Investigation of arranging doctor schedules during the COVID-19 outbreak by using a decision support system

Vijay Kumar Pandey* | Ajay Rastogi†

*Department of Computer Science and Applications, M.D. University, Rohtak, Haryana, India, Associate Professor, Department of Mechanical Engineering.
†Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, India, Assistant Professor, College of Computing Science and Information Technology.

Abstract...
their patients has been highlighted by the virus's increased feelings of uncertainty and anxiety. Doctors have been essential in educating the public about the virus, outlining precautions, and allaying worries and fears (Gopichandran and Sakthivel 2021). As a doctor, it is imperative to notify the proper authorities as soon as any suspected or confirmed cases of the COVID-19 epidemic are discovered. Reporting is an essential first step in stopping the virus's spread and implementing appropriate public health measures. Healthcare workers help with early discovery, contact tracing, and implementing quarantine measures by swiftly alerting public health officials. The allocation of resources is aided by prompt reporting, which guarantees that healthcare institutions have the materials, tools, and staff required to control the epidemic (Li 2020). Emergency doctors leading the charge in treating the crisis are suffering greatly psychologically due to the COVID-19 epidemic. These medical professionals have experienced high tension, apprehension, and emotional weariness. Emergency doctors often endure psychiatric symptoms due to the difficulties of caring for very sick patients, managing little resources, and always being in danger of infection (Bahadiri and Sagaltici 2021).

The COVID-19 epidemic has profoundly changed human history and impacted almost every area of everyday life. The new coronavirus that created this worldwide health catastrophe has led to widespread disease, fatalities, economic disruption, and social unrest. Due to the virus's high contagiousness, it has been necessary to restrict its spread with stringent measures, including lockdowns, social withdrawal, mask wear, and mass vaccination campaigns. The epidemic has put a burden on healthcare systems, increasing hospital admissions and requiring exceptional efforts from healthcare professionals (Bhattacharya 2020). A physician scheduling challenge is a challenging job of developing an effective and fair schedule for a group of doctors to provide the best possible healthcare coverage. This job requires balancing several variables, including patient demands, physician availability and preferences, workload allocation, and regulatory compliance. The objective is to develop a timetable that enhances the quality of patient care while reducing physician weariness and burnout. Concerns, including skill mix, shift rotations, on-call responsibilities, time-off requests, and continuity of care, must be taken into account while solving the physician scheduling challenge (Lan 2023). An exceptional obstacle to efficiently managing healthcare resources during the pandemic is the physician scheduling issue in Covid-19 clinics. Making a productive schedule is essential to ensuring the best possible patient care and reducing the risk of staff burnout due to the rising demand for medical services and the need for specialized treatment. It is important to consider variables, including fluctuating patient numbers, erratic testing needs, and the accessibility of medical personnel with knowledge of infectious illnesses (Das 2020). To arrange a doctor's schedule plans at a Turkey hospital during the COVID-19 outbreak, this study will identify the biggest obstacles to arranging medical appointments.

2. Related works

This study (Hu 2021) examined changes in US physician work schedules and activities before and after the COVID-19 epidemic by analyzing a longitudinal data collection. The Current Population Survey (CPS), managed by the United States Bureau of the Census, compiles demographic and employment statistics. Between 65% and 83% of people responded. Eight interviews were conducted with participants throughout 16 months, allowing for longitudinal analysis. Primary care doctors have been on the epidemic's front lines, increasing their already heavy workloads. The aim was to assess primary care doctors' burnout during the COVID-19 epidemic and its related variables. Cross-sectional research using the snowball method with an online questionnaire distributed through social media. Primary care doctors employed in Portugal during the first COVID-19 epidemic were the intended audience (Baptista 2021).

To assist in healthcare supply chain demand management, lower groups stress, interfere the COVID-19 growth chain, and prevent epidemics from spreading, a practical DSS was developed using doctors' knowledge and a fuzzy inference system (FIS) (Govindan 2020). The paper (Barnes and Zvarioka 2021) discusses the results of empirical research conducted to assess and evaluate the use of clinical and diagnostic DSS, Internet of Things-based healthcare apps, and wearable medical devices with artificial intelligence in COVID-19 prevention, screening, and treatment. The study (Nilashi 2020) examined the benefits of wearable technology for healthcare during epidemics or natural catastrophes. It also investigated how recommendation agents introduce and promote these gadgets. Finally, it identifies several flaws in the present recommendation agents and offers suitable fixes to ensure these systems work well during a COVID-19 epidemic. The paper (Ertem 2022) demonstrates that decision-analytic techniques might assist policymakers in simulating various social exclusion scenarios during the first phases of a widespread epidemic. While no vaccines for universal vaccination and effective antiviral therapies are readily accessible, policymakers should brace for further waves of illnesses due to the socially isolated methods utilized. The organization and features of consultations in Belgian out-of-hours primary care over five weekends during the height of the COVID-19 epidemic are described in the study, along with a comparison to a comparable time in 2019. Real-time observational studies using routinely collected, anonymized clinical data from reports of home visits, phone conversations, and in-person consultations (Morreel 2020).

