Optimization of Medical Personnel in Response to COVID-19 in the Philippines: A Working Time Scheduling Problem

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Abstract

The paper addresses an actual personnel scheduling problem in the COVID-19 pandemic, which happened in one of the hospitals in the Philippines. The scheduling focuses on the doctors, nurses, and health aides to meet the current and future workforce demands at the hospital. However, there has not been much attention given to optimizing working time schedules specifically for medical personnel. For this reason, the study's objective is to achieve labor efficiency, lowering hospital and medical center costs to increase the productivity of medical front-liners while developing an ideal schedule for healthcare workers in charge of COVID-19 patients. The researchers used a cost-benefit trade-off analysis to determine how many hospital personnel should be on duty at any given time. It provides an answer to the question of how many hospital personnel should begin work on each shift. And what time do they start each 24 hour day of a seven-day week? Use of Linear Interactive and Discrete Optimizer (LINDO) software to solve the working time scheduling problem. The beginning cost for employee scheduling was $ 5188.35 and resulted in a monthly total labor cost of $ 1880.13 as optimized through the utilization of Operations Research analysis. The hospital savings in this paper are 63.61% as an improvement to reducing labor costs, and the recommended number of hospital staff shows to improve labor efficiency to 64.07%.

Keywords

Personnel Scheduling, Operations Research, Cost-benefit-trade-off, LINDO, COVID-19

1. Introduction

The novel coronavirus 2019 (COVID-19) disease is a terrifying problem that has remained a continuing issue in several countries worldwide, as propounded by Sy. et al. (2021). According to the World Health Organization (WHO) the year 2021, this infectious disease is one of the leading causes of death worldwide, accounting for a quarter to one-third of all deaths. Furthermore, the virus's global spread has overburdened healthcare systems and caused widespread social and economic instability (WHO, 2021). Along with this, the study of Mascha et al. (2020) states that Healthcare Workers also have pivotal importance during a pandemic because their health and well-being ensure that health care institutions function well. In the Philippines, hospitals are always overcrowded for COVID-19 patients and add more rooms to their service area to cater to more patients. With these, the need to hire more medical front-liners from their hospital staff is necessary. However, as stated by Abdalkareem et al. (2021), hiring is still unclear, as a result, personnel scheduling issues have received much interest in this study as more appropriate services can be provided at a lower cost. This study focuses on addressing the working time conditions that help in the sequencing of various works and establishes optimization with time and resources in the medical field to respond to the COVID-19 effectively and efficiently. Personnel scheduling has revolved around optimizing work schedules or determining the best times and shifts for a company's employees to work (Mascha et al. 2020.). Given the information, this paper recognizes the importance and the need for this issue to minimize labor costs while maximizing productivity given the additional working hours for the medical front-liners in the Philippines. In this study, we address the concern of the working time scheduling for medical personnel in response to COVID-19 to accomplish labor productivity, reducing hospital and medical center costs, and develop an ideal schedule for the healthcare workers through the use of LINDO, an Operational Research tool.

1.1 Objectives

The objective is to apply the cost-benefit trade-off analysis and LINDO in Paranaque Hospitals and Medical Centers for COVID-19 patients. To achieve labor efficiency, lower hospital and medical center costs, and increase the productivity of medical front-liners while developing an ideal schedule for healthcare workers in charge of COVID-19 patients. As a response to the rising number of patients and to help the management of the medical hospital to determine how many hospital personnel should be on duty at any given time. Which provides an answer to the question, how many hospital personnel should begin work on each shift and what time they begin each 24 hour day of a seven-day week. The researchers recognize the need for cost control while also consistently providing a satisfactory level of service to the hospital's customers, so the recommended hospital savings in this paper are 63.61% as an improvement to reducing labor costs. Recommend the number of hospital staff shows to improve labor efficiency to 64.07% through the application of Operations Research optimizing the medical industry's response to COVID-19.

