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CREATION OF TOTAL SHIFT SCHEDULING MODEL IN RESTAURANT SERVICE − AN EXAMPLE OF THE HIGHLY CLASSICAL LUXURY HOTEL RESTAURANT –

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***Abstract*—This paper focuses on hotel restaurant staff shift scheduling problem. Personnel costs make up a high percentage of the total operating costs at hotels and hotel restaurants, so keeping those costs down is a critical management issue for these managers. We developed the Total Shift Scheduling Model (TSSM) as a method for creating restaurant shift schedules that can maintain service quality while cutting costs (by keeping personnel costs to a minimum). The TSSM simultaneously delivers quality customer service while considering employee tasks, as it is designed to calculate the optimum number of personnel needed. More specifically, the TSSM (1) forecast the number of likely restaurant customers by looking at past operational history and accommodation trends, (2) calculates the number of workers needed by looking at what employees do on the job and how duties are assigned at the restaurant, (3) calculates workload by looking at what services employees provide and operational trends in the restaurant, and (4) creates an employee shift schedule. With these steps, the TSSM is able to produce shift schedules designed to level out employee workloads and improve customer service, thus reducing overall labor costs. We then make use of the insights gained through this process to verify the effectiveness of the TSSM, and obtain the desired results.**

***Keyword*— shift scheduling, restaurant service, employee workload**

I. INTRODUCTION

Shift scheduling represents a challenge for employers trying to plan work shifts for their employees. A lot of studies have been conducted on staff scheduling problem around the world [1-6]. Most studies have focused on scheduling in other industries, including airline crews [7-9], railroad crew [10-11], nurses in hospitals [12-15] and service clerks in call centers[16]. Scheduling problem is a critical management issue, as it determines employment costs and service evaluations. For this reason, it is of great interest to scheduling managers and business operators alike. The importance of this issue has led to a good amount of research that approaches scheduling challenges from both business and academic perspective. Shift scheduling had been of particular interest in the field of nurse scheduling at hospital wards, with experimental studies broadening in recent years to include many business sectors such as hotels, traditional Japanese inns, restaurants, and call centers.

Personnel costs make up a high percentage of the total operating costs at hotels and Japanese-style inns, so keeping those costs down is a critical management issue for these establishments [17].

Within these businesses, restaurants in particular depend heavily not only on their menu selections and ingredients, but also on the level of staff service for customer satisfaction. Putting together a shift schedule designed to provide peak customer service requires a considerable number of staff members and therefore higher personnel costs.

On the other hand, trying to improve service without increasing the number of personnel causes the bulk of the work duties to fall on specific employees. This results in overwork among the mid-career and younger employees who handle most of the frontline service tasks at these establishments, which gives rise to the ongoing problem of considerable turnover rates among these staff members [18].

In this research, the Total Shift Scheduling Model (TSSM) is developed as a method for creating shift schedules for restaurant work. The TSSM improves upon the implicit knowledge of those who traditionally put together the shift schedule by applying statistical methods and mathematical programming to the process. The result is a shift schedule that delivers a more consistent level of customer service while leveling out the employee workload, which in turn allows restaurant operators to reduce their overall personal cost.

II. CURRENT STATUS AND ISSUES FOR SHIFT SCHEDULING IN RESTAURANT SERVICE

We conducted interviews and observed workplaces in order to assess the current status of shift schedule creation in the restaurant business and to identify key issues. These issues are listed below.

(1) Predicting the number of customers:

The relationship between the number of hotel guests and the number of restaurant customers is unclear

(2) Employee considerations:

Significant variation among employees means that most of the work falls to specific staff members

(3) Predicting the number of employees:

The optimum number of employees needed to serve any given number of customers is unclear

(4) Creating the shift schedule:

Those who create the shift schedules rely heavily on knowledge gained through personal experience

These findings indicate that at present, the core issue is securing enough workers: a priority that has placed cutting employee costs on the back burner. In order to address the situation, we searched the literature for research on creating work shift schedules in the restaurant business (both in Japan and overseas) and found that although previous studies had been done to (1) closely monitor employee costs and (2) to consider ways of cutting those costs while leveling out work hours, to their knowledge there had been no comprehensive research on creating shift schedules based on calculations to predict the number of customers.

