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Case Article

Greenleaf Polyclinic: The Doctor Will See You Now

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Abstract. This case focuses on process mapping and analysis in a primary healthcare setting to decide on staffing levels of nurses and administrative assistants to support the fixed number of doctors operating in the polyclinic while meeting the limit on total system waiting time. The case describes how different patients interface with the service touch points throughout their stay in the facility. This introduces the students to the complexity and variety of patient journeys within a clinic and gives them the opportunity to build a representative process map to form the basis of a queuing or discrete-event simulation model to analyze the current state. The students are tasked with studying the sensitivity of waiting times to important service and demand parameters, and evaluating possible process improvements such as staff pooling and technology adoption to reduce waiting times. This case is recommended in an undergraduate level course on service or healthcare operations.

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Keywords: teaching healthcare operations • process analysis • spreadsheet modeling • teaching service operations management

1. Introduction

Given the rising chronic disease burden and ageing populations, healthcare providers are strained and costs are soaring. Polyclinics serve as a first point of contact in the healthcare infrastructure, delivering primary healthcare and offering a comprehensive array of outpatient services under one roof. Given their significance in the public healthcare landscape in Singapore, effective management of polyclinics is imperative to ensure optimal patient care and operational efficiency. This entails meticulous attention to resource utilization and service delivery. The case follows Sarah, an intern at Greenleaf Polyclinic, as she is tasked with analyzing the polyclinic’s operations to determine the required capacity of auxiliary staff for a given number of doctors working in the clinic.

The case invites the students to follow the discovery process of a newly joined intern as they discover the patient flow from the text. The case prompts them to propose and evaluate process improvements, for example, staff pooling and technology adoption, allowing to complete the arc from descriptive modelling of the current situation to prescriptive analysis.

The tools and frameworks of operations management are ideally suited to provide recommendations

to healthcare practitioners aiming to manage patient flow to minimize waiting time and provide efficient healthcare delivery. Queuing theory is one of the mathematical frameworks of choice to analyze and optimize healthcare processes as it allows to understand the impact of patient flow, resource allocation, and clinic operations on patient waiting times (Green 2006). Healthcare queuing models aim to balance system efficiency with patient experience by minimizing waiting times and resource utilization costs (Hall 2012). Queuing models have become well established in medical practice with applications in ICUs (McManus et al. 2004), in emergency departments (Joseph 2020), or bed management in hospitals (Proudlove 2022). Models often attempt to ensure high utilization of the most expensive resource, typically the doctors, while maintaining certain minimum service experience. Such models can be used to inform staffing policies and to plan for peak times and seasonal variations in patient demand. A more comprehensive list of examples can be found in the literature review by Lakshmi and Iyer (2013).

In practice, the patient’s journey through the healthcare system may flow across multiple interconnected units within a facility, resulting in complex queuing

networks (Gupta 2013). For example, patients may be transferred from a general ward to a specialty unit or discharged from one unit and readmitted to another. Furthermore, patients may be readmitted into the flow multiple times, which may result in deviations from the results of simple multiserver queues (Yom-Tov and Mandelbaum 2014). Finally, no-shows and the combination of appointment and walk-in patients may also lead to significant deviations from the results obtained with closed-form analytical approaches of M/M/n queues (Green and Savin 2008).

Consequently, such complex planning scenarios necessitate more sophisticated modeling approaches to provide a comprehensive view of resource utilization across an entire healthcare facility (Worthington 1987). Discrete-event simulation (DES) is a successful approach that allows for detailed and flexible modeling of patient flow through a healthcare facility (Jun et al. 1999, Fone et al. 2003, Vázquez-Serrano et al. 2021). By capturing the complex interactions between different departments and processes, such as admissions, discharges, and transfers, these models provide a more accurate view of capacity utilization. Their flexibility also allows to more readily evaluate the impact of staffing, budgeting, and other policy decisions on system performance (Song et al. 2015, Baril et al. 2019). Consequently, hospital administrators and physicians have promoted the implementation of DES in healthcare practice as valuable decision-support tools (Hamrock et al. 2013). Brailsford et al. (2014) explore the many ways in which DES can support decision makers by testing different resource allocation policies and capacity planning scenarios under various assumptions. Even more complex and dynamic situations, such as pandemics or mass casualty events, may benefit from hybrid models that combine queuing theory with simulation and agent-based modeling (Günel and Pidd 2010).

