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Determining Number of Workers for Front Office Using Shift Scheduling Considering Workload

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Abstract. This research is motivated by conflicting condition of satisfying forward rotation shift allocation and available workers constraint. Shift scheduling generally considers number of workers as input parameter that represents the demand especially for service industry. As consequence, shift workers will apply short rest time because of violation of forward rotation shift allocation to satisfy number of workers constraint. This condition could decrease workers satisfaction of their schedule and also influence workers performance. The proposed model has develop 2 stages procedure, i.e. (1) Shift schedule development using initial number of workers, (2) adjusting number of workers to minimize violation of soft constraint. Numerical example shows that the developed shift schedule results global optimal solution for small problem. It is better to adjust the number of workers by decreasing female worker and increasing male workers, because flexibility of male workers to be assigned in all shifts. However, the proposed model can recommend the composition of male and female workers to maintain the advantages of female workers.

Keywords: shift scheduling, number of workers, forward rotation shift allocation, workload

1. INTRODUCTION

Service industries compete in competitive environment caused by demand fluctuation. Service demand varies as function of time in day, week, or seasonally, with random arrivals. Moreover, service industry has to deal with the variability of customers requirements. There is direct interaction between customers and workers so that generally work activity in service industry is oriented toward people rather than toward things (Fitzsimmons & Fitzsimmons, 2004). Service industry operation strategy has to manage its workers in order to supply the fluctuating demand. Shift scheduling is an important staffing problem for many service organizations. The working time is arranged using shift scheduling to meet the demand. However, poor working arrangement in shift scheduling may influence workers performance (Chiang *et al.*, 2010; Puttonen *et al*, 2010; Lee *et al.*, 2011; Wittmer *et al.*, 2015), and it will endanger the service delivery to the customers.

Researches in shift scheduling have been conducted by many researchers. The researches have focused on shift arrangement of workers to meet the demand. Therefore commonly procedure in developing shift scheduling is demand forecasting, demand to number of workers requirement conversion, and shift arrangement based on number of workers requirement. Conversion of demand to number of workers generally also has considered the labor cost. This approach is base on manager viewpoint. On the other hand, shift workers sometimes have problem with their social requirement because of unregular working hours. So that managing shift workers needs to consider working-life balance.

Shift scheduling developing has to consider fairness schedule to all workers by balancing the workload among workers. Researches in shift scheduling considering workload balance have been conducted in many parameters of workload. Shift scheduling considering workers workload balance in parameter of working hours or working days has been conducted by Kassa & Tizazu (2013), Rocha *et al*. (2014), Han & Li (2014), Todovic *et al*. (2015), and van Veldhoven (2016). Some of researches have considered shift allocation as workload balance, founded in Rocha *et al*. (2013), Dahmen & Rekik (2015), van der Veen (2015), Jafari & Salmasi (2015), Todovic *et al*. (2015), and Smalley & Keskinocak (2016). Besides the workload balance, many researches in shift scheduling have considered workers' preference to accommodate schedule flexibility maintaining workers social life requirement, such as in Han & Li (2014), Labidi *et al*. (2014), Jafari & Salmasi (2015), Todovic *et al*. (2015), Jafari & Salmasi (2015), and van Veldhoven (2016).

Jockvom *et al* (2016), Silvania *et al*. (2017), and Herawati *et al* (2017) have developed shift scheduling

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model for different departments in hotels, motivated by weakness identification of applied shift schedule of 20 observed hotels in Yogyakarta, Indonesia (Purnama & Yuniartha, 2014). The developed models have considered physical workload balance and workers' preference. The workers physical workload has been measured using rating of perceived exertion (RPE) Borg's Scale. Weaknesses of long working hours and inadequate rest hours in Purnama & Yuniartha (2014) has been eliminated by Jockvom *et al* (2016), Silvania *et al*. (2017), and Herawati *et al* (2017) using forward rotation shift allocation constraint. But this constraint may not be fully satisfied because of limited by available workers constraint. The objective of proposed model in this research is to determine number of workers as adjustment of available workers obtaining ideal schedule by considering workload balance and forward rotation.

