Process Data: a Means to Measure Operational Performance and Implement Advanced Analytical Models

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Abstract. We present the case of an ambulatory clinic where an operational review was conducted to identify opportunities for efficiency in appointment scheduling and capacity allocation. We required process data to compare what was planned to what actually happened, and to develop advanced analytical models. Similarly to other health care studies, this type of data proved limited or non-existent, necessitating time consuming collection of operational metrics.

Keywords. Ambulatory care unit, outpatient clinic, process performance data.

Introduction

We examine the case of an outpatient clinic where patient delays and suboptimal resource utilization led to an operational review. The situation experienced here is common across the health care system: a service with variable demand undergoes complex processes under limited resource availability, resulting in operational difficulties especially during periods of high activity.

Determining an efficient process configuration is a very difficult task, mainly due to the presence of variability, but also because of the complex interaction of multiple entities that typically share resources in the process. Therefore, a detailed analysis of the system and decision support tools are required to address these issues effectively.

Advanced analytical methods from the Operations Research (OR) field provide the means to approach this type of problems. OR is the science of developing and applying mathematical models to provide decision-makers with better strategies to plan and operate systems. Techniques from this field are extensively and successfully being used in many industries \cite{1}, such as automobile, airlines, forestry, electronics, telecommunications and transportation, and are becoming more common in health care.

To understand the current state and identify problems, we required detailed data about the processes and resources in the system. In particular, we needed to contrast what was initially planned and what actually happened, and develop metrics to evaluate the performance of the operations. The focus of our study was on achieving a better

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utilization of resources through changes in the processes, but also on improving the patient experience, an aspect not usually considered in this type of reviews.

To test scenarios with different configurations of the process, we developed a computer simulation model of the outpatient clinic. This type of model is very helpful, but also demands detailed data to accurately replicate the process and performance metrics for comparing scenarios.

Unfortunately, process-related data are usually not collected in the health care sector, hindering the development of advanced quantitative models and evaluation of process changes. During this study, process data proved very limited for our purposes, necessitating time consuming collection of operational performance measures.

Our analysis of the data and the use of our simulation model identified a range of opportunities to improve operations. A complete discussion of the simulation model and the results is available in Santibañez et al [2].

This paper describes the data needs for this type of study methods, the challenges we faced regarding access to appropriate process data, and recommendations as to what and how data should be collected to support similar advanced analytical studies.

1. Context and Problem

Our study was developed for the Ambulatory Care Unit (ACU) in the Vancouver Centre of the British Columbia Cancer Agency (BCCA), a province-wide provider of cancer care services for the residents of British Columbia and Yukon, Canada.

The ACU, an outpatient facility, is the primary point of physician-patient interaction. BCCA is an academic teaching and research institution, and in addition to oncologists there are also medical students, residents and fellows participating in the consults. Clinics consist of an oncologist and the group of patients scheduled for the day. During a given day, there are multiple clinics running in the ACU.

At the operational level, clinics are to some extent independent to the others in that patients have a pre-scheduled appointment with a specific oncologist. However, clinics share physical space and nursing and clerical staff. Each clinic is assigned one or more examination rooms depending on whether other physicians will be participating in the clinic that day, and the amount and type of appointments. These rooms are dedicated to a particular oncologist for a given clinic session.

Part of the complexity in the process comes from the scale of operations. In terms of patient volume, the ACU has an average of 200 patient visits per day (more than 50,000 per year). On a typical day there are between 15 and 25 clinics operating simultaneously, and there are a total of 45 examination rooms for consults.

One of the problems is that at times of peak volume, ACU personnel experienced a limited supply of physicians’ space, clerical support and examination rooms. This led to delays in the clinics’ operation, overcrowding, stress, and an inferior patient experience. The general consensus was that additional rooms, both for examination and physicians, would help alleviate these issues. During busy days, all examination rooms were assigned to clinics, leaving no apparent surplus in physical capacity.

