefiting from bilateral talks at the appropriate unit is arranged below constraints;

- Any shifts will work from that unit total number of workers, it should not exceed the number of units formed working groups;

$$\sum_{i=1}^{8} X_{ijk} \leq 8 \qquad \text{Aj,k} \qquad (2)$$

$$\sum_{a=1}^{3} XK_{ajk} \leq 3 \qquad \text{Aj,k} \qquad (3)$$

- Each shift and the experience of more than one group of workers to work day, the same day and you do not wish to work in the same shift;

$$\sum_{a=1}^{3} XK_{ajk} \leq 1 \qquad \text{Aj,k} \qquad (4)$$

- There is a foreman and the foreman workers working in the service under consideration is only required to work in the first shift on weekdays;

Xijk=1 i=1;j=1;k≠6,7 (5)

- The number of workers on weekdays to work in the first shift is DS I;

$$\sum_{i=1}^{8} X_{ijk} + \sum_{e=1}^{8} Z_{ejk} + \sum_{a=1}^{3} XK_{ajk} = 5 \quad \text{j=1;k≠6,7} \qquad (6)$$

- Number workers to work in the second shift during the week is DS_II;

$$\sum_{i=1}^{8} X_{ijk} + \sum_{e=1}^{8} Z_{ejk} + \sum_{a=1}^{3} XK_{ajk} = 4 \quad \text{j=2, k=1.,7} \qquad (7)$$

- Number workers to work in the third shift during the week is DS_III;

$$\sum_{i=1}^{8} X_{ijk} + \sum_{e=1}^{8} Z_{ejk} + \sum_{a=1}^{3} XK_{ajk} = 4 \quad \text{j=3, k=1,.,7} \qquad (8)$$

- At the weekend, the number of workers to work in the first shift is DS_I_hs;

$$\sum_{i=1}^{8} X_{ijk} + \sum_{e=1}^{8} Z_{ejk} + \sum_{a=1}^{3} XK_{ajk} = 4 \quad \text{j=1, k=6,7} \qquad (9)$$

- Weekly working time must not exceed 40 hours for each worker;

$$\sum_{j=1}^{3}\sum_{k=1}^{7} 8X_{ijk} + S_i \leq 40 \quad i=1,..,8 \qquad (10)$$

- Weekly working time must not exceed 40 hours per skillful workers;

$$\sum_{j=1}^{3}\sum_{k=1}^{7} 8X_{ijk} + S_a \leq 40 \quad i=1,\ldots,8 \qquad (11)$$

- Weekly working time must not exceed 40 hours for each additional employee;

$$\sum_{j=1}^{3}\sum_{k=1}^{7} 8Z_{ejk} + S_i \leq 40 \quad e=1,\ldots,8 \qquad (12)$$

- Negative values are not receiving condition;

$$S_i \geq 0 \quad i=1,\ldots,8 \qquad (13)$$

$$S_a \geq 0 \quad a=1,\ldots,3 \qquad (14)$$

- Each worker will work at the most one shift on the same day;

$$\sum_{j=1}^{3} X_{ijk} \leq 1 \quad i=1,\ldots,8;\ k=1,\ldots,7 \qquad (15)$$

$$\sum_{j=1}^{3} XK_{ajk} \leq 1 \quad a=1,\ldots,3;\ k=1,\ldots,7 \qquad (16)$$

- The total weekly working hours for all workers and skillful working group;

$$HTÇS_i = 8\sum_{j=1}^{3}\sum_{k=1}^{7} X_{ijk} \quad i=1,\ldots,8 \qquad (17)$$

$$HTÇS_a = 8\sum_{j=1}^{3}\sum_{k=1}^{7} X_{ijk} \quad a=1,\ldots,3 \qquad (18)$$

- Each worker, throughout the week, will only operate in a kind of shift;

$$1-\sum_{k=1}^{7} X_{ijk} \leq (1-Y_{ij}) \times M \quad i=1,..,8;\ j=1,2,3 \qquad (19)$$

$$\sum_{k=1}^{7} X_{ijk} \leq Y_{ij} \times M \quad i=1,\ldots,8;\ j=1,2,3 \qquad (20)$$

$$1-\sum_{k=1}^{7} XK_{ajk} \leq (1-YK_{aj}) \times M \quad a=1,..,3;\ j=1,2,3 \qquad (21)$$

$$\sum_{k=1}^{7} XK_{ajk} \leq YK_{aj} \times M \quad a=1,\ldots,3;\ j=1,2,3 \qquad (22)$$

5. Computational Results

In this study, the LINGO program is used for solving the mathematical model. The obtained results are summarized in Table1.

In this study, unlike the literature, assigning additional workers to the schedule status is concerned. Moreover, no previous studies restrict where they can be assigned any number of shifts of workers in particular experience is added to the model.