III. Total Shift Scheduling Model "TSSM"

A. The Goal of Total Shift Scheduling Model "TSSM"

In an effort to address the issues outlined above, we came up with a four-step approach that they organized into the TSSM. The model was then put into action and further developed.

Specifically, we employed statistical methods and mathematical programming to (I) forecast the number of likely restaurant customers by looking at past operational history and accommodation trends (step #1), (II) calculate the number of workers needed by looking at what employees do on the job and how duties are assigned at the restaurant (step #2), (III) calculate workload by looking at what services employees provide and operational trends in the restaurant (step #3), and (IV) create an employee shift schedule (step #4). By following these steps, we created shift schedules designed to level out employee workloads and improve customer service, thus reducing overall personal costs.

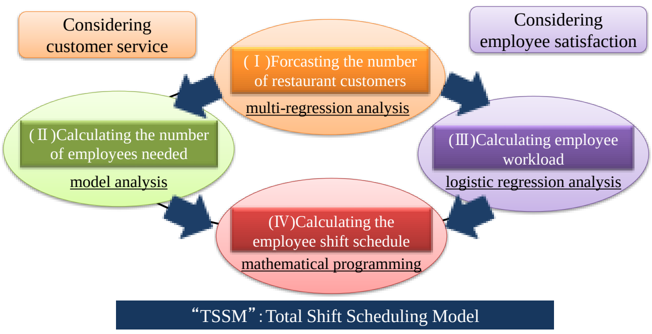

Fig. 1. **Total shift scheduling model "TSSM"**

IV. Expanding "TSSM"

A. Forcasting the number of restaurant customers (Step#1)

For the first step in TSSM, we identified the number of customers to serve in the scheduling based on past operational history and accommodation trends data.

In this chapter, we propose how to forecast the number of restaurant customers. When we first analyzed restaurant operational data, we found that demand is concentrated during peak periods (in Japan, this was Golden Week, Bon vacation, and the year- end and New Year holidays) and that demand also tends to differ depending on the day of the week (more customers visited the restaurant on weekends). We stratified the data based on peak periods and the other, and then conducted a multiple regression analysis predicting to identify fluctuations in the number of restaurant customers. This allowed them to come up with a model that could forecast the number of customers that would actually visit the restaurant on any given day.

With the number of restaurant users defined as the objective variable, we analyzed the number of hotel restaurant customers in the hotel, the month, and whether there were holidays, extended holidays, or events (such as festivals and Christmas party) near the hotel as explanatory variables. Table 1 displays the descriptive variable means.

$$y = \alpha + \beta_1 x_1 + \beta_2 x_2 \cdots + \beta_n x_n \qquad \ldots(1)$$

index	Breakfast	
	β	p
Rreservation status	1.12	0.00**
Customers of the last year same day	0.41	0.01**
Public holiday	5.78	0.46
Consecutive holidays	2.72	0.71
Before consecutive holidays	−6.80	0.30
Events	14.82	0.09
・Month dummy variable :		
February	−1.51	0.80
March	−18.04	0.01**
April	−11.12	0.07
May	−8.10	0.15
June	−9.24	0.13
July	−12.70	0.035*
August	−17.17	0.01*
September	−18.92	0.01**
October	−14.89	0.02*
November	−20.99	0.01**
・Week dummy variable :		
December	−2.87	0.63
Tuesday	7.35	0.07
Wednesday	2.90	0.48
Thursday	7.25	0.01**
Friday	0.62	0.88
Saturday	−1.73	0.70
Sunday	−3.25	0.45
Constant	−25.58	0.01**
R-square	0.85**	
Adjuted R-square	0.73**	
N	358	

1%significance:** 5%significance:*

TABLE I. The descriptive variable means (Step#1)

With the number of restaurant users defined as the objective variable, we analyzed the number of guests in the hotel, the month, and whether there were holidays, extended holidays, or events (such as festivals) near the hotel as explanatory variables. The results indicated a contribution ratio (R*2) of 0.8~0.9 for the day of the week, while residual analysis, a partial regression plot, and other confirmation procedures revealed that the analysis was sufficiently accurate.

B. Calculating the number of restaurant customers (Step#2)

The next step was to take the number of restaurant customers calculated in step #1 and use it to come up with the number of employees needed to run the restaurant. The process for calculating the number of workers was based on the following three considerations regarding work duties.

(a) Frontline staff:

These are the employees that actually interact with customers. The required number changes based on how busy the restaurant is.