2. Literature Review

In the article of Zucchi, et. al. (2021) The number of healthcare workers in treating COVID-19 patients is insufficient in the current situation since they have a higher chance of acquiring the virus and the pandemic had a physical and mental health impact on them such as having a high risk of infection and mental stress, which affects the capability of healthcare workers or medical front liners to provide critical health services in healthcare systems as well as in the study of Shaukat, Al Thobaity, Nyashanu, (2020). In the Philippines, one of the most significant sectors is the healthcare industry, however, with the surge of the COVID-19 cases the need for medical front liners in this time of pandemic affects the shifting schedule of healthcare workers to be in 12-hour shifts compared to the 8-hour shifts before as reported by Inquirer Lifestyle (2020). In agreement with Zucchi et. al. (2021) and Al Thobaity et. al. (2020), optimizing the use of personnel scheduling in the healthcare industry is important especially when unexpected circumstances arise such as the pandemic, and can also address the challenges faced by the medical front liners will help the resiliency of hospitals and medical centers to respond to emergencies which can improve readiness and crisis recovery. Besides, as claimed by Inquirer.Net (2020) personnel scheduling was considered rostering, the act of creating work schedules for employees so that a company can meet the demand for its goods or services. As per the Corporate Finance Institute (2019), the first step in this procedure is to figure out how many people with specific talents are needed to meet the service demand. Individual employees are assigned to shifts to meet the required staffing levels at various times, and duties are subsequently assigned to them for each shift. During the process, all industry regulations related to the applicable workplace agreements must be followed. Conflicting with the study of Chandrakantha, L. (2014), as rostering is a complicated scheduling issue that impacts hospital employees all over the world regularly. It is critical, in particular, to make efficient use of time and effort, to evenly distribute responsibility among employees, and to try to accommodate human preferences. However, it was also being added that a high-quality roster can lead to a happier and more productive workforce, and sustaining nurse manpower would have an impact on the quality of care provided. Comprehensively, staff scheduling, ranging from spreadsheet adaptations of manual processes to mathematical models that use efficient optimum or heuristic algorithms, intends to meet consumer needs cost-effectively while satisfying requirements such as flexible workplace agreements, shift equity, staff preferences, and part-time work.

3. Methods

Operations Research (OR) is an analytical approach to problem-solving and decision-making beneficial in organization management. In operations research, problems are separated into parts and solved with specified steps by mathematical analysis or software. Also, use Operations research to maximize employee productivity and minimize labor costs of the hospital and medical center.

Personnel scheduling or workforce scheduling is the method of developing hourly schedules to satisfy immediate and potential demands that is beneficial in the decision-making approach to uncertain conditions. To methodically achieve labor efficiency that minimizes the cost of hospitals and medical centers, increasing the productivity of medical aides, and developing an ideal schedule for healthcare workers responsible for COVID-19 patients.

Linear Interactive and Discrete Optimizer (LINDO) Software was also used to formulate the solution and solve linear programming, integer programming, nonlinear programming, stochastic programming, and global optimization. The researchers used this to maximize the profit while minimizing capital budgeting, scheduling, resource allocation, and other decisions.

Decisions. The decisions to be made are:

X1 = Number of medical personnel to assign to shift 1 (starts at 6 AM)
X2 = Number of medical personnel to assign to shift 2 (starts at 12 NN)
X3 = Number of medical personnel to assign to shift 3 (starts at 12 AM)

Constraints. The constraints are:

Total number of medical personnel serving 6 am - 9 am $\geq$ 26 (minimum number needed)
Total number of medical personnel serving 9 am - 12 nn $\geq$ 36 (minimum number needed)

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.
.

Total number of medical personnel serving 12 nn - 3 pm $\geq$ 20 (minimum number needed)

Moreover, the study is to formulate another solution by using the Lindo software. It is used to solve problems in linear programming, integer programming, nonlinear programming, stochastic programming, and global optimization. The researchers used this to maximize profit while minimizing costs on capital budgeting, scheduling, resource allocation, and other decisions.

Summary of Formulation.

$$\text{Minimize Cost: } 14X1 + 16X2 + 17X3 \text{ (in dollars)}$$

Subject to:

$$X1 \geq 26$$
$$X1 \geq 36$$
$$X1 + X2 \geq 24$$

.
.
.

$$X3 \geq 20$$

and

$$X1 \geq 0,\ X2 \geq 0,\ X3 \geq 0$$

4. Data Collection

A case study is utilized to test the proposed solution in the personnel scheduling problem of the Parañaque Hospitals and Medical Centers in response to the surge of COVID-19 patients. Parañaque City has a population of 665,822 this constitutes about 4.70% of the total population of the National Capital Region (NCR) and 0.60% of the Philippine population. For the city area, Parañaque has 47.69 square kilometers of the land area shown in Figure 1.

Figure 1. Geographic Area of Parañaque City

According to the Department of Health (DOH), Parañaque City Health Office, and Parañaque City Epidemiology and Surveillance Unit (CESU) the City of Parañaque has over 9,200 Cases accounting for 232 deaths for COVID-19 alone. As one of the cities in the Philippines that experiences a considerable amount of cases and deaths, the city implements city-wide lockdown and calibrated lockdown to control and prevent confirmed COVID-19 cases to spike in number.

