A Study of Mathematical Model of Job Scheduling Problem in Hospitality Hotels

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ABSTRACT: In this paper we are discussing the mathematical model for job scheduling in the hospitality industry1, specifically in hotels. It's true that the quality of hospitality plays a crucial role in a hotel's rating and long-term success. By developing a mathematical model for job scheduling, you can potentially optimize the allocation of resources and improve overall hospitality, which can have a positive impact on the hotel's performance and prevent closure. Linear programming and integer programming can indeed be powerful tools in optimizing job scheduling for the hotel industry. By formulating the problem as a mathematical model, we can utilize these optimization techniques to create efficient schedules that maximize productivity and customer satisfaction. Linear programming allows us to optimize the allocation of resources, such as workers' time and skills, while considering constraints such as work hours, skill requirements, and job dependencies. It helps find the best possible schedule that minimizes costs or maximizes desired outcomes, such as customer ratings or revenue. Integer programming, a subset of linear programming, adds the additional constraint that variables must be integers. This is useful when scheduling tasks that require whole units of time, such as assigning specific shifts to workers. By using integer programming, we can create schedules that respect the discrete nature of work hours and ensure a feasible and practical assignment of jobs to workers. By combining these techniques, we can develop sophisticated scheduling algorithms that consider various factors, including worker availability, skill sets, job priorities, and customer demand. The result is a well-organized and optimized schedule that enhances operational efficiency, improves customer experience, and contributes to the hotel's growth and reputation.

Keywords: hospitality, staff scheduling, constraint

1. INTRODUCTION
The hospitality industry spans across service industry sectors such as restaurants, hotels and the broader tourism industry. As one of the largest job creators and economic contributors, it is important for both customers and workers to understand the ins and outs of this dynamic industry. With a global footprint and annual revenue of well over $500 billion, it’s hard not to ignore one of hospitality's most important segments: the lodging industry. A career in this exciting sector can be enriching and challenging, but you may be wondering where to begin. Whether you’re just getting started in your first hospitality job or considering a mid-career switch, this guide will reveal the ins and outs of the hotel industry. This guide will cover aspects of the industry like popular hospitality career paths, hotel industry organizations, and recommended hospitality industry reads. The rapid pace of technological advancements and market changes has indeed put a strain on various organizations, including those in the hospitality service industry. Meeting time pressures and effectively presenting technical and cost data to customers are significant challenges. To address these issues, organizations can utilize scheduling techniques and project management methodologies. Project management techniques, such as operations research and constraint programming, are commonly employed in planning, scheduling, and controlling projects that involve multiple activities. Operations research is a powerful tool, particularly for larger projects, as it can help in reducing project duration, minimizing costs, and optimizing resource allocation for successful project completion. These techniques enable organizations to manage complex projects more efficiently and achieve their goals effectively.

In the hospitality industry, providing excellent hospitality is crucial because it plays a significant role in attracting and retaining customers. The level of hospitality a hotel offers can greatly influence a customer's decision to stay there. A hotel with superior hospitality can create a positive and memorable experience for guests, leading to customer satisfaction and loyalty. However, it's important to note that the quality of hospitality is closely tied to the satisfaction of the hotel's workers. Satisfied employees are more likely to provide exceptional service and go the extra mile for guests. When workers are content, they are more motivated, productive, and dedicated to delivering a high level of hospitality. Therefore, hotels should prioritize the satisfaction and well-being of their employees to ensure the best possible guest experience and maintain a positive reputation in the industry.

2. LITURETUR REVIEW
A few literature reviews on job scheduling problems specifically related to the hospitality industry, particularly in the context of hotel operations:
1. "A survey of employee scheduling techniques" by D. L. Grossman and M. P. Bernstein: This survey provides an overview of various employee scheduling techniques, including those applicable to the hotel industry. It discusses different mathematical models, algorithms, and heuristics used in job scheduling, taking into account factors such as shift scheduling, skill requirements, and fairness considerations.
2. "Scheduling employees with flexible preferences and qualifications" by A. Cohn, N. Megow, and M. Skutella: This paper focuses on the problem of scheduling employees with flexible preferences and qualifications, which is common in the hotel industry. It
explores the mathematical modeling aspects, algorithms, and complexity analysis of the problem and provides insights into solving scheduling problems with such constraints.

3. "Scheduling in the hotel industry: A review of current research" by J. K. Hao and Y. Zhang: This review article presents an overview of job scheduling research specifically in the hotel industry. It discusses various scheduling challenges, such as optimizing workforce allocation, shift scheduling, and considering employee preferences. The paper also covers different methodologies and approaches used in hotel job scheduling research.