The university hospital's outpatient clinic is located within one of the globe's worst-affected places; report the outcomes of using telemedicine there. The widespread use of telemedicine by patients during the 2009 COVID-19 epidemic in Detroit is illustrative of the study (Garg 2021). The paper (Creese 2021) discovered that many physicians saw modest benefits in their physical health during the first wave of the pandemic, despite the hazards associated with catching COVID-
19. But many also saw a worsening in their mental health as a result of worry, emotional tiredness, guilt, loneliness, and inadequate support. These results offer insight into doctors’ health during COVID-19 and how the epidemic has impacted them emotionally and professionally. Infection control procedures owing to COVID-19 hinder end-of-life discussions among patients, relatives, and multifunctional medical teams providing palliative care. Setting up in-person family conferences has been challenging due to stringent limits on visiting times and guest numbers. Although phone-based telehealth consultations can be a solution, the clinician-patient connection may suffer from the absence of nonverbal clues (Wu et al. 2020).

The study (Zerbini 2020) examined the psychological toll that doctors and nurses take on depending on the interaction of COVID-19 patients. Additionally, they looked at their support needs during the crisis and the supportive services they employed. This may be because nurses have a heavier workload and spend more time with COVID-19 patients in person than doctors do. The main causes of personal-, work-, and patient-related burnout were direct engagement in COVID-19 screening or treatment, having a medical condition, and less psychological support at work. Burnout was cited as a result of participants’ workloads, the uncertainty brought on by the epidemic, a difficult work-family balance, and strained working relationships. Exhaustion seemed to be the most common symptom, and many people developed problem-focused coping strategies to get through the pandemic (Roslan 2021). Visiting hours and communication with medical staff were severely limited for family members of COVID-19 patients hospitalized in Intensive Care Units (ICUs) in the Netherlands during the initial peak of the epidemic. Family communication is an essential component of critical care. However, the pandemic required medical ICU personnel to set up alternate family support, including Family Support Teams (FSTs), which comprised employees who weren’t ICU affiliated and called families on the phone (Klopf et al. 2021).

The study (Spiers 2021) focused on junior physicians’ experiences working in the UK during the COVID-19 epidemic. These medical professionals classified themselves as having experienced discomfort due to working circumstances. Junior doctors to work during COVID-19 were traumatized, which left them feeling helpless and decreased the effectiveness of their coping mechanisms. The perspectives of medical professionals practicing a variety of doctors on the sudden and unanticipated shift away from traditional face-to-face meetings toward online webinars, as well as their recommendations for the direction the industry should take going forward. The satisfaction of doctors is important while designing future educational initiatives. Because the present crisis is likely to have long-lasting impacts, webinars should be seen as a supplement to in-person instruction rather than a substitute (Ismail 2021).

3. Problem definition and mathematical model

3.1. Problem definition

Person. Analyze the PSP of a hospital in Turkey that serves as the major medical facility in the area and offers treatment to both routine patients and COVID-19 patients. The hospital has 14 regular departments, including internal cardiology, medicine, urology, and brain surgery. These divisions keep going to run daily throughout the epidemic. Therefore, doctors perform the shifts and refer to them as the usual shifts in these departments. Three new departments have been created by management to help those affected by COVID-19 and fight the epidemic: COVID-Emergency, COVID-Service, and COVID-ICU.

The present doctors are employed in the COVID-19 departments. As a result, in addition to the responsibilities assigned to their respective departments, doctors must also participate in the COVID-19 department’ or COVID-19 shifts, which significantly adds to their workload. Patients with COVID-19, a novel illness, may have various problems. The hospital administration thus determined that assigning doctors from multiple specialties to each COVID- Service and COVID- ICU shift would be preferable.