5. Results and Discussion

5.1 Numerical Results

Cost control is essential in the medical industry to provide higher quality care for patients. When the funds of the hospitals and medical centers are budgeted, saved, and allocated to the service care of the patients to improve its efficiency, quality, and functionality. Then, the researchers can say that the money being paid by the patients is utilized to improve its services with minimum cost.

Table 1. Data for the Parañaque Hospitals and Medical Centers for COVID-19 Personnel Scheduling Problem

Time Periods Covered by Shift				
Time Period	**1**	**2**	**3**	**Minimum Number Needed**
6AM - 9AM	✓			26
9AM - NOON	✓			36
NOON - 3PM	✓	✓		24
3PM - 6PM		✓		23
6PM - 9PM		✓		30
9PM - 12AM		✓		35
12AM - 3AM		✓	✓	30
3AM - 6AM			✓	25

6AM - 9AM			✓	30
9AM - NOON			✓	48
NOON - 3PM			✓	20
Daily cost per hospital staff	$ 14	$16	$ 17	

Table 1 shows the new schedule of the medical staff for Parañaque Hospitals and Medical Centers, an analysis has been made of the minimum costs while maximizing the staff in its periods to provide a satisfactory level of service. The checkmarks show the periods covered by the respective shifts shown in the table. Each shift has an assigned daily cost per hospital staff involved in each shift. Daily compensation for each assigned hospital staff is shown in the bottom row. The problem is to determine how many hospital staff should be assigned to the respective shifts each day to minimize the personnel cost for each medical staff, based on the bottom row while meeting the service requirements given in the last column.

Table 2. Authorized Shifts for the Parañaque Hospitals and Medical Centers Personnel Scheduling Problem

Authorized shifts are:	
Shift 1	6 AM - 3 PM
Shift 2	3 PM - 3 AM
Shift 3	3 AM - 3PM

Table 2 shows the other entries involving the assigned hospital staff during the 12-hour shift. As shown in the table above for the periods given in the first column. The authorized shifts are: (1) Shift 1: 6 AM - 3 PM, (2) Shift 2: 3 PM - 3 AM and (3) Shift 3: 3 AM - 3PM.

5.2 Graphical Results

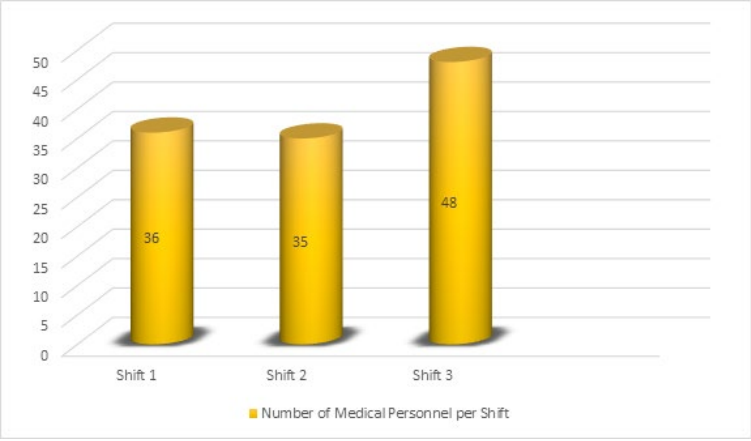

Figure 2. Number of Medical Personnel per Shift

Figure 2 shows the number of medical personnel per shift. Shift 1 which starts from 6 am-3 pm requires 36 medical personnel, 35 medical personnel for shift 2 which starts from 3 pm-3 am, and shift 3 which starts from 3 am-3pm needs 48 medical personnel to meet the demand of the hospital.

```
Minimize 14 X1 + 16 X2 + 17 X3
Subject to
X1              >= 26
X1              >= 36
X1 + X2         >= 24
     X2         >= 23
     X2         >= 30
     X2         >= 35
     X2 + X3    >= 30
          X3    >= 25
          X3    >= 30
          X3    >= 48
          X3    >= 20
```

