Hopital Roster Optimization

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1 Introduction

Currently lots of hospitals are under stress due to Covid 19. They are struggling to create a proper roster for nurses, doctors, mid-wifes and other hospital staff. What we want to do is to create an optimized roster for hospital based on their wards, beds demand, patient, disease that those patients have then roster all these people.

2 Case study in hospital rostering

2.1 The Manpower Rostering Problem

The Manpower Rostering Problem is the problem of assigning manpower to shifts so to satisfy some basic constraints.[Chu21]

- Manpower demand constraints: defines manpower requirement for a special rank, staff group, gender or their combination in a particular shift(ex at least 1 male registered doctor in night shift)
- Working hours constraints: defines the total number of working hours for a staff within the specified time period(ex an enrolled nurse should work exactly 88 hours per fortnight)
- Shift distribution constraints: defines the frequency that a staff may be assigned a particular shift during the specified time period (ex at most 1 night shift on Sunday per fortnight)
- Days between same shift constraints: defines the number of days that should elapse before a staff member takes another shift of the same type(ex minimum 4 days between night shifts)
- Consecutive day-of-week constraints: defines the total number of consecutive occurrences of a particular shift assigned to a staff on a certain day (ex cannot assign night shifts on 2 consecutive Sundays)
- Shift sequence pattern constraints: defines a pattern of shifts to be assigned on consecutive days (ex prefer a day off right after a night shift.) shift.

There are some case that is in emergency scenarios such as the number of staff(doctor, nurse,...) is not enough to satisfy the demand [Sec20]. In ordinary situations hospital facilities may consider employing further nurses so to satisfy constrain as suggested. However in emergency situations they need to deal with this issue by asking the employees to work extra hours. This problem is not usually contemplated in scheduling problems being overtime work considered as something that cannot be scheduled in advance. To avoid solutions where the workload is unevenly distributed among the staffs, we can require both the number of extra hours worked and the overall number of hours worked by each staff.

2.2 Scheduling the shifts of physicians

There are regular departments that are actively working in the hospital such as internal medicine, urology,... These departments continue their daily routine operations in the pandemic period, hence physicians work in the shifts of these departments which we called as the regular shifts. In order to cope with the pandemic, the management has established three new departments to serve those who are infected by Coronavirus (i.e., COVID-19 Departments): COVID-Service, COVID-ICU, and COVID-Emergency. The COVID-19 departments are staffed with the current physicians. Therefore in addition to their own workload in their departments, the physicians have to work in the shifts of COVID-19 departments, i.e., COVID-19 shifts, which increased their workload significantly.[GG20]. Following rules should be met for a legitimate working schedule:

- COVID-ICU has two shifts: (i) day shift and (ii) night shift. There must be three physicians in each shift.
- COVID-Service has also a day and a night shift that lasts twelve hours each. There should be three physicians.
- The hospital management decided that it's better to allocate physicians from different professions at each COVID-ICU and COVID-Service shifts.
- COVID-Emergency has three shifts of eight hours. The first shift starts at 08:00 and lasts until 16:00. For each shift, one physician must be assigned to the shift.
- The number of needed physicians for each regular shift depends on the number of physicians in the department.
- Some physicians are not eligible for particular shifts of COVID-19 departments. For example a neurosurgeon or a general surgeon can work in COVID-ICU but an urologist cannot.
- The shifts should be distributed to physicians evenly. Distributing shifts evenly can be achieved in two steps. First, physicians in the same department should have similar COVID-19 shifts. For example the physicians in urology should have similar (preferably same) number of shifts in COVID-Service. In the second level, number of COVID-19 shifts of physicians from different departments should not vary too much. For example number of COVID-ICU shifts for general surgery and internal medicine must be close (preferably equal) to each other.
- There should be one off-day between the shifts. Furthermore, there can be two off-days between consecutive two shifts, if possible.