(b) Management staff:

These are the employees that oversee restaurant operations (e.g. restaurant manager, waiting staff manager). Their numbers do not change based on how busy the restaurant is.

(c) Prep staff:

These are the employees that assist new hires and trainees or interact with customers during peak hours.

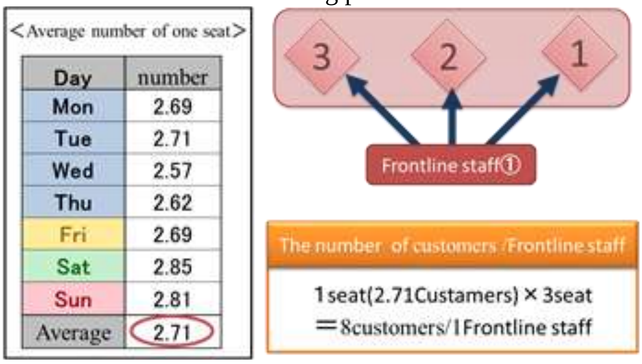

Fig. 2. **The number of Frontline staff**

Frontline staffs are assigned to zones throughout the restaurant in groups of three, with each frontline staff member typically put in charge of serving three tables. Calculations revealed that each table serves an average of 2.71 customers, meaning that each frontline staff member is in charge of serving around 8 customers.

C. Calculating the employee workload (Step#3)

We conducted additional interviews with employees to determine the following two pieces of information regarding workload.

(a) Frontline employee workload is affected by the type of meal course that the customer selects (workload is higher for fancier courses).

(b) Serving customers on the weekends is more complicated than serving customers on weekdays (each customer must be visited more times, they tend to order more items, and the per-item cost is higher), when employees are busier, have a higher workload, and tend to work many overtime hours.

TABLE II. CUSTOMERS ORDER COURSE AND THE NUMBER OF SERVICES

index	Normal course	Middle course	Expensive course
Course price	¥10,000	¥14,000	¥18,000
Number of items	5 items	7 items	9 items
Number of services	12 times+α	18 times+α	23 times+α

As Table 2 indicates, the number of items increases as customers order more expensive courses (regular, mid-level, or high-level). The high-level course requires that servers visit customers more times, thus increasing their workload.

We analyzed the above information in terms of per-customer cost on the weekdays (Monday through Thursday) and weekends (Friday through Sunday) by looking at the difference between F-test (equal variance test) and t-test (mean difference test) results. It was confirmed that per-customer spending was higher on weekends than it was on weekdays (5% significance). (F-test: *F(31,41)=1.864,p<.01$^{***(1\%)}$)(t-test: *t(72)=-5.389,p<.05$^{**(5\%)}$)

We then looked for high workload days where per-customer spending was at least one standard deviation above the average.

A logistic regression analysis was then conducted in order to come up with a mathematical model (1) that could predict (estimate) days with high workload.

$$\log\left(\frac{p}{1-p}\right) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k \quad \ldots(1)$$

Variable	index	β	SD	Wald	odd raties	p
β_0	Forecased result of the number of restaurant customers(Step#1)	0.07	0.42	1.46	0.03	0.01**
β_1	Rreservation status	0.08	0.02	16.70	0.00	0.00**
β_2	Customers of the last year same day	0.01	0.08	2.59	0.11	0.11
β_3	Public holiday	0.29	1.00	0.08	0.78	0.78
β_4	Consecutive holidays	−0.18	0.95	0.04	0.85	0.85
β_5	Before consecutive holidays	−0.42	0.92	0.20	0.65	0.65
β_6	Events	1.16	1.22	0.91	0.34	0.34
	・Month dummy variable :					
β_7	February	−2.76	1.35	4.17	0.04	0.04*
β_8	March	−4.17	1.40	8.85	0.00	0.00**
β_9	April	−1.19	1.00	1.43	0.23	0.23
β_{10}	May	−1.21	0.88	1.87	0.17	0.17
β_{11}	June	−2.16	1.15	3.56	0.06	0.06
β_{12}	July	−2.51	1.16	4.72	0.03	0.03*
β_{13}	August	−2.81	1.06	6.98	0.01	0.00*
β_{14}	September	−1.66	1.01	2.68	0.10	0.10
β_{15}	October	−2.21	1.06	4.37	0.04	0.04*
β_{16}	November	−1.91	1.00	3.65	0.06	0.06
	・Week dummy variable :					
β_{17}	December	−0.33	0.98	0.11	0.74	0.74
β_{18}	Tuesday	0.91	0.60	2.30	0.13	0.13
β_{19}	Wednesday	−1.47	0.82	3.21	0.07	0.07
β_{20}	Thursday	−1.28	0.76	2.80	0.09	0.09
β_{21}	Friday	−1.02	0.62	2.74	0.10	0.10
β_{22}	Saturday	−1.76	0.69	6.49	0.01	0.01**
β_{23}	Sunday	−1.36	0.65	4.44	0.04	0.04*
α	Constant	−7.85	1.66	22.27	0.00	0.00**
	Nagelkerke R-sq.	0.38	1%significance:** 5%significance:*			
	-2Log Likelihood	0.22				
	p	0.00**				
	N	365				

