Shift scheduling model considering workload and worker’s preference for security department

A Herawati, D R Yuniartha\textsuperscript{1*}, I L I Purnama\textsuperscript{1} and LT Dewi\textsuperscript{1}
Department of Industrial Engineering, Universitas Atma Jaya Yogyakarta, Yogyakarta, Indonesia

* dena@mail.uajy.ac.id

Abstract. Security department operates for 24 hours and applies shift scheduling to organize its workers as well as in hotel industry. This research has been conducted to develop shift scheduling model considering the workers physical workload using rating of perceived exertion (RPE) Borg’s Scale and workers’ preference to accommodate schedule flexibility. The mathematic model is developed in integer linear programming and results optimal solution for simple problem. Resulting shift schedule of the developed model has equally distribution shift allocation among workers to balance the physical workload and give flexibility for workers in working hours arrangement.

1. Introduction
Personnel scheduling is a complex problem since it has many factors to be considered, not only satisfying workforce requirement, management rules, and government regulation, but also the human factor itself as the main role. Biologically people work at morning to afternoon, but nowadays increasing productivity drives many sectors operate for more than 8 hours a day and also in weekend day, mainly in public service such as health center, security service, transportation service, hotels, and retail. Many researchers have found that shift scheduling could cause fatigue and influences workers’ performance, such as in [1][2][3][4][5]. So that the shift arrangement to the workers become one of the important factor considered in managing workers.

Research in [6], [7], and [8] have observed 3 departments of 20 hotels in Yogyakarta, Indonesia, i.e. Security Department, Front Office Department, and Housekeeping Department. There have been identified weaknesses of applied shift schedule for all observed departments [6]. Therewith, [7] has measured workers’ physical and psychosocial workload from the same observed hotels. Since that the 3 observed departments have different job description then the worker’s physical workload has measured using rating of perceived exertion (RPE) Borg’s Scale, conversion of measured worker’s heart rate in performing their job; and using Copenhagen Psychosocial Questionnaire (COPSOQ) for the psychosocial workload to assess worker’s subjective perception of individual interaction with their job and work environment. Some of observed hotels for all the departments in [7] have indicated workers dissatisfaction, shown by moderate level of workers’ psychosocial workload. This indication may be caused by weaknesses of the applied shift schedule, i.e. long working hours in a day, short between-shift break time, and consecutive night shift [6]; in spite of it has found that there is no direct relation between applied shift schedule and workers’ workload of the observed hotels [8].
This research focuses on developing a shift scheduling model for the Hotel Security Department, to eliminate shift schedule weaknesses in [6] and consider workers’ workload. Particularly, security departments operate for 24 hours every day and definitely apply shift systems for managing its workers. The workers have to be in good physical condition, moreover, in night shift. There is a strong relationship between workers’ preference, attitudes, and retention indicators toward shift schedule, especially for working in evening or night shift and weekend day [9]. Furthermore, [9] has found that the key of reducing negative workers’ reactions to working outside standard hours and day is managing better work schedule.

The workload balance has been considered in personnel scheduling in many ways; [10] has developed an integer programming model for shift scheduling of a hotel’s engineering department. The shift scheduling model in [10] has balanced the workers’ workload by limits the working hours in a week and allocates adequate rest hours between shift allocations. Shift scheduling models considering working hours to balance worker’s workload have been studied in [10][12][13][14]. The shift scheduling model could manage the workload balance among workers by considering the shift allocation or the off-day as discussed in [15][16][18][19]. The allocation of shift and off-day to balance workers’ workload balance could be arranged in cyclic scheduling’s [10][15][20]. Besides balancing the workload, researches in personnel scheduling also focus on maintaining work-life balance to accommodate workers’ social and family life. Shift scheduling in [12][14][20][21] has considered workers’ preference to develop schedule flexibility accommodating work-life balance. The developed shift scheduling model in this research would balance the workers’ physical workload in rating of perceived exertion (RPE) Borg’s Scale to maintain workers’ physical performance. The psychosocial workload relates with workers’ social and family time which is in evening or night and weekend day. So that the developed shift scheduling model would consider schedule flexibility applying worker’s preference of not assigned in certain shift in certain day. The management rule considered in the model would base on shift scheduling parameters in [6], referred to [20] for the similar parameters and [19] for balancing the physical workload.

