Optimum scheduling of physicians in a small size clinic

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Abstract

This paper combines simulation and mathematical modeling for optimally scheduling physicians in small size clinic where resources are scarce and the need is high. Physicians' preference timing, patients waiting times as well as facility utilization are considered in measuring the quality of scheduling. Alternative schedules are generated for additional objectives

Keywords: Health care, Scheduling, Simulation

Introduction

Health care institutions face real challenge in satisfying their patients' needs and at the same time meet physicians preferences in terms of working hours and load. Health care facilities are suffering from long waiting queues which negatively effects the perception of service quality. This problem is harming their reputation and reflecting negatively on their financial performance. Health care facilities also face tremendous pressure from the society for faster response to patients'' needs of quality and efficient treatment, which in affect reduces time wasted in queues. On the other hand, direct health service quality is not only affected by physicians' qualifications but also their level of satisfaction with working environment including hours and timings of service.

Scheduling is an activity that highly impacts operational efficiency in all types of organizations. It becomes highly critical whenever resources are scarce and demand is high. It is widely used in health care organizations in scheduling staff and operating rooms. However, it is done in an ad-hoc manner or by ready-made scheduling software that does not necessarily meet the specific operating conditions. The increasing competition in health care accelerated the need for higher utilization of resources and service quality and, in a way, attracted the attention of researchers in the scheduling area.

Ernst et al. present a review of staff scheduling literature for various application areas and the models and algorithms that have been reported for their solution. Bard and Purnomo (2005) consider reactive scheduling of nurses in light of shift-by-shift imbalances in supply and demand in response to emergencies, call-outs, and normal fluctuations in personnel requirements. Individual preferences are also taken into account. The problem is formulated as an Integer Program (IP) and solved within a rolling horizon framework that takes into consideration 24 hours at a time, but to only implements the results for the first 8 hours. The IP is then re-solved for the next 24 hours after several hours have elapsed and new data are available, and so on.

This paper addresses the case of scheduling physicians in a small size clinic with the objective of maximizing resource utilization and service quality. It is required to keep the number of physicians on duty during official working hours at its minimum while maintaining a bound on patient average waiting time and satisfying Physicians preferences on working hours. Considering preferred timing contributes positively on the quality of service provided for patients. Part of this research was published by Al-Turki (2010). This paper presents further analysis and results on the problem.

In the next section, a brief background about the clinic and its services followed by data collection and analysis. After that, the simulation model is described and used for determining the hourly requirements of physicians. Alternative schedules that satisfy the requirements are then generated and analyzed. The paper concludes with some recommendations and further research.

Problem description

The clinic under consideration is a nonprofit facility operated for the primary purpose of providing outpatient public health services and includes customary related services such as laboratories and treatment rooms. The clinic is dedicated to provide basic medical care for a small and coherent community. The clinic has a total of ten physicians with different specialties but they are all considered general doctors and can receive patients of all kinds of health issues. Patients that need special attention are transferred to specialized hospitals nearby. Patients arrive to the clinic with no prior arrangement or appointment and they usually ask for a specific preferred physician. Some patients ask for the least busy physician.

Currently, during the regular working days, the clinic opens at 7 A.M and closes at 10 P.M with one hour lunch break at 12 P.M. In weekends (in this case, Thursdays and Fridays), the clinic opens at 9 A.M and closes at 12 P.M and then opens again at 7 P.M and closes at 10 P.M. In regular working days, Six to seven physicians are available from 7 A.M to 4 P.M. After 4 P.M, one physician is available until 7 P.M, at which another physician joins to the end of the working hours.

“The clinic under consideration is facing problems in serving its patients needs in terms of response time and waiting time duration”, Al-Turki (2010). The clinic management is receiving an increasing number of complaints regarding long waiting for service and sometimes little attention from physicians. Physicians are also expressing their increasing dissatisfaction with the working schedule and working load. However, the clinic have limited budget that prevent them from recruiting more physicians. It is felt that an improvement in service quality can be achieved by better scheduling of resources (physicians).

The main objective of this study is to design a new working schedule for the physicians that meets the daily demand for health service and reduces waiting time while taking limited resources and physicians’ preference into account. The system under consideration is highly stochastic due to patients flow pattern and service time. Simulation is used to estimate the minimum number of physicians needed to satisfy health service demand with bounded waiting time. Afterwards, heuristics are used to generate alternative schedules for further comparison and final selection.

Methodology

Manpower scheduling is a wide area of research where different tools are used to find optimal or near optimal schedules. Mathematical modeling is widely used for solving such problems. Brunner (2010) presented a methodology to solve the flexible shift scheduling problem of physicians when hospital administrators can exploit flexible start times, variable shift lengths, and overtime to cover demand. Staffing policies, individual preferences and on-call requirements are taken into consideration. The objective is to minimize the total assignment cost. The resulting model constructs shifts implicitly rather than starting with a predefined set of several shift types. To find high-quality rosters, a Branch-and-Price (B&P) algorithm is developed. Wang and Fung. Developed two integer programming models for scheduling decisions to maximize the degree of patients' satisfaction and revenue.