TABLE III. PARTIAL REGRESSION COEFFICIENTS

As Table 3 indicates, if partial regression coefficients are positive, their workload is increasing. On the other hand, if partial regression coefficients are negative, their workload is decreasing.

D. Calculating the employee shift schedule (Step#4)

We took the number of employees calculated in steps #1 and #2 and the workload level identified in step #3 and entered them as conditions in order to create a shift schedule that could be used to manage work at highly classical luxury hotel restaurants.

The shift schedule in Table 4 was created in order to make sure that employees provided a sufficient workforce to cover restaurant operations. In situations where the company could not provide a sufficient number of workers using only its existing employee base (57 employees), it could bring in extra servers (temporary workers) to cover the gap—but these workers cost more than the regular workforce and often result in poorer service quality. In addition, the required tasks differ depending on the workplace, and so different skill sets and work experience are needed. We classified employees into teams according to years of experience and special skills (e.g. sommeliers, bartenders).

TABLE IV. OUTLINE OF CREATING SHIFT

index	Outline
employees	Existing employee (57 employees) Extra servers (temporary workers)
Restaurants	Restaurant(French, Western, Café, Bar) Banquet room(Main, Sub)
Shift	6 Pattern(Rest, BLD, BL, BD, LD, Bar)
Day	1 month (30day)
Team	Skills (Chief, Cashier, Sommelier, Bartender) Career (Intern, Younger, Mid-career, Expert,)

Notation

$I = \{1, 2, \ldots, i\}$: The set of ID-numbers for employee involved

J = {day 1, day 2, …, day j}: The set of days in scheduling period
K = {shift 1, shift2, …, shift k}: The Set of work shift
R = {restaurant 1, restaurant 2, …, restaurant r}: The set of restaurants
M = {meal 1, meal 2, …, mealm}: The set of mealtime, e.g. Breakfast, Lunch, Dinner
P = {p|p means a position group}
: The set of position groups that are grouped by skill level or service period
G_p = {p|p means a staff belonging to position group p}
V = {v|v means work shift}: The set of work shifts (Except holiday shift)
W_v ={v|v means as shift belonging to work shift}
A_{pjk} , $p \in P$, $j \in T$, $k \in U$: The low limit for the number of staff assigned to shift k from position group p on day j
B_{pjk} , $p \in P$, $j \in T$, $k \in U$: The high limit of the number of people assigned to shift k from position group p on day j
C_{pk} , $p \in P$, $k \in U$:The low limit of the number times assigned shift k from position group p
D_{pk} , $p \in P$, $k \in U$:The high limit of the number times assigned shift k from position group p
E_p , $p \in P$, :The low limit of the total working hours of position group p
F_p , $p \in P$, :The high limit of the total working hours of position group p
N_{rjm} ,r∈R, j∈U :The necessary number of staff to meal m in restaurant r on day j
R: The high limit of the number times assigned continuous working
T_k , k∈Shift :Standard working hours of the shift k
U_i , i∈I :The number of continuous working from the previous month
(i,j,k) $\in Q_1$, $i \in I$, $j \in J$, $k \in K$: Fix staff i to shift k on day j
(i,j,k) $\in Q_0$, $i \in I$, $j \in J$, $k \in K$: Avoid staff i to shift k on day
$x_{ijk} \in \{0,1\}$, $i \in I$, $j \in J$, $k \in K$: Binary variable(1:staff i work shift k on day j, 0:not)
$y_{jm} \in \{0,\text{Integer}\}$, $j \in J$, $m \in M$: The number of temporary workers for meal m on day j