2. Shift Scheduling Model

The developed shift scheduling model in this research would eliminate schedule weaknesses founded in [6] by developing shift allocation constraint and consecutive night shift constrain. The physical workload balancing would manage the shift allocation as in [19] and consecutive workdays arrangement in workstretch. The main objective of the developed shift scheduling model is worker’s preference of assigning in certain shift in certain day fulfillment. So that the objective function of the mathematic model is minimizing violation of workers’ preference fulfillment.

\[
\sum_{i=1}^{N} \sum_{j=1}^{3} \sum_{k=1}^{P} R_{ijk} O_{ijk}
\]

Parameters and variables in the model are:

- \(i\): index for worker, \(i = 1, 2, …, N\)
- \(j\): index for shift, \(j = 1, 2, 3\)
- \(k\): index for day, \(k = 1, 2, …, P\)
- \(m_j\): minimum number of workers in shift \(j\)
- \(n_j\): maximum number of workers in shift \(j\)
- \(A\): physical workload in RPE scale for shift 1
- \(B\): physical workload in RPE scale for shift 2
- \(C\): physical workload in RPE scale for shift 3
- \(S\): physical workload deviation among workers
- \(Y_{ijk}\): binary value for worker’s preference, 1 if worker \(i\) asks for assigned in shift \(j\) of day \(k\)
- \(R_{ijk}\): weight of worker’s preference of assigned in shift \(j\) of day \(k\), i.e. \(\{1, 2, 3, 4\}\)
- \(X_{ijk}\): binary value of worker assignment, 1 if worker \(i\) assigned in shift \(j\) of day \(k\)

Constraints of the mathematic model are:
A worker would be assigned only one shift in one day or had off-day
\[ \sum_{j=1}^{3} X_{ijk} \leq 1 \quad \forall i, \forall k \quad (2) \]

A worker who have been assigned in shift 3, would not be assigned in shift 1 on the next day
\[ X_{3ik} + X_{1i(k+1)} = 1 \quad \forall i, \forall k \quad (3) \]

A worker who have been assigned in shift 2, would not be assigned in shift 1 on the next day
\[ X_{2ik} + X_{1i(k+1)} = 1 \quad \forall i, \forall k \quad (4) \]

A worker would be assigned in shift 3 for maximum 2 consecutive days
\[ X_{3ik} + X_{3i(k+1)} + X_{3i(k+2)} = 1 \quad \forall i, \forall k \quad (5) \]

Maximum and minimum number of workers in a shift
\[ \sum_{i=1}^{N} X_{ijk} \leq n_j \quad \forall j, \forall k \quad (6) \]
\[ \sum_{i=1}^{N} X_{ijk} \geq m_j \quad \forall j, \forall k \quad (7) \]

Balancing the physical workload
\[ \sum_{i=1}^{N} \sum_{k=1}^{p} AX_{ik} + \sum_{i=1}^{N} \sum_{k=1}^{p} BX_{12k} + \sum_{i=1}^{N} \sum_{k=1}^{p} CX_{13k} = L \]

\[ \frac{L}{N} = S \quad (8) \]

\[ \sum_{k=1}^{p} AX_{ik} + \sum_{k=1}^{p} BX_{12k} + \sum_{k=1}^{p} CX_{13k} \leq L + S \quad \forall i \quad (9) \]

\[ \sum_{k=1}^{p} AX_{ik} + \sum_{k=1}^{p} BX_{12k} + \sum_{k=1}^{p} CX_{13k} \geq L - S \quad \forall i \quad (10) \]

Worker’s preference fulfillment
\[ |X_{ijk} - Y_{ijk}| = Q_{ijk} \quad (11) \]

3. Model Evaluation and Discussion
The developed shift scheduling model has been evaluated using actual data investigated in [6] and physical workload data in [7]. Table 2 shows the example of scheduling result for security department which has 4 workers and other scheduling parameters in Table 1.