Figure 3.Summary of Formulation using LINDO Software

Figure 3 shows the objective function, variables, and constraints in order to get the number of medical personnel per shift and total daily cost of hospital staff.

```
LP OPTIMUM FOUND AT STEP      3

        OBJECTIVE FUNCTION VALUE

        1)      1880.000

 VARIABLE        VALUE          REDUCED COST
       X1        36.000000          0.000000
       X2        35.000000          0.000000
       X3        48.000000          0.000000


      ROW   SLACK OR SURPLUS     DUAL PRICES
       2)        10.000000          0.000000
       3)         0.000000        -14.000000
       4)        47.000000          0.000000
       5)        12.000000          0.000000
       6)         5.000000          0.000000
       7)         0.000000        -16.000000
       8)        53.000000          0.000000
       9)        23.000000          0.000000
      10)        18.000000          0.000000
      11)         0.000000        -17.000000
      12)        28.000000          0.000000

NO. ITERATIONS=       3
```

Figure 4. Data of Medical Personnel Needed using LINDO Software

Based on figure 4, the daily salary cost of all the hospital staff is reduced to $ 1880. To achieve the demand, 36 medical personnel are needed for the 8-hour shift, 35 for the 10-hour shift, and 48 medical personnel for the 12-hour shift.

RANGES IN WHICH THE BASIS IS UNCHANGED:

OBJ COEFFICIENT RANGES

VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
X1	14.000000	INFINITY	14.000000
X2	16.000000	INFINITY	16.000000
X3	17.000000	INFINITY	17.000000

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	26.000000	10.000000	INFINITY
3	36.000000	INFINITY	10.000000
4	24.000000	47.000000	INFINITY
5	23.000000	12.000000	INFINITY
6	30.000000	5.000000	INFINITY
7	35.000000	INFINITY	5.000000
8	30.000000	53.000000	INFINITY
9	25.000000	23.000000	INFINITY
10	30.000000	18.000000	INFINITY
11	48.000000	INFINITY	18.000000
12	20.000000	28.000000	INFINITY

Figure 5. Data for Daily Salary Cost of Nurses using LINDO Software

Based on figure 5, the first shift is represented by X1 which is $ 14, the second shift which is equivalent to $ 16, and the third shift which is $ 17 for the daily salary cost.

5.3 Proposed Improvements

A solution was provided through the use of Operations Research tools and techniques to schedule the medical front-liners as well as provide the satisfactory service with the smallest personnel cost possible. Based on the gathered data, the researchers were able to propose improvements to the pandemic widespread reassessment of healthcare workers. The researchers are planning to ensure the workforce has a sufficient number of working hours and healthcare workers needed in every shift to utilize the Paranaque Hospitals and Medical Centers for Covid-19 using various input variables and shifting hours for our simulations for COVID-19 services.

6. Conclusion

The model enables the hospital and medical centers' personnel department management to create a fair personnel schedule as needed and to properly employ staff resources while achieving a variety of technical, legal, and economic constraints. This application demonstrates with the help of OR/MS approaches, local enterprises can simplify their management's task and amass the benefits of effective and fair utilization of their scarce resources.

Table 3. Comparison of Results Before and After Using LINDO Software

			Before Optimization		**After Optimization**	
	Total Working Hours	**Daily Cost per Shift**	**Total Employees per shift**	**Total Daily Cost per Shift**	**Total Employees per Shift**	**Total Daily Cost per Shift**
Shift 1 (6AM-3PM)	8	$ 14	86	$ 1204	36	$ 504
Shift 2 (12NN-3AM)	10	$ 16	113	$ 1808	35	$ 560
Shift 3 (12AM-3PM)	12	$ 17	128	$ 2176	48	$ 816

TOTAL:			327	$ 5188	119	$ 1880

As shown in the table, reducing the number of employees per shift will have an impact on the total daily cost while still achieving the ideal solution for the number of medical front-liners that should be allocated to each shift and how much the entire cost would require using operations research approaches, notably the use of the software. The overall cost of medical per shift before utilizing LINDO software was $ 5188, while the total cost after using LINDO software was $ 1880.

To further improve the productivity of the hospital and medical center, this paper recommends further improvements:

Elimination of Unnecessary Workers

Through the use of LINDO Software, unnecessary workers are identified. It is therefore recommended to follow the employee scheduling system, as this will ensure labor efficiency, yielding to the optimization of the number of hospital staff by 63.61%.

Establishment of an Ideal Timetable for Healthcare Workers

Developing a work schedule for hospital employees ensures that responsibilities are completed in the time allotted while also encouraging them to do their work effectively and efficiently. As a result, the researchers recommend an ideal timetable to provide order and flow to management while ensuring that important tasks are completed at appropriate times.

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