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Establishment of a Staff Allocation Method Reflecting Customer Information

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Abstract: *As staff at Japanese-style hotel must provide meticulous hospitality, the way staff members are allocated can have a significant effect on the evaluation of the hotel. In order to increase customer satisfaction, it is absolutely vital that the allocation of staff takes such factors into account to prevent the quality of service from deteriorating. Additionally, as customer preferences differ depending on the customer, it is also necessary to quickly and effectively allocate staff based on customer information. At the same time, staff allocation must also take into account both CS and employment costs.Thus, this research investigates the hospitality provided at high-class Japanese-style hotel and proposesa staff allocation methodusing mathematical programming to take into account employment costs and CS. This allocation method enables the optimum staff to be allocated for each situation, and also allows for unexpected changes.*
Keywords: *Services in guest rooms, Staff allocation, Mathematical programming*

I. Introduction

Generally speaking, Japanese-style hotels (inns) place far more emphasis on hospitality and customer service than typical Western-style hotels, and as a result spend a great deal of time on individual customers [1-3]. A survey conducted by the JAPAN RYOKAN & HOTEL ASSOCIATION on customer motives for choosing a particular inn found that people were extremely concerned with how well customers were treated by the staff. Surveys like these tell us that, particularly at high-class inns, staff allocation can have a powerful impact on the reputation of the facility.

Competition in the Japanese-style hotel industry is understandably fierce, and even top-tier inns must balance their overarching emphasis on CS with other important business considerations—such as keeping employment costs low. When it comes to CS, executives and head managers at prestigious inn consider hospitality to be the lifeblood of their operations, and are therefore greatly concerned with how to assign the perfect staff member to each customer in order to foster lasting bonds of loyalty [4,5].

The daily staff allocation process is led by the head manager, who looks at customer information, time spent with the customer, staff experience and ability (talent, attentiveness, compatibility with the customer, past performance), and a variety of other factors. However, if we take a closer look at this process, we find that the head manager relies on subjective assessments and past experience in making these decisions—which are sometimes nothing more than spur-of-the-moment choices. This makes staff allocation a challenge in the Japanese-style hotel business, as current methods often compromise customer service quality. In short, the industry needs a new method for logically assigning staff; yet, at the time of this writing, no other studies that address staff allocation at Japanese inns from the perspective of CS were found [6-11].

II. Staff Allocation Based On Customer Information

2.1 Conventional staff allocation methods

A preliminary survey was conducted in order to collect the data needed to come up with a staff allocation method that reflected customer information. We went to a long established high-class inn to find out exactly how the head manager had been structuring the employee shifts. The following data items were gathered to form a clear picture of the conventional staff allocation methods.

1) Exhaustive list of all tasks being carried out at the inn
2) Considerations when making employee shifts
3) Factors impacting CS
4) CS level (seven-point scale)
5) Employee shifts on the day of the survey
6) Data needed to conduct mathematical simulations

2.2 Preconditions

Based on the findings from the above preliminary research, we defined the following essential preconditions for creating the employee shift formulas proposed in section 2.4.

1) Required advanced reservations (e.g. customers even select meal items beforehand)
2) Employee shifts are determined by the previous day
3) The inn knows the customers' schedules (mealtimes, menu selections, etc.) before they arrive
4) All guests in the same party have the same activity schedule
5) Changing the staff member tending to a certain guest is avoided whenever possible
6) Staff allocations include extra personnel on standby

2.3 Mathematical formula: using multivariate statistical analysis to calculate CS

Based on the findings obtained in section 2.1, we came up with a mathematical formula(1) by applying a multivariate statistical analysis (multiple regression analysis) method to a causal analysis as shown in Table 1. CS among those who had previously visited the inn (information collected from a customer survey) was used as the explanatory variable, while information on customer interaction collected from the tending staff member was used as the explanatory variable.

