

Workshop 1 “From Theory to Problem Solving: Promoting
Mathematics in Academic Studies in North Macedonia”

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An optimization model for medical personnel scheduling during pandemic

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Abstract

- During a pandemic, the medical staff have a problem in dealing with the care of hospitalized patients. This paper aims to find solution of the problem of medical personnel scheduling in a covid centre during Covid- 19 pandemic. Covid centers face up with a problem how the employees should be organize throughout the working day. This study intend to minimize the number of medical personnel who must be on duty during the weeks when the number of infected is high. So, the staff work schedule must be the best possible so they will optimize all available resources and in the same time will satisfy all operational constraints.

Introduction

- The emergence of the covid 19 pandemic made the work of the medical staff more difficult and indicated the need for new employment and additional engagements of doctors and nurses. The organization of medical staff dealing with sick patients from covid was quite often a problem.
- Sometimes the hospital had excess hired staff, sometimes there was a lack of staff, sometimes the organization of work and the way of defining the shifts were a problem, etc. All the problems came out, because the number of cared for patients often changed, grew and then fell, and this indicated the need for a change in the distribution of the medical staff.

Introduction

- On the other hand, healthcare workers have been under a lot of stress during the covid 19 pandemic. This affected on their mental health. Medical workers had the hardest time in their work experience during the pandemic.
- Every day, medical personnel saw serious health conditions in people of different ages.
- The attached pictures confirm that difficult period:

Introduction



Introduction



Introduction

- In the paper from Zucchi et. al. (2021) and Al Thobaity et. al. (2020) we can see that optimizing of personnel scheduling in the healthcare industry is important especially when arise the pandemic, and especially when the pandemic arised unexpected.
- Healthcare workers in treating COVID-19 patients is insufficient 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 to provide critical health services in healthcare systems as well as in the study of Shaukat (2020).

Introduction

- The researchers as well as Reiniel D et. al. (2021) used a cost benefit trade-off analysis to determine how many hospital personnel should be on duty at any given time and provides from that an answer to the question of how many hospital personnel should begin work on each shift.
- Abdalkareem, Z.A et. al. (2021) offers a summary of the latest studies on healthcare scheduling problems including patients' admission scheduling problem, nurse scheduling problem, operation room scheduling problem, surgery scheduling problem and other healthcare scheduling problems.

An idea

- The goal of this paper, to reduce hospital costs by reducing the number of nurses, we want to achieve by making an ideal schedule for health workers in charge of patients sick with Covid-19 who are cared for in the hospital in Kavadarci, Republic of North Macedonia, as well as patients who come for examination. In doing so, we want to determine how many hospital staff should be on duty 24/7.

An idea

- By using operational research we will minimize labor costs in the hospital.
- To achieve the goal of the paper: minimize costs for hospitals, increase the productivity of medical assistants and develop an ideal schedule for healthcare workers responsible for patients with COVID-19 we use Linear Interactive and Discrete Optimizer (LINDO) software to formulate the solution and solve the problem.

An idea

To find a solution it is necessary to decide:

- X_1 = Number of medical personnel to assign to shift 1 (starts at 7 AM)
- X_2 = Number of medical personnel to assign to shift 2 (starts at 1 PM)
- X_3 = Number of medical personnel to assign to shift 3 (starts at 7 PM)

A case study is utilized to test the proposed solution in the personnel scheduling problem of the Hospital in Kavadarci response to the surge of COVID-19 patients.

Results

The formulation of the problem is

Minimize cost $700X_1 + 750X_2 + 900X_3$ (in denars)

Subject to:

$$X_1 \geq 26$$

$$X_1 \geq 16$$

$$X_1 + X_2 \geq 14$$

$$X_2 \geq 13$$

$$X_2 + X_3 \geq 18$$

$$X_3 \geq 13$$

$$X_3 \geq 11$$

$$X_3 \geq 10$$

Results

- In order to ensure better quality patient care in hospitals, costs must be considered.
- For this reason and many others related to the above, research was done in the hospital in the city of Kavadarci, and according to the received information and data, the following table was made:

Results

	Time per Shift			
Time period	1	2	3	Minimum number needed
7 AM-10 AM	x			26
10AM-1PM	x			16
1PM-4PM	x	x		14
4PM-7PM		x		13
7PM-10PM		x	x	18
10PM-1AM			x	13
1AM-4AM			x	11
4AM-7AM			x	10
Daily cost per hospital staff	700 denars	750 denars	900 denars	

Table 1. Data for the Hospital in Kavadarci during a COVID-19 pandemic for Personnel Scheduling Problem

Results

- Each shift has an assigned for each day cost per hospital staff involved in it.
- The daily allowance for hospital staff can be seen in the last row.
- Should be determined how many hospital staff should be schedule to the respective shifts each day to minimize the cost of medical staff.

Results

```
Min 700X1+750X2+900X3  
st  
X1>=26  
X1>=16  
X1+X2>=14  
X2>=13  
X2+X3>=18  
X3>=13  
X3>=11  
X3>=10
```

Figure 1. Summary of Formulation using LINDO Software

Results

```
LP OPTIMUM FOUND AT STEP      0

      OBJECTIVE FUNCTION VALUE

    1)      29650.00

      VARIABLE            VALUE            REDUCED COST
      X1              26.000000             0.000000
      X2              13.000000             0.000000
      X3              13.000000             0.000000

      ROW    SLACK OR SURPLUS    DUAL PRICES
      2)           0.000000        -700.000000
      3)          10.000000           0.000000
      4)          25.000000           0.000000
      5)           0.000000       -750.000000
      6)           8.000000           0.000000
      7)           0.000000       -900.000000
      8)           2.000000           0.000000
      9)           3.000000           0.000000

      NO. ITERATIONS=          0
```

Figure 2. Data of Medical Personnel Needed using LINDO Software

Results

- Based on figure 2, the daily salary cost of all the hospital staff is reduced to 39650 denars.
- To achieve the demand 26 medical personnel are needed for shift 1, 13 for the shift 2, and 13 medical personnel for the shift 3.

Results

RANGES IN WHICH THE BASIS IS UNCHANGED:

VARIABLE	CURRENT COEF	OBJ COEFFICIENT RANGES	
		ALLOWABLE INCREASE	ALLOWABLE DECREASE
X1	700.000000	INFINITY	700.000000
X2	750.000000	INFINITY	750.000000
X3	900.000000	INFINITY	900.000000

ROW	CURRENT RHS	RIGHTHAND SIDE RANGES	
		ALLOWABLE INCREASE	ALLOWABLE DECREASE
C1	26.000000	INFINITY	10.000000
C2	16.000000	10.000000	INFINITY
C3	14.000000	25.000000	INFINITY
C4	13.000000	INFINITY	8.000000
C5	18.000000	8.000000	INFINITY
C6	13.000000	INFINITY	2.000000
C7	11.000000	2.000000	INFINITY
C8	10.000000	3.000000	INFINITY

Figure 3. Data for Daily Salary Cost of Nurses using LINDO Software

Results

- Based on figure 3, the first shift is represented by X_1 which is 700 denars, the second shift which is equivalent to 750 denars and the third shift which is 900 denars for the daily salary cost.
- Using the LINDO software, redundant workers are identified. Therefore, is needed to follow the employee scheduling system due to ensuring labor efficiency, what will be achieved through optimization of the number of hospital staff.

Conclusion

- The model allows the management of the hospital to create a schedule of the medical staff.
- With the help of the software, all enterprises can simplify the obligations regarding the correct and appropriate schedule of the employed personnel.

Conclusion

			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	9	700 denars	56	39200 denars	26	18200 denars
Shift 2	9	750 denars	28	21000 denars	13	9750 denars
Shift 3	12	900 denars	30	27000 denars	13	11700 denars
Total:			104	87200 denars	52	39650 denars

Table 2. Comparison of Results Before and After Using LINDO Software

Conclusion

- As shown in the table 2, reducing the number of employees per shift will have an impact on the total daily costs.
- The costs for a medical person per shift before using the LINDO software amounted to 87200 denars, while the total costs after using the LINDO software amounted to 39650 denars.

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