2. MATHEMATICS MODEL

The proposed model in this research is modified the mathematics model in Silviani *et al*. (2017) to determine number of workers requirement for front office. Silviani *el al*. (2017) has developed shift scheduling model considering workers physical workload and worker's preference in 0-1 Goal Programming. The Goal Programming model has 2 constraints, i.e. hard constrain and soft constraint. The hard constraint is not violated constraint, while soft constraint may be violated in minimum. The hard constraints in Silviani *el al*. (2017) have concerned the management rule to meet the demand and maintain labor cost, as well as maintain workers performance. The hard constraints of management rule have been minimum and maximum number of workers in each shift to meet the demand, minimum working days in a week, and number of available workers. The hard constraints to maintain the workers performance by giving adequate rest have been one shift allocation in a day and forward rotation shift allocation, i.e. not assign to morning shift after night shift the day before. The soft constraints in Silviani *el al*. (2017) have been forward rotation shift allocation, i.e. not assign to morning shift after afternoon shift the day before and not assign to afternoon after night shift the day before. These constraints have been considered as soft constraint because conflicting condition between the forward rotation against minimum workers requirement in each shift and number of available workers. The forward rotation will tend to require more workers compare to number of available workers. Other soft constraints in Silviani *el al*. (2017) have been balancing the physical workload and workers' preference fulfillment. Balancing the physical workload will give fairness arrangement among workers to create workers satisfaction to their schedule. Considering workers' preference will give schedule flexibility to accommodate workers social life requirement. The objective function of Silviani *el al*. (2017) shift scheduling model is to minimize violation of the soft constraints.

The objective of the proposed model is to determine the number of workers using the shift scheduling. The procedure consists of 2 stages; (1) Shift schedule development using initial number of workers, (2) adjusting number of workers to minimize violation of soft constraint. In the first stage, the proposed model has modified the shift scheduling model in Silviani *el al*. (2017). The soft constraints of forward rotation in Silviani *el al*. (2017) will be considered as hard constraints in the proposed model to generate more ideal shift arrangement for all workers by giving adequate rest time during the working period. Same as in Silviani *el al*. (2017), the proposed model has considered balancing physical workload and workers preference as soft constraints, in order to prioritize the manajement rule of minimum number of workers in a shift and minimum working days in a week.

The objective of the shift scheduling model in the first stage is to minimize violation of balancing the physical workload and workers' preference fulfillment.

$$\text{Min } Z = \sum_{j=1}^{J}\left(d1_j^+ + d1_j^-\right) + \sum_{k=1}^{K}\left(d2_k^+ + d2_k^-\right) + \sum_{i=1}^{I}\sum_{j=1}^{J}\left(d3_{i,j}^+ + d3_{i,j}^-\right) + \sum_{i=1}^{I}\sum_{k=1}^{K}\left(d4_{i,k}^+ + d4_{i,k}^-\right) + \quad (1)$$

Notations, parameters, and variables:

$PY_{i,j}$: 1 if male worker j is assigned in morning shift of day i, 0 otherwise
$SY_{i,j}$: 1 if male worker j is assigned in afternoon shift of day i, 0 otherwise
$MY_{i,j}$: 1 if male worker j is assigned in night shift of day i, 0 otherwise
$PX_{i,k}$: 1 if female worker k is assigned in morning shift of day i, 0 otherwise
$SX_{i,k}$: 1 if female worker k is assigned in afternoon shift of day i, 0 otherwise
P_{min} : minimum number of workers in morning shift
S_{min} : minimum number of workers in afternoon shift
M_{min} : minimum number of workers in night shift
P_{max} : maximum number of workers in morning shift
S_{max} : maximum number of workers in afternoon shift
M_{max} : maximum number of workers in night shift
i : index for day, $i = 1,2,\ldots,I$
j : index for male worker, $j = 1,2,\ldots,J$
k : index for female worker, $k = 1,2,\ldots,K$
l : maximum number of working days in a month
n : working days in a week
t : working day at the beginning of week
w : consecutive working days

a : RPE scale for morning shift
b : RPE scale for afternoon shift
c : RPE scale for night shift
FY_j : physical workload of male worker in a month
FX_k : physical workload of female worker in a month
g : average physical workload among all workers
$QY_{i,j}$: 1 if male worker j ask for assigned in morning shift, 0 for ask off-day
$RY_{i,j}$: 1 if male worker j ask for assigned in afternoon shift, 0 for ask off-day
$OY_{i,j}$: 1 if male worker j ask for assigned in night shift, 0 for ask off-day
$QX_{i,k}$: 1 if female worker k ask for assigned in morning shift, 0 for ask off-day
$RX_{i,k}$: 1 if female worker k ask for assigned in afternoon shift, 0 for ask off-day