### Table 1. Scheduling parameter for security department with 4 workers.

| Parameter                        | Shift 1 | Shift 2 | Shift 3 |
|----------------------------------|---------|---------|---------|
| Number of minimum workers        | 1       | 1       | 1       |
| Number of maximum workers        | 1       | 1       | 2       |
| RPE scale of physical workload   | 10.7    | 10.3    | 10.3    |
| Schedule period                  | 30 days |         |         |
| Physical workload deviation among workers | 1     |         |         |

### Table 2. Schedule Result for security department with 4.

| Day | Worker | A | B | C | D |
|-----|--------|---|---|---|---|
| 1   |        | 2 | 1 |   | 3 |
| 2   |        | 2 | 3 | 1 | 3 |
Day Worker
---
3 | 2 | 3 | 1
4 | 3 | 2 | 1
5 | 3 | 2 | 3 | 1
6 | 3 | 1 | 1 | 2
7 | 2 | 3 | 1 | 3
8 | 2 | 3 | 1 | 3
9 | 2 | 3 | 1 | 2
10 | 3 | 2 | 1 | 3
11 | 3 | 1 | 3 | 2
12 | 1 | 3 | 2 | 3
13 | 1 | 3 | 2 | 3
14 | 1 | 3 | 2 | 3
15 | 1 | 3 | 2 | 3
16 | 2 | 2 | 1 | 3
17 | 3 | 1 | 3 | 2
18 | 3 | 1 | 3 | 2
19 | 2 | 1 | 2 | 3
20 | 2 | 3 | 1 | 3
21 | 2 | 3 | 1 | 3
22 | 3 | 1 | 2 | 3
23 | 3 | 1 | 2 | 3
24 | 1 | 3 | 3 | 2
25 | 1 | 2 | 3 | 3
26 | 1 | 3 | 3 | 2
27 | 1 | 3 | 3 | 2
28 | 3 | 1 | 3 | 2
29 | 3 | 3 | 2 | 1
30 | 3 | 3 | 2 | 1

The shift scheduling model has resulted better schedule in shift allocation arrangement and consecutive night shift. Resulted schedule has eliminated long working hours by assigned a worker only one shift in a day in constraint (2), short break time between shift by applying forward rotation in constraint (3) and (4), and long consecutive night shift by constraint (5). To get the forward rotation, the resulted schedule will assign off-day after 2 consecutive night shifts.

The resulted schedule has balanced the workers’ physical workload so that the shift evenly allocated among workers. Physical workload in RPE scale for the workers in the resulted schedule of Table 2 are 260.3, 260.7, 260.7, and 260.3, respectively for worker A, B, C, and D. The schedule flexibility will assign the worker’s preference for certain shift in certain day that also fulfills the workforce requirement in each shift but restricted off-day assignment. For the case in Table 2, worker A, B, C, and D request for assigning in shift 2 in day 2 as tight worker’s preference. To fulfill the minimum number of workers in all shifts and forward rotation, the model only assign worker 2 in shift 2 of day 2, and other workers in shift 1 and 3.

Model evaluation has been conducted to identify the model behavior by modifying the RPE scale of physical workload and number of workers. For the same value of physical workload for all shift would resulted equal number of shift allocation among workers for each shift. When one of the shifts has physical workload value far different among others, than the model would evenly allocate the highest physical workload shift among workers. As the consequences, the other shifts allocation would not be evenly distributed to fulfill the minimum number of workers in a shift and forward rotation.
Increasing number of workers as logically would resulted more balance physical workload as well as number of each shift allocation among workers; however it would need more computation time.

4. Conclusion and Future Research
The developed shift scheduling model has resulted optimal solution for simple problem but it would time consuming for more number of workers. Resulted schedule has assigned workers in forward rotation shift allocation to give adequate break time between shifts. The model has equally distributed shift allocation among workers to balance the physical workload. As security department operates for 24 hours, the worker’s preference of shift assignment in certain day has provided flexibility for workers to arrange their work hours. The shift scheduling model considering workload for housekeeping department has been already conducted in [22] and for front office department has been considered.

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