Table 1. Factors to Influence CS

Objective Variable	S_{ij}	CS
Explanatory Variable	α_{1i}	Staff experience
	$\alpha_{2i}\beta_{2j}$	Politeness
	$\alpha_{3i}\beta_{3j}$	Experience with wedding services
	$\alpha_{4i}\beta_{4j}$	Food knowledge
	$\alpha_{5i}\beta_{5j}$	Knowledge of the area
	$\alpha_{6i}\beta_{6j}$	Good with children
	$\alpha_{7i}\beta_{7j}$	Services for elderly and/or disabled guests
	γ_{ij}	The differences in age between customer and staff

Table 2. Symbol description (multiple regression analysis)

i	Staff number
j	Customer number
p	Factor number to influence CS
S_{ij}	CS per unit time when staffi services to customer j
α_{pi}	Value of factor p for staff i
β_{pj}	Value of factor p for customer j
γ_{ij}	Differences in age between customer j and staff i
ε_k	Partial regression coefficient (k≥1), Constant term (k=0)

Mathematical formula

$$S_{ij} = \varepsilon_1\alpha_{1i} + \sum_{p=2}^{7}\varepsilon_p\alpha_{pi}\beta_{pj} + \varepsilon_8\gamma_{ij} + \varepsilon_0 \qquad ...(1)$$

2.4 Applying mathematical programming to develop a staff allocation method

Based on the findings obtained in section 2.3, we applied mathematical programming to propose a staff allocation method that takes both employment costs and CS into account.The method converts the preconditions listed in section 2.2 into a formula.However, when assignments are made after the start of the workday, the allocation done earlier (including the current time t) is used as the initial value, and new staff assignments are made starting with t+1. Also note that the timeframe in this case is split into 30-minute intervals during business hours.

Using items 1 to 4 below that need to be considered and the symbols listed in Table 3, formulation is conducted.

1) Maximize CS while keeping employment costs low
2) Shorten the amount of time each staff member spends at the inn
3) Whenever possible, have the same staff member tend to a customer for the duration of their stay
4) Consider extra personnel on standby for staff allocations

Table 3. Symbol description (mathematical programming)

Set	Staff={Staff 1, Staff 2, …, Staff m}	Set of staffs
	Customer={Customer 1, Customer 2, …, Customer n}	Set of customers
	Hour={Hour 1, Hour 2, …, Hour t}	Set of hours
	$Hour_j : j \in Customer$	The servicing time for customer j, Subset of hours
Variable	$x_{ijk} : i \in Staff, j \in Customer, k \in Hour$	Binary variable (1: staff i services to customer j at hour k, 0: not)
	$y_{ik} : i \in Staff, k \in Hour$	Binary variable (1: allocations are carried out prior to and at time k, 0: not)
	$z_{ik} : i \in Staff, k \in Hour$	Binary variable (1: allocations are carried out posterior to and at time k, 0: not)
	$A_{jk} : j \in Customer, k \in Hour$	Number of staffs that customer j need to at hour k
Constant	$S_{ij} : i \in Staff, j \in Customer$	CS per unit time when staff i services to customer j
	$C_i : i \in Staff$	Cost per unit time when staff i work
	W_1, W_2, W_3, W_4	Weighting
	$R_k : k \in Hour$	Number of extra personnel on standby at hour k
	T	Maximum number of extra personnel to each hour and customer

Formulation
minimize

$$\sum_{i \in Staff, j \in Cusomer} \left(\sum_{k \in Hour_j} (-W_1 |y_{ik} - z_{ik}| C_i - W_2 S_{ij} x_{ijk} + W_3 (y_{ik} + z_{ik})) + W_4 \sum_{k=1}^{Hour-1} \frac{1}{2} |x_{ijk} - x_{ij(k+1)}| \right) \quad ...(2)$$

subject to

$$\sum_{i \in Staff} x_{ijk} \geq A_{jk} \quad j \in Customer, k \in Hour_j \quad ...(3)$$

$$\sum_{i \in Staff} x_{ijk} \leq A_{jk} + T \quad j \in Customer, k \in Hour_j \quad ...(4)$$

$$\sum_{i \in Staff, j \in Customer} x_{ijk} \geq \sum_{j \in Customer} A_{jk} + R_k \quad k \in Hour_j \quad ...(5)$$

$$\sum_{j \in Customer_k} x_{ijk} \leq 1 \quad i \in Staff, k \in Hour \quad ...(6)$$

$$\sum_{j \in Customer} x_{ijp} \leq y_{ik} \quad i \in Staff, k \in Hour, p = \{1, 2, ..., k\} \quad ...(7)$$

$$y_{ik} \leq 1 \quad i \in Staff, k \in Hour \quad ...(8)$$

$$\sum_{j \in Customer} x_{ijp} \leq z_{ik} \quad i \in Staff, k \in Hour, p = \{k, k+1, ..., t\} \quad ...(9)$$

$$z_{ik} \leq 1 \quad i \in Staff, k \in Hour \quad ...(10)$$

2.4.1Maximize CS while keeping employment costs low

For the objective variable (formula (2)), CS can be calculated by using the mathematical formula from the previous section (formula (1)) to determine CS level per unit of time (S_{ij}) and adding this figure to a measure of current staff–customer interaction (x_{ijk}) multiplied by weight W_1 and -1, then solving for the shift that will yield the highest customer satisfaction.