Table 1. Computational Results

	k=1	k=2	k=3	k=4	k=5	k=6	k=7
j=1	X_{111} X_{611} X_{811} Z_{111} Z_{511}	X_{112} X_{812} Z_{212} Z_{612} Z_{812}	X_{113} X_{613} X_{713} XK_{113} Z_{813}	X_{114} X_{714} XK_{314} Z_{114} Z_{814}	X_{115} X_{315} XK_{115} Z_{315} Z_{515}	X_{616} XK_{116} Z_{316} Z_{516}	X_{317} X_{417} XK_{317} Z_{317}
j=2	X_{721} Z_{221} Z_{621} Z_{821}	X_{222} X_{422} X_{522} XK_{322}	X_{323} XK_{323} Z_{123} Z_{723}	X_{324} Z_{224} Z_{424} Z_{724}	X_{725} XK_{225} Z_{225} Z_{625}	X_{826} XK_{226} Z_{726} Z_{826}	X_{227} XK_{127} Z_{427} Z_{627}
j=3	Z_{331} Z_{431} Z_{631} Z_{731}	X_{332} X_{632} X_{732} XK_{232}	X_{533} XK_{233} Z_{133} Z_{233}	X_{234} X_{634} X_{834} XK_{134}	X_{235} X_{535} XK_{335} Z_{335}	X_{236} X_{436} Z_{136} Z_{736}	X_{537} X_{837} XK_{237} Z_{537}

In this study, which will be the number of workers in skilled workers per shift or unit can be determined. In this model, the working hours of additional workers from outside is minimized. Unlike the literature, the experience the group has been created and is made with scheduling constraints associated with it.

6. Conclusion

Taking into accountthe different approaches and practices, optimal solution with integer linear programming methods of the mathematical model was found. LINGO software solution by the mathematical model has been implemented. The resulting solution is expressed in the table above. As can be seen from the table; 37 of them coming from outside is assigned the task shifts from a total of 89 additional workers. All eight workers who will be appointed as additional items are assigned. Consequently, the workers must study in shifts in the engine unit 8 in addition to the outside.3 skillful worker is assigned 5 shift duty. Similarly, in its own working unit, it was assigned to 5 shift duty. All workers worked 40 hours per week to be worked.

References

[1] Sigrid Knust, Elisabeth Schumacher, “Shift scheduling for tank trucks”, Omega, 513-521, 2011.

[2] Tanguy Lapegue, Odile Bellenguez-Morineau, Damien Prot, “A constraint-based approach for the shift design personnel task scheduling problem with equity”, Computers & Operations Research, 40, 2450-2465, 2013.

[3] MiekeDefraeye, Inneke Van Nieuwenhuyse, “A branch and bound algorithm for shift scheduling with stochastic non-stationary demand”, Computers & Operations Research, 65, 149-162, 2016.

[4] Javier Puente, Alberto Gomez, Isabel Fernandez, Paolo Priore, “Medical doctor rostering problem in a hospital emergency department by means of genetic algorithms”,

Computers & Industrial Engineering, 56, 1232-1242, 2009.

[5] Edmund K. Burke, Jingpeng Li, Rong Qu, “A hybrid model of integer programming and variable neighbourhood search for highly-constrained nurse rostering problems”, European Journal of Operational Research, 203, 484-493, 2010.

[6] Joao Telhada, “Alternative MIP formulations for an integrated shift scheduling and task assignment problem”, Discrete Applied Mathematics, 164, 328-343, 2014.

[7] ŞeydaTopaloğlu, “A shift scheduling model for employees with different seniority levels and an application in healthcare”, European Journal of Operational Reserch, 198, 943-957, 2009.

[8] A.T. Ernst, H. Jiang, M. Krishnamoorthy, B. Owens, D. Sier, “An annotated bibliography of personnel scheduling and rostering”, Annals of Operations Research, 127, 21-144, 2004.

[9] Jorne Van Den Bergh, JeroenBelien, Philippe de Bruecker, Erik DEmeulemeester, Liesje De Boeck, “Personnel scheduling a literature review”, European Journal of Operational Research, 226, 367-385, 2013.

[10] Edmund K. Burke, DeCaumaecker P., Van Den Bergh G., Van LAndeghem H., “The state of the art of nurse rostering”, Journal of Scheduling, 7, 99-441, 2004.

[11] Kohl N., Karisch S.E., “ Airline crew rostering: problem types, modelling and optimization”, Annals of Operations Research, 127, 57-223, 2004.

[12] Bard J. F., Bibici C., De Silva A.H., “Staff scheduling at the United States postal service”, Computers & Operations Research, 30, 71-745, 2003.

[13] Mehrota A.J., “Ringing up business”, OR/MS Today, 24, 1997.

[14] Beaumont N., “Scheduling staff using mixed integer programming”, European Journal of Operational Research, 98, 84-473, 1997.

[15] Mason A.J., Ryan D.M., Panton D.M., “Integrated simulation, heuristic and optimization approaches to staff scheduling”, Operations Research, 46, 75-161, 1998.

[16] Vakharia A.J., Selim H.S., Husted R.R., “Efficient scheduling of part-time employees”, Omega, 20, 13-201, 1992.

[17] Lauer J., Jacobs L.W., Brusco M.J., Bechtold S.E., “An interactive, optimization-based decision support system for scheduling part-time computer lab attendants”, Omega, 22, 26-613, 1994.

[18] Blöchliger I., “Modelling staff scheduling problems”, European Journal of Operational Research, 158, 42-553, 2004.

[19] DeCausMaecker P., Demeester P., Van Den Berghe G., Verbeeke B., “Analysis of real world personnel scheduling problems”, Proceedings of the Fifth International Conference on Practice and Theory of Automated Timetabling in Pittsburgh, 97-183, 2004.

[20] Meisels A., Schaerf A., “Modeling and solving employee timetabling”, Annals of Mathematics and Artificial Intelligence, 39, 41-59, 2003.

[21] Sarin S.S., Aggarwal S., “Modelling and algorithmic development of a staff scheduling problem”, European Journal of Operational Research, “128, 69-558, 2001.

[22] Baran E., Erol S., “A Model suggestion to determine the order quantity in supplier selection problems”, Gazi University Journal of Science Part A: Engineering and Innovation, 3, 45-50, 2014.