This is the title

Today, there is an ongoing discussion on the increasing costs in health care. Pressure is put on hospitals to cut costs, whereas the quality of care needs to remain at a high level. Therefore, hospitals aim at increasing efficiency. During my internship at the HagaZiekenhuis, I was able to increase efficiency while improving the service level.

Introduction

The HagaZiekenhuis in The Hague facilitates a lung department, where all medical facilities concerning the lungs are located. The lung department consists of lung specialists, an inpatient department for lung patients and a lung function department. This research focuses on the lung function department. Here, a number of tests can be performed, each giving information on several capabilities of a patients' lungs. At the HagaZiekenhuis in The Hague, 23 different tests can be performed, and each patient undergoes a selection of these tests based on the information the lung specialist or general practitioner is interested in.

Currently, the lung department as a whole copes with a room shortage. However, the rooms at the lung function department seem to be unused rather often. This leads to the main question of this research: is it possible to operate the lung function department with fewer rooms? We look at the possibilities of using a room completely for other purposes as well as releasing a room on fixed days in the week, such that on those days, this room can be used for other purposes.

Current planning practice

When a patient is referred to the lung function department, he contacts the secretary, who makes an appointment. The patient is assigned to a time slot and a lung function analyst. At the beginning of the patient's appointment, the analyst determines in which of the nine available rooms the treatment will take place. Preferably, this is a room where all examinations of this patient can be performed. However, some combinations of examinations are not available in one room. Besides, since the rooms are not taken into account when scheduling patients, the room containing all necessary equipment is often already occupied. In that case, the patient needs to undergo some of his examinations in one room, and then move to another room for the remainder of his examinations.

Data analysis

Before investigating in detail whether it is actually possible to close rooms at the lung function department, a data analysis is performed in search for indicators that rooms can be (partly) released. We did not have to search long: the average room utilization over the year 2011 appears to be only 48%. Furthermore, the working hours of analysts prevent a high room utilization. During 2011, each day the number of analyst hours available for examination lay far below the number of room hours. This implies that with the current staff, it is not possible to reach a high room utilization.

Despite these figures, the lung function department feels that all rooms are necessary. According to the department, at several moments in time all rooms are occupied, which is at odds with the very low average room utilization. This contradiction can be explained by the spread of the patients over time: the demand strongly varies per day. On top of that, hardly any patients are scheduled early in the morning, whereas around 2 pm each analyst is performing examinations, resulting in peak moments.

A final interesting feature that becomes apparent from the data analysis is the usage of room 9. This room contains only two devices, both of which are needed for only a small amount of time per week. This results in room 9 being used for only 15 minutes a day. Therefore, during the course of this research, management

has decided to give this room another purpose. Room 9 is thus not taken into account in this research anymore, and eight rooms remain.

The data analysis thus indicates that it is possible to reduce the number of rooms used at the lung function department. An uneven spread of patients over time causes the department to feel that they need all of their rooms. Therefore, this research aims at a better spread of patients over time. However, this might result in patients waiting for their appointment, which we need to try to avoid.

Planning method

As explained before, the secretary assigns each patient to an analyst. However, the analysts redistribute the work among them at the beginning of each day. Furthermore, scheduling per analyst has some disadvantages. As explained before, the preferred room for a patient might not be available, resulting in moving patients between rooms. It is also hard to see at a glance how many patients are already planned at a certain moment in time, which makes spreading appointments over time more difficult. Scheduling per room instead of per analyst can solve these problems.

The assignment of patients to rooms instead of analysts has one main disadvantage. Due to the distribution of equipment over the rooms, for several patients it is inevitable to visit multiple rooms. These patients should thus be scheduled at two or even three rooms consecutively. However, since we are dealing with patients, the treatment durations are highly variable. A delay for a patient on his first room thus results in a delay on his second room, which yields a high risk of delays at several rooms throughout the day. Therefore, the first step in this research is to investigate the possibilities of moving equipment between the rooms such that as many patients as possible can visit a single room.

Assignment of equipment

In order to redistribute the equipment among the rooms, two assignments of equipment are developed based on intuition. Furthermore, a third equipment assignment is found as a result from a mixed integer programming (MIP) model. The input data for the model consists of the patient data over the year 2011. For each patient, it is known when he had his appointment, and which set of examinations he needed to undergo. Furthermore, for each examination, the planned duration is known.