Employment costs are determined based on the amount of time each employee is at the inn. Therefore, this time must be kept to a minimum to save cost. A means for doing this is outlined in formula (2) below.
In the objective function, by changing weight W_1, which is multiplied by employment cost (C_i), and weight W_2, which is multiplied by CS (S_{ij}), several shifts can be calculated.

2.4.2 Shorten the amount of time each staff member spends at the inn

We'll start by defining variables y and z.In formulas(7) and (8), y is equal to 1 when allocations are carried out prior to and at time k. If allocations are not carried out prior to or at this time, y is equal to 0 or 1. In the same way, in formulas (9) and (10), z is equal to 1 when allocations are carried out posterior to and at time k. If allocations are not carried out posterior to or at this time, z is equal to 0 or 1.

Furthermore, the formula has the property whereby adding $-W_1|y_{ik} - z_{ik}|C_i$ to the objective function (formula (2)) to solve for the smallest objective function generates an optimum solution. As a result, the difference between the value of y_{ik} and the value of z_{ik} can be maximized as the cost of the employee increases. It also has the property whereby adding $W_3(y_{ij} + z_{ij})$ to the objective function (formula (2)) to solve for the smallest objective function generates an optimum solution. So if W_3 is set to an extremely high value, allocation can be carried out in such a way that values y_{ik} and z_{ik} are kept at zero whenever possible.

Because of these limitations, y_{ik} is always 1 for every hour k starting with the initial hour when an employeei is assigned, and $y_{ik}$is always 0 for every hour k prior to that hour. For z, $z_{ik}$is always 1 for every hour k prior to and including the last hour that employee i spends with a customer, and $z_{ik}$is always 0 for every hour k after that. Therefore, every hour k where both $y_{ik}$and $z_{ik}$are equal to 1 is an hour during which employee i is on the job.

As indicated earlier, $W_3(y_{ij} + z_{ij})$ is part of the objective function (Formula (2)), so allocations should be made so that the values of y_{ik} and z_{ik} are at 0 whenever possible. This allows us to calculate a shift that minimizes the amount of time each staff member spends at the inn and the costs.

2.4.3 Whenever possible, have the same staff member tend to a customer for the duration of their stay

The penalty for having an employee hand off a customer is represented by W_4. By multiplying the formula that expresses the number of times the employee i assigned to customerj changed by penalty W_4 and adding the resulting figure to the objective function (Formula (2)), we can arrive at a solution that indicates the minimum number of employee switches.

Here, the number of employee switches for employee iand guest j is considered linked to changes in the way employee i tends to customers. Once the employee tending to a customer is switched, two changes occur simultaneously: the employee that was able to be assigned at hour k but unable to be assigned to hour k+1 changes, and the employee that was not assigned at hour k but able to be assigned to hour k+1 changes as well. Therefore, every time anemployee switch occurs, it generates two changes in the status of that employee's customer interaction. The number of employee switches is therefore the number of changes in employee customer interaction status multiplied by 1/2. This value is then multiplied by penalty W_4generated by each employee switchand added to the objective function.

2.4.4 Consider extra personnel on standby for staff allocations

Formulas (3) and (4) indicate that the number of employees that interact with customerj for k hours should be at least A_{jk} and at most A_{jk}+T. Formula (3) also prevents employee allocation from becoming concentrated on customers with high satisfaction.

Formula (5) indicates that during hour k, staff can be allocated so that there is a standby staff of at least $R_k$employees.

Finally, during hour k, the number of extra employees is$\sum_{i\in \mathrm{Staff}} y_{ik} z_{ik} - \sum_{j\in \mathrm{Customer}} A_{jk}$, and this measure should be taken when staff members are working overtime with other customers or when a new customer needs to be tended to. Formula (6) indicates that individual employees cannot interact with more than one party at the same time.