Minimize

$$\sum_{j \in J} \sum_{m \in M} y_{j,m} \qquad j \in J, m \in M \qquad \ldots(3)$$

Subject to

$$\sum_{k \in K} x_{ijk} = 1 \qquad i \in I, j \in J \qquad \ldots(4)$$

$$\sum_{i \in J} \sum_{k \in S_m} x_{ijk} + y_{j,m} \geq \sum_{r \in R} N_{r,j,m} \qquad j \in J, m \in M \qquad \ldots(5)$$

$$A_{pjk} \leq \sum_{i \in G_p} x_{ijk} \leq B_{pjk} \qquad p \in P, j \in D, k \in S \qquad \ldots(6)$$

$$C_{pk} \leq \sum_{i \in G_p} \sum_{j \in D} x_{ijk} \leq D_{pk} \qquad p \in P, k \in S \qquad \ldots(7)$$

$$E_p \leq \sum_{j \in D} \sum_{k \in K} (x_{ijk} \times T_k) \leq F_p \qquad i \in G_p \qquad \ldots(8)$$

$$\sum_{\alpha=1}^{h} x_{i(j+\alpha-1)k} \leq R \quad i \in E, j = \{1,2,\ldots,n-1+h\}, k \in W_s, (k,R) \in P_h \qquad \ldots(9)$$

$$U_i + \sum_{\alpha=1}^{R-U_i} x_{i(j+\alpha-1)k} \leq R \quad i \in I, j = \{1,2,\ldots,n-1+h\}, k \in W_s, (k,R) \in P_h \qquad \ldots(10)$$

$$x_{i,j,k} = 1 \qquad (i,j,k) \in Q_1 \qquad \ldots(11)$$

$$x_{i,j,k} = 0 \qquad (i,j,k) \in Q_0 \qquad \ldots(12)$$

Minimize:
Minimize the sum of (1) number of extra servers (temporary workers) ….(3)

Constraints:
1) Have employees select one work shift ….(4)
2) Provide the number of workers needed during the entire period ….(5)
3) Define the number of each group of team needed ….(6)
4) Set upper and lower limits on the number of shifts assigned ….(7)
5) Limit the number of total hours worked per month ….(8)
6) Do not allow employees to work more than seven days in a row ….(9)
7) Set specific shifts for specific employees ….(10)
8) Do not allow specific shifts for specific employees ….(11)

V. EFFECTIVENESS OF TOTAL SHIFT SCHEDULING MODEL

We compared the TSSM-based schedules with those created by shift schedulers making predictions based on their personal experience in order to confirm the effectiveness of the TSSM.

TABLE V. COMPARISON OF THE ACTUAL WORK SHIFTS AND THE WORK SHIFTS CALCULATED USING TSSM

index	The actual work shifts	The work shifts using TSSM
Personnel costs	About 1,490	About 1,340
Temporary servers	369 person	271 person
Unevenness in the workload	28.48 hours	10.51 hours
High workload days	5.1 day	1.4day

Schedulers working from personal experience had a prediction error of 16.5% when estimating the number of customers in step #1, while the TSSM was able to reduce this prediction error to just 4.6%.

In estimating the number of employees needed in step #2, the prediction error was decreased from 18.4% to 6.0%. This made it possible for restaurants to create shift schedules a month in advance—something could not be done without this predictive model, given the high error rate of the previous method.

Table 5 compares the actual work shifts (using the previous method) at a hotel for June 2013 with the work shifts calculated using TSSM for steps #3 and #4.

Table 5 indicate that the hotel was able to reduce labor costs by nearly 10.0% in one month while eliminating nearly 100 temporary servers. The use of TSSM also helped reduce unevenness in the workload.

VI. CONCLUSION

Here, we present the TSSM for the purpose of resolving problems in the hotel industry with creating employee work schedules for food and beverage service tasks. More specifically, the model is applied to create a shift schedule for an actual highly classical luxury hotel restaurant, making it possible to quickly come up with a schedule that more accurately predicts the number of customers. The model's calculations also helped level the workload among individual employees, eliminating variations in the number of hours and high-volume days worked as a way of cutting back on employee costs. The TSSM was thus demonstrated to be effective in this example. In the future, we plan to examine customer attributes and create shift schedules that take into account customer service improvements as well as conditions related to specific employee combinations.

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