2. Appointment Process and Assessment

ACU appointments can be described by the following steps, as depicted in Figure 1:
a) Patients arrive to the ACU and check-in at the reception. This event is recorded in the booking system, registering the time of arrival of the patient.
b) The patient goes to the waiting room and remains there until called.
c) A nurse or volunteer takes the patient into an available examination room, and fills in basic information such as weight and overall status in the patient record.
d) The patient waits in the room for the physician(s).
e) The physician(s) come into the room, perform the consultation and prepare orders (to be processed next by clerical staff at the nursing stations) for diagnostic tests, treatment or future appointments.
f) In the case of multiple consults, the patient waits in the room for the next physician to arrive, subsequent consults take place, and then the patient exits the room and goes back to the waiting area.
g) After the orders are processed, the patient is discharged from the ACU.

Each clinic has the planned activity for the day in the schedule with all the booked appointments. Schedules indicate the start and finish times for each patient appointment, and assume all resources are available. This includes that the patient has arrived, there is an examination room accessible when needed, and the physician is available. If for any reason the patient is not ready, there is no room available, or the physician is busy with another patient, the appointment will not be executed as planned. If schedules are executed as planned, there should not be delays for patients or any other operational problem.

The difficulty is that schedules only provide information about what is planned to happen, not what actually occurred, and therefore cannot be used for performance evaluation. Both the schedules and its execution are required to quantify delays and resource usage, and identify bottlenecks in the process.

Consequently, we needed to analyze the execution of each appointment, and determine the availability of resources at any time. This means having, for every appointment, the time of patient arrival, the times patient entered and exited an examination room, the times physicians went in and out of those examination rooms, and the numbers of examination rooms being used at any moment in the day.

Comparing planned versus actual process times allows to determine if schedules are being realized as intended, and to identify process bottlenecks and their causes. Unfortunately, the appointment systems contained only booking data (i.e. scheduled activity), with no information on the actual execution of the schedules. No other information source was available to evaluate how schedules were being carried out.

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Figure 1: Patient process for an ACU appointment
3. Data Collection of Process Times

We carried out a data collection study to capture a representative sample of the process times required to perform the evaluation of the schedules. To be the least invasive, we hired graduate students during spring break to observe individual patient appointments in several clinics simultaneously. Time stamps were captured for every stage in the process described above, including patient arrivals, physician-patient interaction, chart/order processing, turn-around times, and room utilization.

Prior to collecting data for the entire clinic, we piloted different methods. The first one was a MS Excel-based tool on a laptop computer. Using Visual Basic for Applications (VBA), we built a graphical representation of the facility layout and implemented click-and-record counters for each type of event, storing the data in spreadsheet format, ready to be analyzed. The graphical user interface (GUI) displays the individual status of up to 6 examination rooms as time stamp data are entered for each event. This simplifies the data collection by allowing the surveyor to visually keep track of patient/room utilization. However, we encountered several difficulties with this method. First, the battery life of our laptops was less than the duration of a clinic (3 to 4 hours). It was inconvenient to charge the computers while collecting data since power outlets were not available in proximity, and using extension cords will interfere with patient flow and potentially be of risks to patients and staff. Second, it was impractical for surveyors to hold a laptop for the entire observation period, and using chairs and tables proved disturbing in the clinic environment, both for staff and patients.

Our second collection method was based on hand-held devices with a modified version of the MS Excel/VBA application. The much smaller devices, with longer battery life and still a user-friendly, full-color GUI, resulted in an improved experience. Nevertheless, we also encountered challenges. The most significant was to append and/or amend recorded data when necessary, which was slow and difficult to execute.

The third method we tried was a low-tech version of our application: we used the traditional clipboard, a stopwatch, and pen and paper to capture event times. Following the format of our Excel/VBA tool, we created paper-based forms and organized them in stacks representing the location of the rooms being observed by a surveyor. This served as a visual aid to relate events with the forms where they should be recorded. This method allowed for amendments to be easily incorporated, full view of the current status of the system, and surveyor mobility. Its major drawback was that collected data needed to be transcribed into electronic format. After considering all the advantages and disadvantages of the three systems, we selected the last method for the full study.

We also contemplated technologies such as radiofrequency identification (RFID). After some preliminary research we discarded them as viable options for this phase because of higher implementation cost and development time. We believe that automated, non-intrusive methodologies like RFID or similar are preferred solutions for collecting process data on a permanent basis and at a larger scale.