2.5Expected results from proposed staff allocation methods

Below are the expected results when employees are assigned using the staff allocation method proposed here.

1) Ability to predict the number of additional customers that staff can tend to during each hour

If we use D to represent the number of customers that a single employee can tend to, Formula (11)can be used to calculate the number of additional customers that staff can tend to (e_k) during hour k by multiplying D by the actual number of extra staff members during hour k.If new customers request a reservation once the workday has started, the number of new customers can be compared to the number of additional customers that the inn can handle (e_k) to immediately determine whether or not the reservation can be accepted.

$$e_k = D\left(\sum_{i\in Staff} y_{ik} z_{ik} - \sum_{j\in Customer} A_{jk}\right) \quad ...(11)$$

2) Ability to set restrictions on CS and total employment costs

If we use F to represent the maximum amount of employment costs, adding Formula (12) to constraint conditions allows us to calculate a staff allocation plan that keeps total employment costs under a limitF.

As for CS, the left side of Formula (13) indicates the total CS gained when allocation is implemented. If we set a minimum CS level of G, adding Formula (13)to constraint conditions allows us to calculate a staff allocation plan that keeps total CS above a limitG.

$$\sum_{i \in Staff, k \in Hour} y_{ik} z_{ik} C_i \le F \qquad ...(12)$$

$$\sum_{i \in Staff, j \in Customer, k \in Hour_j} S_{ik} x_{ijk} \ge G \qquad ...(13)$$

3) Ability to determine whether a customer can be given the time they require when the need for additional services arises

4) Ability to calculate what time customers can be tended to if services cannot currently be rendered

When a customer requests services that cannot be rendered because of insufficient personnel resources, in order to calculate the time at which the service is available, it should be determined whether customers can receive services by staggering customer interaction time ahead or behind by 30 minutes. In this case, the number of times service is pushed back is represented by m and the number of times it is brought forward is represented by n. The upper limit for the number of hours a customer will allow the service to be postponed is represented by M_2, and the upper limit for the number of hours a customer will allow the service to be carried out in advance is represented by N_2.

5) Ability to set restrictions on the number of hours an individual employee can be assigned

When the weight assigned to employment costs (W_1) is far larger than the weight assigned to CS (W_2), or the weight assigned to CS (W_2) is far larger than the weight assigned to employment costs (W_1), it will generate large variations in the number of hours assigned to each employee during shifts. More specifically, in the former case almost all shifts will be assigned to low-cost employees, while in the latter case almost all shifts will be assigned to the employees that deliver the highest CS. This will put excessive workload on certain employees and can lead to low employee satisfaction. When there is a significant difference between the values assigned to weights W_1 and W_2, it is necessary to set a cap on the number of hours that can be assigned to a single employee in one day by adding Formula (14) to constraint conditions, in order to prevent the above situation from occurring.H is themaximum number of hours that a single employee can work.

$$\sum_{i \in Staff, j \in Customer, k \in Hour_j} x_{ijk} \le H \quad i \in Staff \qquad ...(14)$$

III. Application

To apply the method detailed above, we used data collected from interaction with 70 parties of customers at the long established high-class inn mentioned above.

3.1 Mathematical formula to calculate CS using multiple regression analysis

We made use of the factors impacting CS listed in Table 1, section 2.3, to develop a mathematical formula for calculating CS.

CS is determined by whether employees have the ability to provide customers with the kind of service they are looking for, as represented by the explanatory variables "politeness", "experience with weddings", "food knowledge", "knowledge of the area","good with children", and "services for elderly and/or disabled guests". The variable α was therefore used to indicate whether a staff member was skilled in each of these areas, while β was used to represent whether a customer was requesting those services. Multiplying the two variables resulted in a value for each of the six explanatory variables listed above.

Specifically, for the five variables other than wedding experience, areas where the employee was skilled are given an α value of 1, while unskilled areas are given an α value of 0. Services requested by a customer are assigned a β value of 1, while areas that are not that important to the customer are given a β value of 0. The analysis then uses the product of the α and β values. For the wedding variable, the number of weddings handled by the employee in the past is used for the value of α. If the customer requests wedding experience β is given a value of 1, and if wedding experience is not important (the customer is not involved in a wedding party), β is given a value of 0. The analysis then uses the product of these α and β values. In this way, the value of the five explanatory variables other than experience with wedding is 1 only when the employee has the given skills and those skills are important to the customer, and this in turn has an impact on CS.