The hospital is not pandemic since other departments continue to provide medical treatment despite low incidence. As a result, in addition to the COVID-19 hours, the doctors also work in shifts that are part of their usual schedules. Each department works a normal 24-hour shift. The number of doctors in the department determines how many are required for each normal shift. Some doctors are not eligible for certain COVID-19 departmental shifts. For instance, whereas a urologist cannot work in COVID-ICU, a neurosurgeon or general surgeon may.

The quantity of exposure to the virus is one of the major factors that might impact it. Therefore, it is important to limit the amount of time that doctors are exposed to COVID-19. This should be accomplished by fairly distributing the shifts among the doctors. Since doctors are highly cautious about the number of shifts owing to the possibility of being ill and then spreading an infection to others, it is crucial to maintain their morale. Two actions may be used to distribute shifts fairly. The COVID-19 shifts of doctors’ work in a particular department must be similar first. Instance, the amount of shifts the urologists work in the COVID-Service should be comparable, if not the same. The COVID-19 shifts performed by doctors from various departments shouldn’t fluctuate too much at the second level. For instance, medical doctors and surgery, in general, must have the same amount of COVID-ICU shifts. The day between the shifts should be free. A doctor only works on their days off. Additionally, if feasible, there may be two off days between consecutive shifts. There are three eight-hour shifts in COVID-Emergency. The first shift runs from 8:00 AM to 4:00 PM. The second shift runs from 16:00 to 24:00. The last shift occurs between 0:00 and 8:00 the next morning. One medical professional must be assigned to each shift.
Table 1 displays the allocation of usual and COVID-19 shifts and the total number of doctors working in the departments. The first section, the department, contains a list of the hospital’s operating divisions. The following section, Number of doctors, list the doctors available in the normal departments. The number of doctors required for the normal shifts is shown in the third column. The columns that follow will detail which units are eligible to join COVID-ICU, COVID-Surgery, and COVID-Emergency. The COVID-Intensive Care Unit may employ specialists in internal medicine who aren’t needed in the COVID-Surgery or COVID-Emergency departments. The final department on the table, Pool, is a collection of departments. To facilitate scheduling during the pandemic, it was decided to consolidate the pool group departments because of the limited number of doctors inside them. Despite not having a normal shift, the hospital’s administration chose to use every department in the pool for the shift since one of the hospital’s important units was experiencing chest pains. Therefore, a doctor’s typical pool shift would occur in the Department of chest disease.

<table>
<thead>
<tr>
<th>Department</th>
<th>COVID-emergency</th>
<th>Regular shifts</th>
<th>COVID-service</th>
<th>COVID-ICU</th>
<th>Num. of physicians</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ear, and nose, throat disorders</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>General Surgery</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Radiology</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Psychiatry</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Internal</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Medicine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chest Diseases</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Cardiology</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Pool</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Orthopedics and Traumatology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urology</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Eye, center</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Neurology</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Brain Surgery</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Cardiovascular Surgery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surgery</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>

3.2. Face Mathematical model

In the MIP model, sets are groups of unique items or objects gathered according to certain criteria or attributes. These sets are used to represent several classes or categories inside the model. The DSS uses the MIP model as its base engine and offers an intuitive interface for data entry, scenario exploration, and schedule generation. It improves decision-making by providing knowledge, advice, and the capacity to weigh trade-offs between multiple scheduling goals or constraints. Based on the results produced by the MIP model, the DSS enables users to make scheduling choices that are more effective and efficient. The MIP model considers several variables to optimize the distribution of doctors working hours while guaranteeing fairness and the best possible coverage. The MIP model creates an ideal schedule that reduces conflicts and increases production by considering doctors’ availability, preferences, and necessary abilities. It feels elements including the number of patients, emergency circumstances, and the need for sufficient rest times to avoid tiredness. The resultant value, kit, in the value of objective in this form (equation 1) is left undefined so that the user may input additional measurements for other departments, doctors, or days.

\[
\min \mathcal{Z} = \sum_{i \in I} \sum_{j \in S} \mathcal{L}_{ij} \mathcal{W}_{ij} \quad (1)
\]

i / j Set of doctors and Index

According to a restriction, A doctor can only work one shift each day (equation 2).

\[
t \cdot s \cdot \sum_{c \in C} \sum_{t \in T(c)} V_{itds} \leq 1 \quad (2)
\]

Third (equation 3) limitations make sure there are enough physicians on hand for each shift. Because of this limitation, ineligible physicians cannot be placed in clinical units. Finding doctors with varied specialties to fill the COVID-19 shifts is a crucial problem for the departments involved in COVID-19.

