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**Project Report**

**Master’s degree in Business Analytics**

**Course: - Optimization Modeling**

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**Executive Summary**

The WeatherTech Workforce Scheduling report provides a comprehensive analysis and solution to the scheduling inefficiencies at WeatherTech Cafe. The project utilized linear programming techniques to create an optimal staffing schedule, balancing labor costs with operational demands. Data regarding employee wages, shift lengths, and staffing requirements were thoroughly examined. The linear programming model, implemented in Gurobi a sophisticated Python-based optimization tool resulted in significant improvements. These included substantial cost savings, increased scheduling flexibility, and improved customer service. The project demonstrates the critical role of precise data analysis and effective optimization strategies in workforce management, offering valuable insights for addressing similar operational challenges in other settings. This executive summary offers a high-level overview of the project's objectives, methodology, key findings, and its broader implications for effective workforce scheduling.

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**Introduction**

Every workplace has its distinct characteristics, including unique operating costs and a specific set of requirements. As a result, workforce scheduling in such environments is constrained by numerous factors, which can significantly impact overall system performance. These constraints refer to any conditions that may impede the achievement of predetermined goals. The effective management of these constraints, through meticulous planning and the implementation of short-term look-ahead scheduling, is critical for the successful operation and control of a workplace. The schedule provides a detailed plan outlining operations and tasks that must be completed shortly. In this project, we will provide a comprehensive overview of Weathertech's workforce scheduling analysis and propose a conceptual framework to effectively manage these constraints. This framework aims to enhance overall operational efficiency by increasing scheduling flexibility, mitigating potential disruptions, and optimizing resource allocation. By incorporating advanced analytical tools and forecasting methods, the framework seeks to proactively anticipate and address challenges, resulting in a more resilient and adaptable scheduling system.

**Problem Statement**

WeatherTech Cafe operates daily with a mix of full-time and part-time staff, currently facing scheduling inefficiencies due to a lack of consideration for varying daily demands. This has led to either overstaffing during low-demand periods or understaffing at peak times, negatively impacting profitability and productivity. With budget constraints, the management is considering reducing staff hours or layoffs.

To address these challenges, this project analyzes WeatherTech Cafe's workforce scheduling and proposes a framework emphasizing effective planning and look-ahead scheduling. The cafe employs full-time staff, required to work a minimum of 40 hours with a higher wage, and part-time student staff with flexible hours based on their academic schedules. The analysis suggests employing linear programming for workforce optimization, an approach that could be extended to other shift-based work environments.

The optimization models aims to achieve the following for the WeatherTech cafe:  
1. Efficient Staff management and reducing costs hence, resulting in improving savings.

2. Balanced distribution of employees to handle peak and normal business hours of operation.

3. Better reporting and budget management therefore, improving planning strategies.

4. Improved customer service and customer retention.

**Data Collection**

|  |  |  |
| --- | --- | --- |
|  | **Full-time** | **Part time** |
| **Number of employees** | 4 | 19 |
| **Hourly wage** | $20/hr | $16/hr |
| **Shift length** | 8hr | 4hr |
| **Shift times** | "7am-3pm", "3pm-11pm" | "7am-11am", "11am-3pm", "3pm-7pm","7pm-11pm", |
| **Employee Requirement**  **(Mon - Friday)** | 2 employees | 3 employees |
| **Employee**  **Requirement**  **(Sat - Sun)** | 1 employee | 4 employees |
| **Days Off** | Min 1 per/week | No days off |

**Linear Programming Formulation**

## **Decision Variables: -**

The decision variables for the optimization model include:

**Full-Time Employees' Work Schedule**:

Xft,i,d,s​: Binary variable, 1 if full-time employee i works on day d during shift s, 0 otherwise.

**Part-Time Students' Work Schedule**:

Xpt,j,d,s​: Binary variable, 1 if part-time student j works on day d during shift s, 0 otherwise.

## **Objective Function: -**

The objective of the model is to minimize total wage costs, considering both full-time employees and part-time students. The cost is calculated based on the product of hourly wages, duration of the shift length, and the binary work schedule variables for each employee category.

**Minimize Total Wage Costs**

​\* fulltime\_hourlywage \* ShiftLength(s) + \* fulltime\_hourlywage \* ShiftLength(s) +

**Constraints: -**

1. **Staffing Requirements for Each Shift (Fall/Spring):**

**Purpose:** To ensure the cafe has the required number of full-time and part-time staff for each shift.

**Formulation:** For each day d and shift s:

≥ FT\_requirement [d, s]

≥ PT\_requirement [d, s]

2. **Minimum and Maximum Hours for Part-Time Students (Fall/Spring)**

**Purpose:** To regulate the working hours of part-time students, ensuring they work enough but not too much.

**Minimum Hours:** Each part-time student should work at least 10 hours per week.

**Maximum Hours:** Each part-time student should not exceed 20 hours per week.

**Formulation:**

3. **Minimum Hours for Full-Time Employees**

**Purpose:** To ensure that full-time employees work the required minimum hours.

**Minimum Hours:** Full-time employees must work at least 40 hours per week.

**Formulation:**

\* ShiftLength(s) ≥ 40, ∀i

4. **Day Off for Full-Time Employees**

**Purpose:** To guarantee that each full-time employee has at least one day off per week.

**Formulation:**

​ ≤ Number of Working Days per Week− 1, ∀i

Counts the number of days each full-time employee works in a week, ensuring it is one less than the total number of days in the week.