Table 4 shows the results of that analysis.The multiple regression analysis results given in Table 4 show a multiple correlation coefficient of 0.888 (coefficient of determination adjusted for degrees of freedom (R^{*2}): 0.76), indicating a significant causal relationship. The factor in the table with the highest partial regression coefficient, indicating the greatest impact on the objective variable of CS, was $\alpha_{2i}\beta_{2j}$, which is politeness. The next most important factor in terms of CS was $\alpha_{7i}\beta_{7j}$, which is services for elderly and/or disabled guests.These analysis results allowed us to develop the mathematical formula (15) below.

$$S_{ij} = 0.028\alpha_{1i} + 1.295\alpha_{2i}\beta_{2j} + 0.065\alpha_{3i}\beta_{3j} + 0.053\alpha_{4i}\beta_{4j} + 0.172\alpha_{5i}\beta_{5j} + 0.054\alpha_{6i}\beta_{6j} + 0.707\alpha_{7i}\beta_{7j} - 0.056\gamma_{ij} + 3.983 \quad ...(15)$$

Table 4. The results of the multiple regression analysis

	Objective variable	Residual sum of squares	Multiple correlation coefficient	Contribution ratioR^2	R*^2
	CS	27.083	0.888	0.788	0.76
		R**^2	Residual degree of freedom	Residual standard deviation	
		0.733	61	0.666	
vNo	Explanatory Variable	Residual sum of squares	Variation	Variance ratio	Partial regression coefficient
0	Constant term	52.866	25.783	58.0701	3.983
1	Staff experience	27.152	0.069	0.1553	0.028
2	Politeness	38.212	11.129	25.0656	1.295
3	Experience with wedding services	27.177	0.094	0.2119	0.065
4	Food knowledge	27.104	0.021	0.0467	0.053
5	Knowledge of the area	27.238	0.155	0.3488	0.172
6	Good with children	27.116	0.033	0.0745	0.054
7	Services for elderly and/or disabled guests	28.924	1.84	4.1447	0.707
8	The differences in age between customer and staff	35.058	7.975	17.9614	-0.056

3.2 Comparison with conventional staff allocation methods

We look at items 1 to 4 below, using data collected in the preliminary research described in section 2.1 (shifts arranged using the conventional method without applying the staff allocation method presented here) and comparing it with shifts arranged using the staff allocation method that we derived here. As with the preliminary research, the comparison used ten employees tending to ten parties of customers for a total of 21 hours. The weighted values used were as follows: W_1=1, W_2=1, W_3=10000, W_4=1.

1) Time used to calculate shifts (calculation time)
2) Employment cost and CS (remuneration between the time the employee clocked in and the time the clocked out was used to represent cost)
3) Number of employee switches
4) Amount of time employees spent at the inn

1) Time used to calculate shifts

Our preliminary research revealed that in the conventional staff allocation method, the manager making the assignments looked at the compatibility between employees and customers to manually arrange the shift—a process that ended up taking around thirty minutes. However, by applying the staff allocation method developed here, it took just two seconds for numerical calculations, representing a major reduction in work time.

2) Employment cost and CS

CS values rose by 1.2 over conventional methods when this staff allocation method was applied. At the same time, costs were reduced by 10 with the new method. The verification process thus indicated that compared with conventional staff allocation, the new method is capable of designing shifts that lead to greater satisfaction with less cost.

3) Number of employee switches

As mentioned above, changing the employee tending to a customer has a negative impact on CS, and for this reason the number of employee switches must be kept to a minimum. While conventional methods resulted in nineteen such switches, the new method reduced this number to just eleven.

4) Amount of time employees spent at the inn

In the table above, employees who ended up staying at the innfor less time under the new method are marked in light blue, while those that ended up staying longer are marked in orange. We found that this new staff allocation method reduced the number of hours worked by relatively costly employees while increasing hours for more economical ones.