Constraints:

$$\sum_{j=1}^{J} PY_{i,j} + \sum_{k=1}^{K} PX_{i,k} \geq P_{\min} \quad \forall_{\text{i}} \tag{2}$$

$$\sum_{j=1}^{J} SY_{i,j} + \sum_{k=1}^{K} SX_{i,k} \geq S_{\min} \quad \forall_{\text{i}} \tag{3}$$

$$\sum_{j=1}^{J} MY_{i,j} \geq M_{\min} \quad \forall_{\text{i}} \tag{4}$$

$$\sum_{j=1}^{J} PY_{i,j} + \sum_{k=1}^{K} PX_{i,k} \leq P_{\max} \quad \forall_{\text{i}} \tag{5}$$

$$\sum_{j=1}^{J} SY_{i,j} + \sum_{k=1}^{K} SX_{i,k} \leq S_{\max} \quad \forall_{\text{i}} \tag{6}$$

$$\sum_{j=1}^{J} MY_{i,j} \leq M_{\max} \quad \forall_{\text{i}} \tag{7}$$

$$PY_{i,j} + SY_{i,j} + MY_{i,j} \leq 1 \quad \forall_{\text{ij}} \tag{8}$$

$$PX_{i,k} + SX_{i,k} \leq 1 \quad \forall_{\text{ik}} \tag{9}$$

$$MY_{i,j} + PY_{(i+1),j} \leq 1 \quad \forall_{\text{ij}} \tag{10}$$

$$SY_{j,i} + PY_{j,(i+1)} \leq 1 \quad \forall_{\text{ij}} \tag{11}$$

$$MY_{j,i} + SY_{j,(i+1)} \leq 1 \quad \forall_{\text{ij}} \tag{12}$$

$$SX_{k,i} + PX_{k,(i+1)} \leq 1 \quad \forall_{\text{ik}} \tag{13}$$

$$MY_{i,j} + MY_{(i+1),j} + MY_{(i+2),j} \leq 2 \quad \forall_{\text{ij}} \tag{14}$$

$$\sum_{i=t}^{i+n} PY_{j,i} + \sum_{i=t}^{i+n} SY_{j,i} + \sum_{i=t}^{i+n} MY_{j,i} = n \tag{15}$$

$$\sum_{i=t}^{i+n} PX_{k,i} + \sum_{i=t}^{i+n} SX_{k,i} = n \tag{16}$$

$$\sum_{i}^{w+i} PY_{j,i} + \sum_{i}^{w+i} SY_{j,i} + \sum_{i}^{w+i} MY_{j,i} = w \tag{17}$$

$$\sum_{i}^{w+i} PX_{k,i} + \sum_{i}^{w+i} SX_{k,i} = w \tag{18}$$

$$\sum_{i=1}^{I} aPY_{j,i} + \sum_{i=1}^{I} bSY_{j,i} + \sum_{i=1}^{I} cMY_{j,i} = FY_j \tag{19}$$

$$\sum_{i=1}^{K} aPX_{k,i} + \sum_{i=1}^{K} bSX_{k,i} = FX_k \tag{20}$$

$$\frac{\sum_{\text{j=1}}^{\text{J}} \text{FY}_\text{j} + \sum_{\text{k=1}}^{\text{K}} \text{FX}_\text{k}}{\text{J}+\text{K}} = g \tag{21}$$

$$FY_j - g + \text{d1}_\text{j}^+ + \text{d1}_\text{j}^- = 0 \tag{22}$$

$$FX_k - g + \text{d2}_\text{k}^+ + \text{d2}_\text{k}^- = 0 \tag{23}$$

$$QY_{j,i} - PY_{j,i} + \text{d3}_\text{j,i}^+ + \text{d3}_\text{j,i}^- = 0 \tag{24}$$

$$RY_{j,i} - SY_{j,i} + \text{d3}_\text{j,i}^+ + \text{d3}_\text{j,i}^- = 0 \tag{25}$$

$$OY_{j,i} - MY_{j,i} + \text{d3}_\text{j,i}^+ + \text{d3}_\text{j,i}^- = 0 \tag{26}$$

$$QX_{k,i} - PX_{k,i} + \text{d4}_\text{k,i}^+ + \text{d4}_\text{k,i}^- = 0 \tag{27}$$

$$RX_{k,i} - SX_{k,i} + \text{d4}_\text{k,i}^+ + \text{d4}_\text{k,i}^- = 0 \tag{28}$$

Constraints (2) to (7) are management rule of minimum and maximum number of workers in each shift to meet the demand. Constraint (8) and (9) ensure ideal working hours, a shift in a day. Constraints (10) to (13) guarantee the forward shift allocation. Constraints (11) to (13) have been modified into hard constraints. Constraint (14) limits consecutive night shift allocation to avoid negative effect in health of working in night shift.