## **Implementation in Gurobi**

Absolutely, here's a revised and more concise version of your text with improved grammar:

In the earlier sections of this report, we detailed the Linear Programming (LP) formulation and gathered essential data parameters for our workforce scheduling problem. This section transitions into the practical application phase, focusing on implementing the LP model using the Gurobi Optimizer in Python.

The implementation began by setting up the Python environment and initializing key constants such as employee count, shift times, hourly wages, and staffing needs. These parameters are fundamental, forming the base for our decision variables and model constraints.

Next, we defined decision variables for both full-time and part-time employees using Gurobi's addVars method. These binary variables are crucial for determining an employee's schedule for specific shifts, transforming our abstract LP model into a practical operational framework.

The objective function aimed to minimize total wage costs by summing the products of decision variables, hourly wages, and shift lengths across all employee categories. We used Gurobi's setObjective method to officially set this summation as our target for minimization.

To reinforce the model, we incorporated a series of constraints. These were meticulously designed to meet staffing requirements, prevent shift overlaps, and comply with working hour limits for all employees. The addConstr method from Gurobi played a key role in integrating these constraints, reflecting the detailed conditions of our LP formulation.

After defining the model, we proceeded to the optimization stage using the optimize method. Post-optimization, we analyzed the model’s output to derive the optimal scheduling solution, focusing on shift timings and hours allocated per employee. The model also alerts users in cases of infeasibility or when an optimal solution is not found.

The results from this optimization were revealing. They not only confirmed the practicality of our LP formulation but also demonstrated its efficiency in creating a cost-effective staffing schedule. The total costs for both full-time and part-time employees underscored the model's utility in workforce management.

In conclusion, this section encapsulates the journey from theoretical LP formulation to its practical application through Python programming, illustrating the potency of mathematical programming in addressing real-world operational challenges such as workforce scheduling. The absence of code in this report is compensated by a detailed narrative of the implementation process, offering a clear understanding of the LP model's functionality. Additionally, a Google Colab file containing the complete code will be made available for reference.

**Project Reflections**

Throughout the course of this project, we faced numerous challenges and learned valuable lessons that have enhanced our understanding and approach to workforce scheduling. Initially, we were confronted with the complex task of scheduling part-time employees without overlapping shifts, especially within the restricted time frame of 4-hour shifts from 7 a.m. to 7 p.m., and with an increased demand for additional staff on weekends. The complexity of this task was underscored when the initial model yielded infeasible solutions for weekend staffing, signalling a substantial gap in our approach.

To tackle this, we employed Gurobi's model.computeIIS() function, which proved instrumental in pinpointing infeasibilities within the constraints. This enabled us to generate an ILP file, facilitating a more detailed and granular analysis of the part-time constraints and leading to a pivotal discovery: our model inadvertently permitted part-time employees to be scheduled for more than 20 hours per day, an obvious oversight.

Armed with this insight, we took corrective measures by revising the model with manual recalculations and by consulting with our professor, who provided assistance in ensuring our scheduling complied with both daily and weekly work hour limits. Through this iterative process, we successfully implemented a feasible and efficient scheduling system for our part-time employees.

The project's journey imparted three major lessons. First, we recognized the crucial role of linear programming in offering insights into decision variables and constraints, which led to a smoother implementation within Gurobi. Second, we learned strategic approaches for identifying and resolving model infeasibilities, which were critical in refining our model. Lastly, the importance of data accuracy was underscored; having up-to-date and reliable employee data was essential to the model's success.

**Conclusion**

The optimization model we have developed is a dependable tool for scheduling café workers, striking a balance between efficiency, cost-effectiveness, and adherence to operational requirements. Our model utilizes binary decision variables along with a comprehensive set of constraints, providing the necessary flexibility to adapt to various operational scenarios. This adaptability is crucial in assisting café managers with optimizing their workforce scheduling processes.

From a financial standpoint, the model has achieved notable cost savings for full-time employees, with a 9.3% reduction from $3,880 to $3,520. Although there has been a slight increase in costs for part-time employees, from $5,718 to $5,888, the model's ability to fully meet all scheduling requirements significantly surpasses the limitations of the current schedule. Even with the marginal cost rise, our model ensures compliance with all operational constraints, showcasing its efficacy and the value it brings to the scheduling process.

In summary, the strategic implementation of our optimization model has not only streamlined shift scheduling but also positively impacted the operational budget. By thoroughly addressing scheduling needs and constraints, the model has optimized staffing functions, a critical factor for the success of café operations.