Table 5.(a) The results of verification (1 to 3)

	Conventional method	Staff allocation method
1)Time used to calculate shifts	About 30 min	2.76 sec
2)Employment cost	￥85225	￥83880
2)CS	454.6	455.8
3)Number of employee switches	19 times	11 times

Table 5.(b) The results of verification (4)

4)Amount of time employees spent at the inn			
Staff No.	Conventional method (h)	Staff allocation method (h)	Employment cost per a hour(￥)
1	1.5	1.5	1400
2	8.5	9.5	1035
3	10.5	10.5	850
4	10.5	10.5	850
5	3.0	1.5	1220
6	10.5	9.0	1220
7	9.5	9.5	1035
8	8.0	10.0	1035
9	9.5	10.5	1035
10	10.0	8.5	1220

3.3 Relationship among CS, employment costs, and maximum number of extra personnel

The shifts designed using the method proposed here examine the following two questions regarding the relationship among the cost spent on employees, CS, and the number of extra personnel. These questions were addressed using the same conditions outlined in section 3.2.

1) How much does CS increase when costs go up?

The graph in Figure 1 shows the relationship between total employment costs and CS. It shows that as total customer satisfaction goes up, labor costs rise as well.

One of the criteria for determining shifts at inns is the point at which costs begin to rise dramatically with increased CS. In other words, an ideal shift is one that has the best cost performance. Fig. 1 indicates that the best shift would be one that achieves a CS level of 570 at a cost of 84,992 yen.

2) How many extra personnel are needed to enhance CS?

Fig. 2 shows the relationship between total CS (horizontal axis) and the maximum number of extra personnel (vertical axis). It indicates that as total CS goes up, the maximum number of extra personnel also increases.

The next is about the relationship between CS and the number of employees at work. Shifts when CS was 580 or lower had only the minimum required number of employees on staff, some of whom were assigned to tend to customers. Shifts where CS went above 580 required that additional personnel be on hand to offer service and enhance satisfaction. The shifts during which CS rose to 796 and above in particular had the maximum number of extra personnel (9) on hand, indicating that assigning all available employees to customers will increase CS. In this case, all ten available employees were tending to customers.

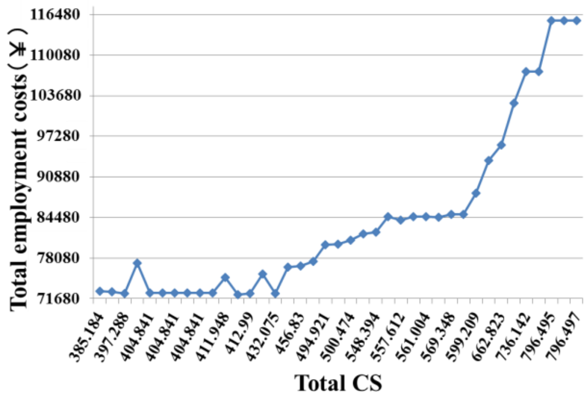

Fig. 1. The relationship between total employment costs and CS

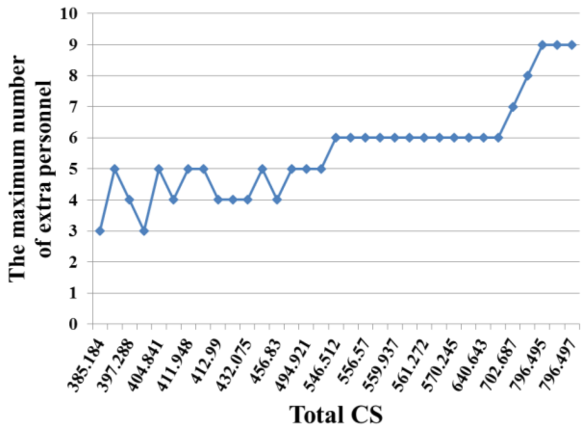

Fig. 2. The relationship between total CS and maximum number of extra personnel

IV. Conclusion

We have seen that applying the staff allocation method developed here allows inns to effectively assign staff members in a way that considers CS, employment costs, and minimizing work times. The method allows the use of weighted employee cost and CS values, changes the number of extra personnel to handle cases where new customers arrive after the workday has started, and offers multiple shift options so that the managers in charge of staff allocation can select shifts to actually assign to their employees. The method is also capable of incorporating changes in the time spent tending to customers, as when new customers arrive after the workday starts.

In the future, it is required to find ways to more accurately predict customer interaction times based on customer attributes and the type of service required.

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