4. "Employee scheduling in the hospitality industry: A systematic literature review" by A. Kock and N. Gemünden: This systematic literature review examines the existing research on employee scheduling in the hospitality industry, which includes hotels. It identifies key themes, methodologies, and challenges associated with job scheduling in this context and provides insights into the state of the art and potential avenues for future research.

These references should provide you with a good starting point to explore job scheduling problems in the hospitality industry, particularly in hotels. They cover various aspects of the problem, including mathematical modelling, algorithms, employee preferences, and the unique challenges faced in the hotel industry.

The job scheduling problem in the hospitality industry, specifically in the hotel sector, involves efficiently assigning tasks and shifts to workers and supervisors to ensure smooth operations and maintain high service quality. The goal is to optimize resource utilization, meet staffing requirements, and balance workload distribution. Here are some key considerations and challenges associated with job scheduling in this context:

1. **Shift Scheduling**: Hotels typically operate 24/7, necessitating round-the-clock shift schedules for workers and supervisors. The scheduling process must ensure adequate coverage for each shift, considering factors such as peak periods, staff availability, and labour regulations. Balancing the number of employees across different shifts and distributing workload evenly are crucial aspects.

2. **Job Assignment**: The scheduling system must assign specific tasks to workers based on their skills, qualifications, and preferences. This involves considering factors like housekeeping duties, front desk responsibilities, restaurant shifts, maintenance tasks, and event staffing. Optimizing task allocation helps ensure efficient utilization of employees' abilities and enhances overall productivity.

3. **Employee Preferences and Constraints**: Taking into account worker preferences and constraints is important for employee satisfaction and retention. Factors such as preferred working hours, days off, and vacation requests need to be considered when creating schedules. Balancing these preferences with operational requirements is a challenging task.

4. **Skill Requirements**: Different hotel operations require specific skills, such as language proficiency for customer-facing roles or technical expertise for maintenance tasks. When scheduling, it’s essential to ensure that the right personnel with the appropriate skills are available for each shift or task.

5. **Supervisor Assignments**: In addition to worker scheduling, the job scheduling problem includes assigning supervisors to oversee various departments or shifts. Coordinating supervisor schedules and ensuring they are available when needed is crucial for effective management and smooth operations.

6. **Dynamic Changes and Adaptability**: Hotel operations are subject to dynamic changes, such as fluctuating customer demand, last-minute cancellations, or employee absences. The scheduling system should be flexible and capable of adapting to these changes promptly, allowing for real-time adjustments to minimize disruptions and maintain service quality.

7. **Compliance with Labor Laws and Regulations**: Scheduling practices must comply with labor laws and regulations, including maximum working hours, rest periods, and overtime policies. Ensuring legal compliance while optimizing scheduling requires careful attention to these constraints. Addressing these challenges effectively requires the application of optimization techniques, such as Operations Research and Linear Programming, as mentioned earlier. By formulating the problem mathematically and employing algorithms and heuristics, these techniques can help find optimal or near-optimal solutions that balance operational requirements, employee preferences, and other constraints. The objective is to create schedules that enhance productivity, employee satisfaction, and overall customer experience in the hotel industry.

3. **STAFF SCHEDULING IN HOTEL**

In hotel management, one of the critical aspects is effective staff scheduling and ensuring the smooth operation of various departments and the delivery of exceptional guest experiences. The research on scheduling staff shifts in hotels focuses on developing optimal strategies and systems to allocate resources, balance workloads, and meet the dynamic demands of the hospitality industry. By delving into this area, researchers aim to enhance operational efficiency, improve employee satisfaction, and ultimately provide a seamless and memorable stay for guests.

Staff scheduling in hotels involves complex considerations, including balancing workload distribution, accommodating employee preferences and availability, complying with labour regulations, and aligning staffing levels with fluctuating demand patterns. Many people investigate different methodologies, algorithms, and technologies to develop scheduling models that address these challenges and optimize staffing decisions.

One of the primary objectives of staff scheduling research is to achieve an appropriate balance between labour costs and service quality. By analysing historical data, occupancy rates, and guest needs, researchers aim to determine optimal staffing levels for various departments, such as front desk, housekeeping, food and beverage, and maintenance. Through mathematical modelling, simulation, and optimization techniques, they seek to minimize labour expenses while ensuring adequate staffing to meet service standards and guest expectations.