In total, we captured up to 14 process time-stamps for 600 patient appointments during a period of two weeks. With these data we reconstructed the different stages in the process for each patient and determined statistical distributions. We also linked the data to the booking system to append appointment information from the schedule.

The data collection was expensive, and difficult to plan, execute and replicate. For subsequent phases of our study, including implementation and evaluation of process changes, we are designing an electronic system that can operate on a permanent basis with minimum human interaction and provide real-time data.
4. Simulation Modelling, Performance Evaluation and Results

To provide a framework for developing recommendations we built a computer simulation model of the process. This technique allows to effectively account for variability, and has been extensively used to address a broad range of problems in health care settings, such as those described by Jun et al. (1999) [3].

Considering the structure of the process, we developed a discrete event simulation model of the entire ACU using the Rockwell Arena (version 11) software. The model encompasses patient flow from arrival to departure from the examination room, seizing limiting resources such as physicians and examination rooms. It incorporates the randomness and variability present in all stages of the process, including patient arrivals, consultation durations, and other process times.

To evaluate the performance of each scenario, we defined the following metrics: patient wait time, clinic duration, physician idle time, and resource utilization metrics including waiting room occupancy and examination room utilization.

We used the simulation model to identify limiting resources and on a “What if?” basis, to evaluate the impact of changes in physical configuration, scheduling and resource allocation policies. We found that a combination of strategies in terms of clinic start, appointment duration, and management of unscheduled cases can significantly decrease patient wait times, with almost no deterioration of the other performance metrics. In these scenarios we also observed, as a derived result, a significant decrease in room utilization, indicating that this was not a limiting resource. We tried additional scenarios with a more dynamic room allocation policy and decreased the availability of examination rooms, finding that under these settings a considerable number of the existing rooms can be spared with no significant impact on the patient experience or utilization of other resources. The liberated rooms can be converted into additional physician space, or used to accommodate more clinics.

5. Discussion

5.1. Problem Generalization

The problem faced in this paper can be generalized to many other settings in health care. At the most simplified level, our case represents an outpatient consult that requires a particular resource (physician), and employs other shared resources such as physical space (room), medical equipment and personnel (nursing, specialists and clerical staff). A natural extension is other ambulatory services in outpatient facilities. These include a range of services along the continuum of care, from primary care clinics to mental health and diagnostics. The methodologies used in our study can be applied to these other cases to streamline the processes and reduce unnecessary waits.

5.2. Health Information Systems and Process Data

Health Information Systems (HIS) contain a wealth of data. However, these data are usually associated to clinical or billing information, with very limited operational value. One of the main challenges in this project was the lack of data in the form required to develop advanced analytical models. Based on our experience in many other health care projects, this is a recurring problem for this sector.
Process-related information has received little attention; it is hardly measured, and even less frequently stored in a database/warehouse. The lack of data prevents the execution of in–depth studies based on advanced analytical methodologies. Furthermore, having no baseline and post-implementation data inhibits the execution of a proper evaluation of the implementation of changes to the processes.

Fortunately, HIS are rapidly evolving. The main focus to date has been on the integration of clinical, imaging, order entry, and other components to implement electronic patient records. We believe an opportunity exists to incorporate operational data to those information systems, which will in turn facilitate the implementation of OR applications that can lead to significant gains in efficiency.

5.3. Recommendations

To support operational performance evaluation and the development of advanced analytical methods, such as those from the Operations Research field, we strongly advise health care organizations to collect process data. These data are related to the temporal realization of the same events that are planned and scheduled in a process, such as start and finish of a consult or appointment duration.

Process data should be collected on a permanent basis and stored in such a way that can be linked to other information systems. Collection of these data is not a simple task and will most likely require additional infrastructure and/or cultural changes to be sustainable, but the benefits of this information are invaluable.

Ideally, the data collection system should be integrated to existing HIS and be readily accessible to allow more informative reports to be developed. This will support both decision makers and operations researchers alike, enabling the development of advanced analytical models to find opportunities for improvement in the processes. Participation of HIS specialists is paramount to the success of these projects.

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References