The model has two important decision variables. The first variable assigns equipment to rooms, and the second variable schedules the patients by assigning them to a room and a week. Patients are not assigned to a specific time slot or day, since this would result in too many variables, and thus a model that is too large to be solved. The objective is to assign as many patients as possible to a single room, under the constraint that the time spent on a certain room during a certain week cannot exceed the maximal available time. Naturally, each patient should be scheduled and must undergo all of his examinations in a single appointment, and in a room where the right equipment is available. The assignment of the equipment is also subject to several constraints. Some of the devices are very large, and thus have to be located in the largest room. Furthermore, the small rooms cannot contain too many devices because of their size.

In 2011 there were busy and quiet weeks. As one can imagine, allowing the model to schedule patients freely results in delaying patients as long as needed, until the room where they can undergo all of their examinations is free. However, a patient should not be delayed too much because of health risks. Therefore, patients can only be delayed for one week, and a penalty is included for each delayed patient.

Figure 1: A standard lung function examination.

Simulation study

Our MIP model considers an off-line scheduling problem, which implies that it has the liberty to fit all patients into the schedule in an optimal way. However, in reality we are facing on-line scheduling: patients are scheduled in order of arrival, and a scheduled patient cannot be rescheduled. Therefore, the MIP model is able to find better solutions than what is possible in reality. Therefore, the equipment assignments are tested by means of a simulation study.

The scheduling of patients is simulated week by week, and schedules all patients who have visited the department in 2011. First, all patients who were originally scheduled in week

1 in the year 2011 arrive in random order. Each patient is assigned a time slot in week 1 on a room (or rooms) where he can undergo all of his examinations. When there is no suitable room available for the patient, he is scheduled in the next week. This procedure continues until all patients who were originally scheduled in the first week have an appointment, and then the model moves on to week 2. This process is repeated until we have reached the end of the year.

During the past decade, the lung function department has grown steadily. Therefore, the simulation study is not only run for all patients of the year 2011, but for an increase in patient demand of 10% and 20% as well.

From the simulation study, for each equipment assignment we obtain information on the number of delayed patients. As stated before, we may not delay too many patients, and thus the number of delayed patients becomes our main performance indicator.

Additional interventions

Besides redistribution of equipment among rooms, other interesting interventions are evaluated by means of the simulation study. From our data analysis, it became clear that one of the devices, namely the body box, might form a bottle neck: many patients make use of this device, while there are only two body boxes available. The easiest solution is to invest in an extra body box. However, this is a very costly investment. Therefore, we also consider the possibility of extending the workday for 15 to 30 minutes on the two rooms containing a body box. The effects of these two interventions are investigated by means of the simulation study. For each configuration, i.e., for each equipment assignment with or without additional body box and extended workdays, we try to close as many rooms as possible without delaying too many patients.

Breathtaking results

From the data analysis, we know that the room utilization at the lung function department has been very low. We thus suspected that the department could function well with fewer rooms. The results from the simulation study confirm that this is very well possible.

First of all, the three equipment assignments are compared to each other as well as to the current situation. The simulation study clearly shows that the current assignment of equipment is not even capable of handling a 10% growth in demand, whereas the new assignments are. Furthermore, one of the intuitive assignments significantly outperforms the other two assignments. Therefore, we only consider this assignment in the remainder of this article, and try to close as many rooms as possible.

When considering the patient demand of 2011, without any additional interventions, already two out of eight rooms can be closed completely, and one room can remain unused for two days per week. When adding a body box, another room can be closed completely. Extending the workday on the two body box rooms even results in a total of four closed rooms.

A demand growth of 10% gives similar results, but naturally, fewer rooms can be closed. Without interventions, we can close one room completely and one room for a few days per week. With an additional body box and extended workdays on two rooms, this can be improved to closing three rooms.

The results for a demand growth of 20% are quite shocking: without additional interventions, the department has to delay an unacceptably high number of patients. Even extending the workday does not yield a sufficiently low number of delayed patients. However, when a body box is added to the system, the department is capable of examining a sufficient number of patients within a week. Remarkably, when investing in a body box, the department is even able to close two complete rooms and have two free days on the third room. From this, we can conclude that the number of rooms is not the bottleneck at the lung function department, but the number of available body boxes is.

Conclusions

The lung department of the HagaZiekenhuis in The Hague is coping with a room shortage. This research has shown that the problem of room shortage can easily be solved. The lung function department can operate at a high service level using fewer rooms, simply by scheduling per room instead of per analyst. In order to make this type of scheduling work, the examination equipment needs to be redistributed among the rooms. Investing in additional equipment increases the flexibility of the department, and is even inevitable in case of a large expected demand growth.

This research shows how efficiency at the lung function department can be improved, without decreasing the quality of care. We have even increased the service level at the lung function department: for patients it is more convenient to stay in one room during all examinations, instead of moving between rooms. This research is now one of the many examples where, with the aid of operations research techniques, efficiency and improved quality in care can go hand in hand.