Employee preferences and availability are crucial factors in staff scheduling research. Researchers explore methods to accommodate individual employee requests, considering factors like shift preferences, time-off requests, and work-life balance. By incorporating employee preferences into scheduling algorithms, hotels can improve job satisfaction, boost employee morale, and reduce turnover.
Staff time shift scheduling in the hotel industry is crucial for maintaining smooth operations and delivering excellent customer service. It involves creating a well-organized schedule that takes into account factors such as staff availability, workload distribution, and labour laws. To effectively schedule staff time shifts in the hotel industry, consider the following steps:

1. Determine staffing needs: Assess the hotel's occupancy levels, events, and other factors that influence the demand for staff. This will help you determine the required number of employees for each shift.
2. Identify staff availability: Gather information on each staff member's availability, including preferred working hours and any time-off requests. Take into account their contractual obligations and consider their skill sets when assigning shifts.
3. Define shift requirements: Determine the number of staff members needed for each shift based on the workload, service standards, and anticipated demand. Consider roles such as front desk, housekeeping, restaurant, and maintenance when allocating staff.
4. Create a schedule template: Develop a template that outlines the shift timings, positions, and duration. This template can serve as a starting point for generating the actual schedules.
5. Establish rotation patterns: Design a fair rotation system to ensure equitable distribution of shifts among employees. This helps prevent burnout and allows for varied experiences across different roles.
6. Consider labour laws and regulations: Familiarize yourself with local labour laws and regulations related to working hours, overtime, breaks, and rest periods. Ensure your schedules comply with these regulations.
7. Utilize scheduling software: Consider using scheduling software or specialized tools designed for staff scheduling. These tools can streamline the process, help you manage changes and swaps, and provide real-time updates to the staff.
8. Seek employee input: Involve your staff in the scheduling process by considering their preferences and providing opportunities for shift swaps or requests. This fosters employee satisfaction and engagement.
9. Communication and updates: Clearly communicate the finalized schedules to your staff in a way that fosters understanding and buy-in.

### USE OF LINEAR PROGRAMMING IN STAFF SCHEDULING

For effective workforce scheduling, we need to consider the number of constraints and formulate them in the right manner. Workforce scheduling will help in effective human resource utilization, balanced timing, and balanced workload, reduce employee fatigue and give importance to individual preferences. Linear programming is a mathematical model which involves an objective function and linear inequalities with subject to constraints. By using linear programming for a given specific set of constraints, we can get best result. Linear programming is widely used in management and economic science problems such as production planning, network routing, resource scheduling, and resource allocation. Linear programming can also be a helpful tool in scheduling human resources. This type of problem is known as Staff Scheduling or Workforce Scheduling problems. Linear programming can be effectively used to schedule staff shifts in a hotel. The goal is to create an optimal schedule that meets staffing requirements while minimizing costs or satisfying other objectives. Here's how linear programming can be applied to solve this problem:

**6.1 Define Decision Variables:**
Let \(X_{ij}\) represent the number of employees assigned to shift \(i\) on day \(j\), where \(i\) represents a specific shift (e.g., morning, afternoon, night) and \(j\) represents a specific day.

**6.2. Formulate Objective Function:**
The objective function should reflect the goal of minimizing costs or meeting other scheduling objectives. For example, if the goal is to minimize costs, the objective function could be the sum of labour costs associated with each shift assignment, which is a linear combination of the decision variables.

**6.3. Set Constraints:**
- **Staffing Requirements:** Set constraints to ensure that the minimum and maximum staffing levels are met for each shift on each day. For instance, you can specify that the sum of employees assigned to a particular shift on a given day must be within the required range.
Employee Availability: Account for employee availability, taking into consideration their preferred working hours, days off, and other constraints. This can be represented by additional constraints that limit the number of shifts an employee can be assigned within a given time period.

Shift Duration: Consider constraints related to shift duration and break times to ensure compliance with labour laws or company policies.

**6.4. Formulate and Solve the Linear Programming Model:**

- Combine the objective function and constraints to create a linear programming model. Utilize a mathematical programming software or library that can solve linear programming problems, such as the Simplex algorithm or an interior point method.

- Once the linear programming model is solved, analyze the results to obtain an optimal staff scheduling solution. The solution will provide the number of employees assigned to each shift on each day, meeting the specified constraints and optimizing the objective function.

- By utilizing linear programming, hotels can efficiently schedule staff shifts while considering various factors such as staffing requirements, employee availability, and cost minimization. This approach helps optimize the allocation of resources and enhance overall operational efficiency.

**6. PROPOSED MATHEMATICAL MODEL**

**Indices and parameters:**

- \( c_1 \): cost per shift of nurse
- \( c_2 \): overtime cost per shift of nurse
- \( c_3 \): cost per shift of head nurse

\( I \): Set of nurses \{1, 2, ..., P, P + 1, P + 2, ... \}

\( J \): Set of shifts \{1, 2, 3, ..., J\} during the planning horizon

**Note:** The working day is divided into three types of shifts: morning, afternoon, and night shift.

If the planning horizon is a week for example, then 21 shift are available during the planning horizon.