2.3 Patient admission scheduling problem[Abd+21]

It included several real-world features, such as the presence of emergency patients, uncertainty in stay lengths; and the possibility of delaying admissions. It takes into consideration the possibility that a patient's stay can be extended. The patient's extended stay might affect the room scheduling, and this may lead to overcrowding.The problem have several basic concepts:

- planning horizon: the measurement of time and is to denote the duration of the determined stay of individual patient

- patient: who needs specific treatments in the hospital and is required to stay in the hospital, the duration of the stay should be continuous. In addition, two kinds of patients have been used, inpatients who are already admitted, and a new patients, who will be admitted.
- room/department: Every room in the hospital can be a single, twin room, or a ward. The capacity of a room depends on the number of beds available. A patient may want to occupy a specific room capacity, but might need to pay extra.
- specialism: should distribute the patients according to their diseases. However, a specific departments may be considered as fully, partially qualified, or not qualified for the patients. Allocating a patient to a partially qualified department is acceptable.
- room feature: such as oxygen, telemetry, and television... Assigning a patient to a room without considering the needs is deemed to be an unfeasible solution, whereas missing the desired features will maximize the objective function.
- room gender policy: four policies SG(both genders can be accepted. But in the same day should be from the same gender), Fe(female patients only), Ma(male patients only), All(the same gender can be accepted at the same time, for example (intensive care)).
- age policy: age limits. For example; the pediatrics department accepts patients ranging from 0 to 12.

Room capacity and patient age are compulsory, and the soft constraints include:

- gender policy room should be fulfilled
- patient prefer to be allocated room special preference
- transfer inpatient from room to another during her stay is undesirable
- delay patient admission
- calculating a number of patients who have been allocated for each room and take the certain, potential attend overstay length of some patients, and capacity of the room.

2.4 Operating Room Scheduling[ALY17]

The peri-operative (periop) process consists of three stages: pre-operative (preop), intra-operative (intraop) and post-operative (postop), where the collection of patients' information and the preparation for surgeries occur in the preop stage, surgeries occur in ORs in the intraop stage, and post-anesthesia care units (PACU), intensive care units (ICU), or wards for recovery are in the postop stage. The problems of ORs(Operating Room) scheduling can be divided into three different problems, namely (i) the Case Mix Problem (CMP), (ii) the Master Surgery Scheduling Problem (MSSP), and (iii) the Surgery Scheduling Problem (SSP)[YHE14].

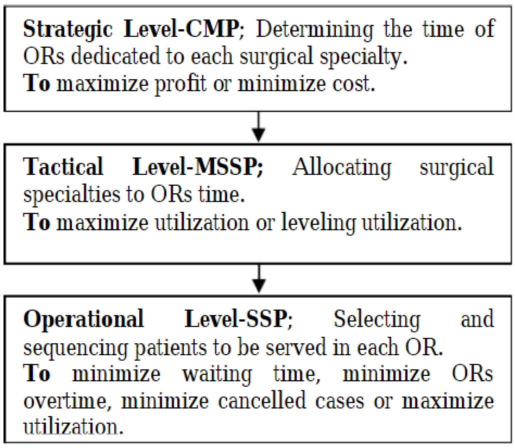

Fig. 1 The three ORs scheduling problems and decision levels

After performing a surgery in an OR, the patient is recovered in PACU, then moved to an ICU bed to receive the required care. The amount of time that a patient stays in ICU before being moved to ward is referred as length of stay (LoS) in ICU. After spending the required time in ICU, the patient is moved to a NonICU bed in the ward. Sometimes based on the acuity level, the patient is directly moved from PACU to the ward. For those patients who don't need the ICU, we can consider their ICU LoS as zero.

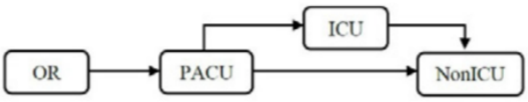

Fig. 2. The patient's path in the peri-operative process [26]

If there is no available bed in ICU, patients have to stay in the PACU, which is considered as blocking. OR blocking means no surgery is performed until a bed in PACU or ICU is available. An efficient OR schedule not only maximizes the OR utilization, but also smooths the patient flow across the periop process, i.e., reducing the number of blockings.
We have the model as below:

- objective function : minimizes the difference between the postop stage capacity and its occupancy (number of patients)
- Symbol:
  - i: index of surgery groups
  - j,k: index of days(k<j)
- constraints:
  - the number of assigned OR blocks assigned to surgery group i on day j is equal to each group i required OR blocks
  - the number of assigned OR blocks assigned to surgery group i on day j doesn't exceed the number of available ORs in the intraop stage
  - the number of patients in the postop stage on day j is equal to the number of arrivals from OR to the postop stage on day j and the number of patients in the postop stage transferred to day j from previous days
  - A patient is sent to the postop stage if his postop LoS is greater than zero, otherwise he will be directly sent to a bed in ward.

– the daily number of OR blocks assigned to each group i must fall between specified minimum and maximum number of OR blocks that should be assigned to group i

– the number of OR blocks assigned to each group i must be a positive integer

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