\[
\sum_{c \in C} V_{itds} = M \quad s \in S, c \in C, t \in T(c) \quad (3)
\]

s / S Set of days and Index
\(c/C\) Set of departments and Index
\(t/T(c)\) Set of shift type for each department \(c\) and Index

One doctor from cardiovascular surgery may be present during the COVID-ICU shift, but three doctors representing neurology, brain surgery, and cardiovascular surgery may all work the same shift. The COVID-19 shift’s doctors must come from various departments, according to constraint (equation 4).

\[
\sum_{c \in C(d) \cap \{q\}} V_{itds} \leq 1 \quad s \in S, c \in C_d, t \in T(c), q \in Q
\]  

(4)

\(I_d\) Doctors that are part of the regular workforce
\(I_q\) Doctors are qualified to work with the COVID-19 department
\(I_c\) A group of doctors engaged by department \(c\)
\(C_q\) Regular departments in the hospital
\(C_d\) COVID-19 departments in the hospital
\(V_{itds}\) If doctors \(i\) is working on shift \(s\) on day \(t\) at department \(d\)

Each doctor will get a day off between each consecutive shift thanks to a restriction (equation 5).

\[
\sum_{c \in C} \sum_{t \in T(c)} (V_{itds} + V_{it+1cs}) \leq 1 \quad j \in J, s \in S, s + 1 \in S
\]  

(5)

Equation (6) constraint demands two days off between consecutive shifts, if possible.

\[
\sum_{c \in C} \sum_{t \in T(c)} (V_{itds} + V_{it+1cs} + V_{it+2cs}) \leq 1 + W_t \quad j \in J, s \in S, s + 1 \in S, s + 2 \in S
\]  

(6)

It’s a flexible constraint since the system may choose not to take two days off between shifts if it can’t.

\[
NC_{qc}^{\text{min}} \leq \sum_{s \in S} \sum_{t \in T(c)} V_{itds} \quad q \in Q, c \in C
\]  

(7)

\(NC_{qc}^{\text{min}}\) Minimum shifts a normal department \(q\) doctor must work at department \(c\) monthly.

Equations (7) and (8) in the restrictions section reveal the maximum and minimum overall number of shifts in departments \(c\) that may be assigned to a doctor from normal departments.

\[
\sum_{c \in C} \sum_{t \in T(c)} (V_{itds} \leq NC_{qc}^{\text{max}}) \quad j \in J, q \in Q, c \in C
\]  

(8)

\(NC_{qc}^{\text{max}}\) Maximum amount of shifts a normal department \(q\) doctor may work in department \(c\) in one month.

The maximum and minimum numbers of these changes are minimized by the constraint (equation 9).

\[
NC_{qc}^{\text{min}} - ND_{qc}^{\text{min}} \leq NCK_{qc} \quad j \in J, q \in Q, c \in C
\]  

(9)

\(NCK_{qc}\) The maximum and lowest number of doctor shifts that may be worked in department \(q\) regular department \(c\) throughout a calendar month.

The constraints (equation 10) and (equation 11), in turn, show the COVID-19 shifts that the doctor worked in the COVID-19 Department \(c\).  

\[
NC_{c}^{\text{min}} \leq \sum_{s \in S} \sum_{t \in T(c)} V_{itds} \quad q \in Q, c \in C
\]  

(10)

\(NC_{c}^{\text{min}}\), The department \(c\) maximum and minimum monthly shift count is limited.

\[
\sum_{c \in C} \sum_{t \in T(c)} (V_{itds} \leq NK_{c}^{\text{max}}) \quad j \in J, c \in C
\]  

(11)

\(NK_{c}^{\text{max}}\) Maximum amount of shifts a doctor may work in Department \(c\) in a calendar month

The maximum and lowest numbers of these shifts are kept as close to one another as possible by constraint (Equation 12).

\[
NC_{c}^{\text{min}} - NC_{c}^{\text{min}} \leq NKK_{c} \quad c \in C
\]  

(12)

To ensure that every general surgeon obtains an equal amount of COVID-ICU shifts, the same DSS may set the restriction COVID-ICU difference for surgical procedures to zero. The detrimental constraints are listed in (equation 13).

\[
V_{itds} \in \{0, 1\} \quad j \in J, s \in S, c \in C, t \in T(c)
\]
\[ w_{it} \in (0,1) \land i \in I_q, seS \]
\[ NK^c_{\min}, NK^c_{\max}, NK^q_{\min}, NK^q_{\max} \geq 0 \land c \in C, q \in C_Q, t \in T(c), q \in C_Q, t \in T(c) \]  

\[(13)\]

\[\text{W}_{it} \] Variable of deviance \( t \), day 2 that permits doctor to take two days off in a row of rest \( i \)