Simulation is also used widely in scheduling staff in health care applications. Jun et al (1999) surveys the applications of discrete-event simulation modeling to health care clinics and systems of clinics (hospitals, outpatient clinics, emergency departments, and pharmacies). Due to the complexity of the problem, heuristics and meta-heuristics are commonly used in the literature combined with some other solution methods.

In this study we combine simulation and heuristics to develop schedules that satisfy the needed objectives. The methodology adopted in this study is composed of the following steps:

1. Define the scheduling objectives and performance measures in coordination with clinic administration..
2. Review the current practice of physician's scheduling.
3. Collect data for patient arrivals pattern for further modeling and analysis.
4. Develop a simulation model that can be used for determining physician requirement and also for evaluating alternative scheduling policies.
5. Identify alternative schedules for the clinic administration to chose the one that best fits other conditions.

Data Collection and analysis

Historical data related to patient arrival pattern is collected from the clinic data base that records the time of issuing admission slip. Arrival rates were clearly noted to differ significantly between days of the week. The seven days of the week are clustered into groups, based on patients' arrival pattern such that the difference in arrival rates within each group is insignificant. The collected data identified three homogeneous groups of days as follows.

- Saturdays and Wednesdays, first and last days of the week,
- Sunday, Mondays, and Tuesdays, middle days of the week
- Thursdays and Fridays, week ends

Patient arrival rate data were collected for four weeks on hourly base throughout the full working hours in each group. Patients' arrival distribution is assumed to follow the Poisson distribution with parameter λ. The value of the parameter is estimated on hourly bases the days of the week.

"Service times were collected by directly by observing the time the patient is admitted to the examination room and the time he leaves it. This was done with the help of the staff working in the clinic. Initially collected data did not indicate any significant difference in service time between physicians. So it was decided to combine all data collected from all physicians as a single data set to be analyzed. The data was analyzed for the best fit distribution using Easy-Fit and found to follow the

Weibull distribution with parameters a=3.7231 and b=9.0772. The distribution passed the Chi-square, Kolomogrov-smirnov and Anderson-Darling tests", Al-Turki (2010).

After some discussion with the clinic administration and group meetings with patients, it was decided that an average waiting time of ten minutes results an acceptable satisfaction level. As waiting time increases beyond 10 minutes, satisfaction is anticipated to decrease to unacceptable level.

The Simulation Model

Given the above assumptions and estimated data, a model is constructed to simulate patients activities in the clinic from arrival to departure. Upon arrival patients go directly to the reception area to select a physician and then join a queue and wait for their turn to be served. After being served, patients leave the system. The waiting time is a function of the service time and the queue length. The queue length is inversely related to the number of physicians available at the time of service. The simulation model is developed to assess the current situation and then used to determine the required number of physicians at each hour in order to satisfy a specified performance measure.

As mentioned earlier, common arrival rates could be used for each of the three groups of days identified earlier. As a result, three models are developed. The three simulation models are almost the same but they only differ in patient's arrival rates. The following assumptions were made while building the simulation model.

1. The service time at reception is negligible.
2. Load is evenly distributed among physicians.
3. Service times for all physicians follow the same rate and distribution.

The model follows a terminating scenario since the clinic is closed at 10 P.M and no entity is allowed to come in after that event. The number of runs for each simulation model was determined using the t-test with 95% confidence level. The number of runs for Saturday and Wednesday group was found to be 110 runs and 50 runs for the remaining working days. For the week-ends (Thursdays and Fridays) 20 runs were found to sufficient for 95% confidence level.

To validate the model, the simulation is run under the current scheduling policy for each set of days. Figure 1 shows the average waiting obtained for Saturdays and Wednesdays over time. The peak hour in terms of waiting times for Saturday and Wednesday is between 5 and 6 PM with a waiting times ranging between 50 and 70 minutes. Actual data collected (by clinic administration) for the same hours on the same days was 58 minutes which matches the results of the model taking into consideration that many patients leave the system when their waiting time extends to more than 60 minutes.

Similarly, Figure 2 shows the average waiting obtained from the model for the set Sunday, Monday, and Tuesday, over time. The waiting times at the peak hours ranges from 30 to 60 while actual data collected from the clinic is 47 minutes which shows the validity of the model.

Figure 3 shows the average waiting obtained from the model for the week end, Thursday and Friday, over time. Clearly the system shows quite low and smooth waiting time leveling over working hours, less than the targeted 10 minutes. This performance is well known fact by administrators.