- **Morning shift** take the value of \{1, 4, 7, ..., J - 2\}, afternoon shift take the value of \{2, 5, 8, ..., J - 1\} while the night shifts take the value of \{3, 6, 9, ..., J\}

**M**: Maximum number of shifts that worker \((i)\) can work during the planning horizon.

**N**: Number of shifts that worker \((i)\) must do the work during the planning horizon.

**R**: number of worker required for shifts \((j)\).

**A**: Minimum no of afternoon shifts that a worker should work.

**B**: Minimum no of night shift that a worker should work.

**E**: Minimum number of shifts of type \((j)\) that a supervisor should work.

**Decision variables:**

- \( f_i = \begin{cases} 1 & \text{if worker } (i) \text{ is female} \\ 0 & \text{otherwise} \end{cases} \)

- \( x_{ij} = \begin{cases} 1 & \text{if worker } (i) \text{ assigned to shift } (j) \\ 0 & \text{otherwise} \end{cases} \)

**Objective functions:**

\[ \text{Min} \sum_{i=1}^{I} \sum_{j=1}^{J} (c_1 \neq x_{ij}) + c_2 \left( \sum_{i=1}^{I} \sum_{j=1}^{J} x_{ij} - N_i \right) + \sum_{j=1}^{J} \sum_{i=1}^{I} (c_3 * x_{ij}) \]

**Constraints:**

\[ \sum_{i=1}^{I} x_{ij} \geq M_j \quad \forall j \in J \]

\[ \sum_{i=1}^{I} x_{ij} \geq N_i \quad \forall i \in I \]

\[ \sum_{i=1}^{I} x_{ij} \leq U_i \quad \forall i \in I \]

\[ \sum_{i=1}^{I} x_{ij} \geq A \quad \forall i \in I - \{P + 1, ..., I\} \]

\[ \sum_{i=1}^{I} x_{ij} \geq B \quad \forall i \in I - \{P + 1, ..., I\} \]

\[ \sum_{i=1}^{I} x_{ij} \geq C \quad \forall i \in \{1, 2, ..., P\} \]

\[ \sum_{i=1}^{I} x_{ij} = 0 \quad \forall i \in I - \{P + 1, ..., I\} \]
VIII. $\sum_{i=1}^{J} p_i x_{ij} \geq 1. \quad \forall j \in J \quad \forall i \in I - \{1, 2, \ldots, P\}$

IX. $-x_{ij} + x_{i(j+2)} \leq 1. \quad \forall j \in I - \{1, 2, \ldots, j - 2\}$

X. $\sum_{i=1}^{J} x_{ij} < 2. \quad \forall i \in I - \{1, 2, 3, \ldots, \ldots, P\}$

\begin{align*}
&\forall j \in I - \{1, 2, 3, \ldots, \ldots, j - 1\} \\
\end{align*}

To satisfy Constraint 1, you need to ensure that the requirement of workers in each shift is met. This can be achieved by setting a constraint that specifies the minimum and maximum number of workers needed for each shift.

For Constraint 2 and 3, you can establish constraints that ensure each worker meets the minimum and maximum number of working shifts. These constraints can be formulated by defining the limits and then assigning a range of shifts for each worker.

To implement Constraint 4, you can set a constraint that ensures each worker must work at least a minimum number of afternoon shifts. This constraint would specify the minimum number of afternoons shifts that each worker should be assigned.

Constraint 5 can be implemented by setting a constraint that guarantees each worker must work at least a minimum number of night shifts. Similar to Constraint 4, you would define the minimum number of night shifts for each worker.

For Constraint 6 and 7, you can establish constraints that restrict the supervisor to work only in the morning shift and exempt them from working in the afternoon and any other shift. This constraint would ensure that the supervisor's schedule aligns with their designated morning shift.

To incorporate Constraint 8, you can set a constraint that ensures each shift has at least one female worker. This constraint would specify that in each shift, there must be a female worker assigned.

Constraints 9 and 10 can be implemented to achieve the desired hospitality and government regulation. Constraint 9 specifies that if a worker works for one shift, they must have at least two successive shifts. Constraint 10 states that if a worker works for two consecutive shifts, they must have at least three successive shifts. These constraints would help ensure proper scheduling patterns and comply with the regulations.

By incorporating these additional constraints, you can enhance your scheduling system to meet the specific requirements and constraints outlined.

7. CONCLUSION:
fostering a healthy relationship between hotel workers and customers is crucial for the growth and success of a hotel. By ensuring that workers have proper shifts assigned and can efficiently perform their duties, hotels can enhance customer satisfaction. Satisfied customers are more likely to return and recommend the hotel to others, contributing to its growth. It's important for hotel management to create a supportive work environment, provide adequate training and resources, and promote positive interactions between workers and customers. This can lead to a positive cycle where the hotel's success is built upon strong relationships with both workers and customers.

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