Constraints (15) to (18) arrange shift allocation to maintain working days according management rule. Constraints (19) to (21) calculate the individual and total physical workload. Constraints (22) and (23) balance the physical workload among workers. Constraints (24) to (28) are workers' preference fulfillment.

In the second stage of proposed model, violation of soft constraint and number of workers allocation in each daily shift become the basis in adjusting number of workers by gender. Number of workers allocation in each daily shift will be compared to maximum number workers in each shift. The model will consider as excess workers if the number of workers allocation if in the shift equal to maximum workers in a shift. If the number of workers adjustment is only based on violation of soft constraints then the model will tend to increase number of workers until no violation. Increasing number of workers will decreasing violation of soft constraints but also increasing daily shift excess workers. It means that increasing number of workers only results in increasing labor cost and not for the schedule quality. The model will stop increasing number of workers when there is no significant improvement in violation of soft constraints and number of shift in maximum workers.

3. NUMERICAL EXAMPLE AND DISCUSSION

The proposed model has been evaluated using real data of shift scheduling parameter identified in Purnama & Yuniartha (2014). Table 1 shows shift scheduling parameter of the 3 hotels as numerical example to evaluate the proposed model. Table 2 to Table 4 shows results of the proposed model for the 3 hotels, respectively.

Table 1. Shift Scheduling Parameter of 3 Hotels

Parameter	Hotel A	Hotel B	Hotel C
Workers	Male 4 Female 1	Male 3 Female 1	Male 3 Female 3
Minimal worker in a shift	1	1	1
Maximal worker in a shift	2	2	2
Workstretch	6-1	5-1	No
Period	30	30	30
RPE scale of morning shift	7.1	8.0	8.9
RPE scale of afternoon/ night shift	7.4	7.8	8.2

Table 2. Results for Hotel A

Workers	4 Male 1 Female	4 Male	5 Male
Physical workload	Balance Average of 187	Balance Average of 187,63	Balance Average of 187, 32
Workers' preference fulfillment	Ok	Ok	Ok
Number of shift in maximum workers	39 shifts	13 shifts	39 shifts

Table 3. Results for Hotel B

Workers	3 Male 1 Female	4 Male	3 Male 2 Female
Physical workload	Balance Average of 196,8	Balance Average of 196,8	Balance Average of 196,8
Workers' preference fulfillment	Not Ok	Ok	Not Ok
Number of shift in maximum workers	10 shifts	10 shifts	35 shifts

Table 4. Results for Hotel C

Workers	3 Male 3 Female	3 Male 2 Female	3 Male 1 Female	4 Male
Physical workload	Balance Average of 212	Balance Average of 211,3	Balance Average of 211,3	Balance Average of 211,3
Workers' preference fulfillment	Ok	Ok	Ok	Ok
Number of shift in maximum workers	60 shifts	36 shifts	10 shifts	10 shifts

Adjustment of decreasing number of male workers less than 4 results no feasible solution because violation of forward rotation, minimum consecutive night shift, and minimum consecutive working days (workstretch) constraint. For Hotel B and C, with male workers of less than 4 may result improving because number of consecutive working days is shorter or no workstretch. Adjustments of Hotel A by eliminate the only female workers results improving in number of shift with maximum workers. But increasing number of male workers into 5 workers results no improvement of shifts in maximum workers. The same condition is shown in Hotel B when adjustment by eliminate the female workers. Decreasing male worker to increase female workers results no improvement as shown in Hotel B. It means that it is better for increasing male workers because of the flexibility of male workers to assign in night shift to satisfy minimum consecutive night shift allocation. However, the proposed model has capability to recommend male and female workers composition to maintain advantages of female workers, as shown also by numerical example of Hotel C.

The proposed model has been evaluated by varying the values of RPE scale and workers' preference. The proposed model will always satisfy physical workload balance. Satisfying workers' preference will be limited by the work stretch pattern. Longer consecutive working days will limit flexibility to satisfy the preference. Model evaluation for developing shift scheduling shows global optimum solution for simple problem but it will be time consuming for increasing number of workers and complex scheduling parameters, such as the workers' preference.

4. CONCLUSION AND SUGESTION

The proposed model can result optimal number of workers base on the improvement of schedule quality in term of violation of workers' preference and excess workers. It is better to adjustment the number of workers by decreasing female worker and increasing male workers, because flexibility of male workers to assigned in all shifts. However, the proposed model can recommend the composition of male and female workers to maintain the advantages of female workers. Satisfying workers' preference is limited by workstretch pattern. More deeply investigation of workers' preference, especially for worker on leave, need to be considered, as well as determining casual workers for increasing demand in high season.

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