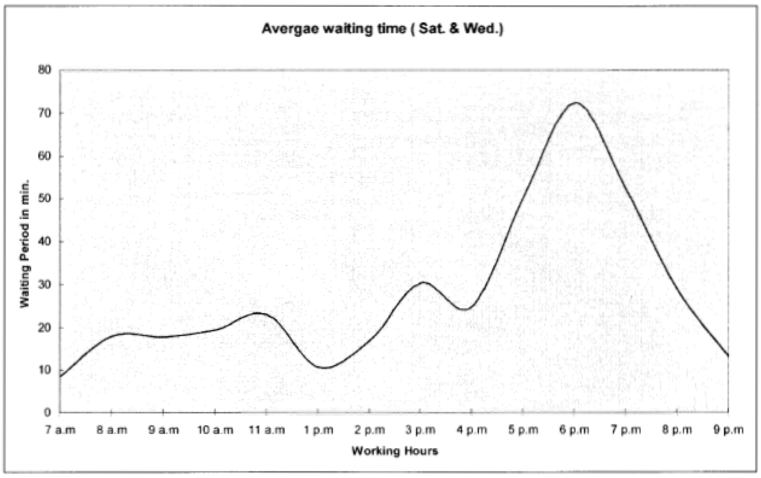

Figure 1- Average waiting times for Saturdays and Wednesdays

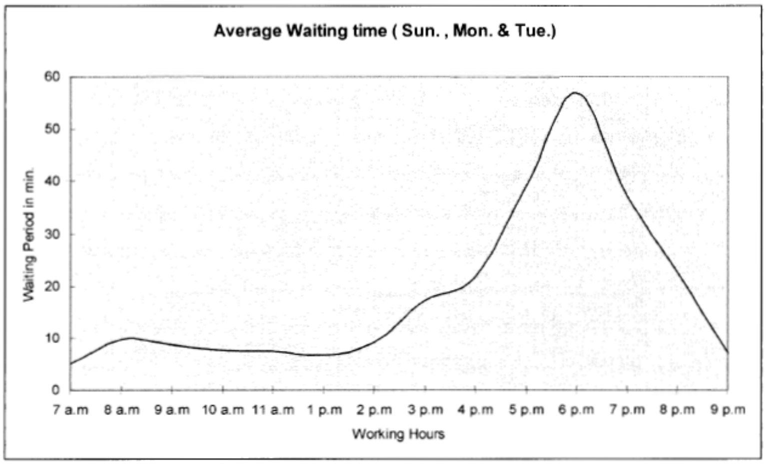

Figure 2- Average waiting times for Sundays, Mondays and Tuesdays

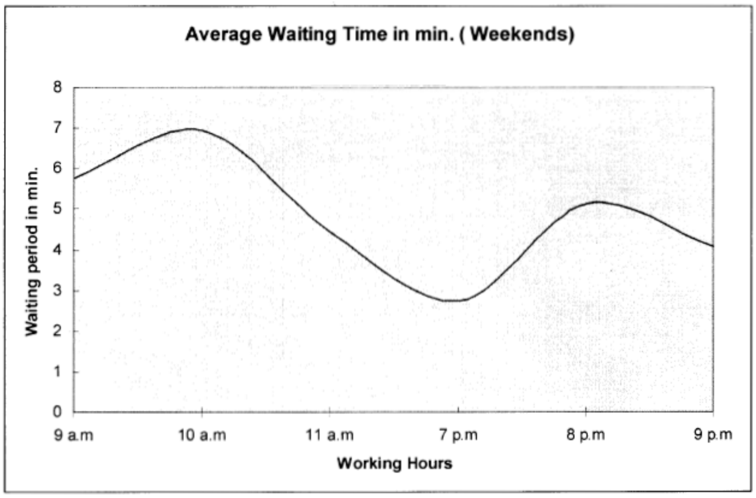

Figure 3- Average waiting times for Thursdays and Fridays

The model is now ready for determining the physicians' distribution over time that satisfies the requirement.

Number of Physicians Required

The model is used to determine the minimum number of physicians needed at any working hour of the week that would result in an average waiting time of less than ten minutes, as determined the clinic administration. Table 1 summarizes the results obtained by the model showing the minimum number of physicians needed to satisfy the 10 minutes waiting time requirement at each hour of the week and the corresponding average waiting time. The results are obtained by the running the model for various number of physicians at each hour and measuring the corresponding resulting average waiting times. This assumes constraints relaxed scheduling and accepts slight over run of the 10 minute requirement.