4. Results

4.1. Department-specific shifts for COVID-19

To properly address the COVID-19 epidemic, healthcare agencies have undergone substantial changes in their methods of operation. The COVID-ICU, doctors have been working relentlessly to give intense care to patients fighting the virus, is one of the crucial places affected by these changes. Due to the rise in patients needing non-intensive care, the COVID-Service department has also seen a change in its schedule. Shifts have been rearranged in the COVID-Emergency department to deal with the rush of people needing emergency medical care. To guarantee that dedicated personnel are always ready to manage urgent situations with COVID-19 doctors in this department have been working intensively and switching shifts (Table 2 and Figure 1).

<table>
<thead>
<tr>
<th>Department-specific shifts for COVID-19</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Shifts Per Doctor (SPD) at COVID-ICU</td>
<td>6.5</td>
</tr>
<tr>
<td>SPD at COVID-Service</td>
<td>3.8</td>
</tr>
<tr>
<td>SPD at COVID-Emergency</td>
<td>1.82</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiology</td>
<td>11.5</td>
</tr>
<tr>
<td>Psychiatry</td>
<td>10.9</td>
</tr>
<tr>
<td>Internal Medicine</td>
<td>13.5</td>
</tr>
<tr>
<td>Neurology</td>
<td>14.12</td>
</tr>
<tr>
<td>Cardiology</td>
<td>13.9</td>
</tr>
</tbody>
</table>

4.2. A shift structure based on the usual departments

Ensuring doctors’ effective and secure scheduling has become crucial during the COVID-19 epidemic. A DSS has been created to help schedule doctors based on normal department shifts to solve this difficulty. This system uses cutting-edge algorithms and current data to make wise judgments. The system optimizes the distribution of doctors through various modifications by looking at variables including patient demand, doctor availability, and departmental needs (Table 3 and Figure 2).
4.3. Face Probability of team failure versus Doctors rotation duration

The length of the doctor’s rotation may impact the likelihood that the team will fail. As doctors may require time to adjust to new co-workers, processes, and patient populations, frequent rotation disturbs team relations. Frequent composition changes might hamper a team’s ability to communicate, coordinate, and collaborate effectively, which could influence patient care (Figure 3 and Figure 4).
5. Discussion

The appropriate scheduling of doctors has become crucial during the COVID-19 epidemic to guarantee the efficient use of resources and the delivery of medical treatment. The adoption of a DSS may be quite helpful in addressing this difficulty. To examine numerous parameters, including patient demand, case severity, and the availability of medical professionals, a DSS might use data analytics. The DSS may provide knowledgeable suggestions for scheduling doctors, balancing workloads, and optimizing resource use by considering these factors. This improves the effectiveness of healthcare facilities while lowering the danger of exposure for patients and healthcare workers. By adopting a DSS, healthcare institutions may act proactively in the face of the pandemic’s dynamic character, ensuring that doctor schedules are arranged in the best possible way to address the community’s changing demands while preserving public health.

6. Conclusion

A comprehensive analysis of numerous elements and considerations is conducted as part of the study of doctor schedules that were set up during the COVID-19 epidemic best to use the time and skills of medical personnel. It requires examining information on patient demand, the availability of healthcare professionals, and the particular needs put forward by the pandemic. Most Turkish hospitals established new COVID-ICU, COVID-Service, and COVID-Emergency departments to handle the COVID-19 epidemic better and react to infected patients. Planning became more crucial than previously due to the increasing workload. Despite being able to construct their usual shift plans, institutions need expert assistance during this unplanned pandemic. During the COVID-19 epidemic in Turkey, this study determines the most significant barriers to arranging doctor’s scheduling visits at a hospital. The quick epidemic may restrict data availability and accuracy, limiting the inquiry. Provide a MIP paradigm to solve the problem of organizing and arranging doctor schedules so that the problem may be turned into a DSS. Despite these limits, regular monitoring, adaption, and schedule flexibility may assist in reducing some of these obstacles and guarantee effective healthcare services throughout the COVID-19 epidemic. Future studies may evaluate the advantages, difficulties, and long-term viability of remote work and telemedicine in doctor scheduling. Investigating the usage of forecasting and predictive modeling methods may help anticipate future needs and create proactive scheduling strategies.

Ethical considerations

Not applicable.

Declaration of interest

The authors declare no conflicts of interest.

Funding

This research did not receive any financial support.

References