Table 1. The minimum number of physicians needed and the average waiting time

days	Sat & Wed		Sun-Tue		Thu & Fri	
Time period	# Phys	Average waiting time (minutes)	# Phys	Average waiting time (minutes)	# Phys	Average waiting time (minutes)
7-8	5	8	4	7.9		
8-9	7	9.6	6	9.3		
9-10	5	10.6	4	9.8	2	6.3
10-11	7	9.5	5	9.3	2	6.8
11-12	6	9.1	4	10.1	2	3.8
13-14	5	9.6	4	9.7		
14-15	6	9.5	5	7.5		
15-16	6	11.2	5	10.6		
16-17	2	5	2	4.2		
17-18	2	7.7	2	6.7		
18-19	2	7	2	5.4		
19-20	3	6	2	5.1	2	2.4
20-21	2	8.9	2	4.5	2	2.7
21-22	2	12	2	4.5	2	2.331

Obviously it is not practical to have an hourly schedule for the physicians to meet the requirement. However, the table can be used to construct various shift schedules.

Shift Scheduling

In this study, an adjusted manual shift scheduling heuristic (MSSH) that was developed by Bechtold and Showalter (1987) is used. The selection was made based on the simplicity of the heuristic and its effectiveness. In this study we adopted a three shift schedule with one hour break each as follows:

Shift A: from 7 AM to 4 PM with a break from 12 to 1 PM)

Shift B: from 10 AM to 7 PM with a break from 12 to 1 PM)

Shift C: from 1 PM to 10 PM with a break from 12 to 1 PM)

Applying the MSSH heuristic results an assignment of seven physicians in shift A, two in shift B and three in shift C, totaling 12 physicians while we have only ten physicians available. The schedule is adjusted for the number of available physicians by removing two physicians from the schedule in a way that have the least negative effect on the objective. The adjustment resulted in having 6 physicians for Shift A, 2 for Shift B and 2 for Shift C, which satisfies the minimum requirements for all hours with the exception of the 8 AM and 7 PM. The number of physician requirement before and after adjustment is summarized in Table 2.

Table 2. Physician requirement for Saturdays and Wednesdays

Shifts	A	B	C
MSSH	7	2	3
Adjusted MSSH	6	2	2

Applying the MSSH for the set Sunday, Monday, Tuesday results an assignment of 6 physicians for Shift A, 2 for Shift B and 2 for Shift C, which satisfies the hourly requirement and matches the available manpower. For the week-end, only two physicians are needed in two shifts to satisfy the requirement. The resulting assignment for the whole week is shown in Table 3.

Table 3. Physician requirement for the whole week.

Shifts	Sat	Sun	Mon	Tue	Wed	Thu	Friday
A	6	6	6	6	6	2	2
B	2	2	2	2	2	0	0
C	2	2	2	2	2	2	2

The resulting schedule assigns the ten physicians to the three shifts in the weekdays while the week-end is covered by overtime shifts rotated between the physicians.

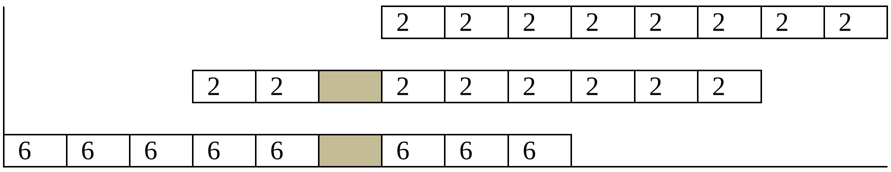

Figure 4. Shift structure requirement for the three shifts for the weekdays

The adjustment made in the original schedule has resulted an increase in the expected waiting time. One alternative to gaining back that loss in the objective function is to modify the schedule by introducing two special shifts. One of the physicians in shift B will be assigned to a special two half shifts per day (8 AM to 12 PM then 6 PM to 10PM) and one from shift A will be assigned to a two half shifts (7 AM to 12 PM then 7 PM to 10 PM). The modified schedule is shown in Figure 5.

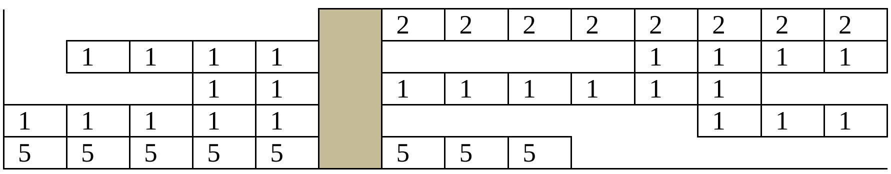

Figure 5. Modified requirement for the weekdays

The result is more efficient schedule with no shortage in manpower. Other alternative schedules are currently under construction.

Conclusions

The scheduling problem of physicians in a small size public clinic is studied with the objective of developing schedules that satisfy patient's need of minimum waiting time for service. Simulation is used for assessing the current situation, determining the minimum physician requirement and evaluating alternative schedules. Heuristics are developed to generate feasible schedules that satisfy service requirements with acceptable level of satisfaction. Future research is geared toward using other methods for developing shift-schedules and testing other scheduling policies.

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