2. Target Audience

The case was designed to allow students to apply the theories and tools described above to promote understanding of healthcare operations and queuing management. As such, the case study is suitable for undergraduate students enrolled in service processes or healthcare operations management courses, providing a real-world context to explore process design and apply queuing theory concepts within a healthcare facility. The students can analyze the challenges associated with patient queuing, resource allocation, and service delivery in nonurgent, primary healthcare. Students also develop critical thinking skills and gain practical insights into the complexities of managing service processes in healthcare contexts.

This case adds to a rich vein of case articles and cases in *INFORMS Transactions on Education* that

allow students to practice and augment their understanding of process mapping, bottleneck analysis, and queuing in various settings (Pazgal and Reinhardt 2014, Sharkey et al. 2020, Dawande et al. 2021, Farajollahzadeh et al. 2025). Existing cases mostly require the students to both map and analyze service processes consisting of a single phase or strictly sequential phases. This case study, reflecting the actual patient flows observed within a polyclinic, allows the students to practice mapping and modeling more complex, and realistic, multiphase processes with various service pathways.

We find that Chambers and Williams (2017), who compare a multiphase process with varied patient journey in a pain treatment clinic for two different clinic configurations, present a comparable process complexity. They use DES to analyze the clinic's efficiency for a fixed set of resources under both configurations. Compared with Chambers and Williams (2017), our case presents a more complex process map that accommodates more varied patient journeys in the polyclinic. We start with a straightforward queuing analysis to first determine resource needs, after which students study the benefits of resource pooling, which Cattani and Schmidt (2005) argue are underdiscussed in operations management textbooks. Finally, our case study can further be extended to build a DES and compare its results with those of the queuing analysis, which highlights the differences between those two approaches. This experiential learning approach allows students to bridge the gap between theory and practice, because they navigate the complexities of service processes and critically apply different theoretical approaches to practical situations. As a result, students are equipped with the knowledge and skills needed to address operational challenges within healthcare organizations.

Students would benefit from studying this case along other cases in healthcare operations covering other important issues such as capacity management (Hans and Nieberg 2007, Vliegen and Zonderland 2017), inventory management (Hicklin et al. 2017), and patient and physician scheduling (Sauré and Puterman 2014, Shechter 2023) to obtain a more comprehensive picture of operations management in healthcare.

2.1. Case Synopsis

The short case describes Sarah's internship at Greenleaf Polyclinic in Singapore, where she is tasked with analyzing patient flow dynamics and propose staff and nursing capacity levels to support the doctors. Sarah observes various stages of the patient journey, from registration to doctor consultations and payment, noting the utilization of different services and resources. Particular attention is devoted to describing the variation in patient journey in the polyclinic as not

all patients use all services. The objective of the case is to get students to conduct a detailed analysis of the clinic's operations, focusing on resource decisions that support the fixed doctor capacity in the clinic. After a preliminary analysis of the current situation, the students are challenged to evaluate the impact of potential changes to the current operations, such as technology adoption and staff pooling or training, on the utilization and patient waiting times. Assessing the differential impact of changes in the demand assumption, and thus utilization rates for the various resources, on waiting times will allow students to appreciate the importance of the bottleneck (i.e., the doctors) vis-à-vis the other resources in managing the patient waiting times. Depending on the time available, the students could also be challenged to think how their model could be used to evaluate broader questions about waiting time guarantees or the impact of long-term population trends (e.g., aging and the rise of chronic diseases).

2.2. Learning Objectives

This case aims to achieve the following learning objectives through hands-on execution and discussion:

- Process mapping:
 - o Draw a process map with multiple service stations and decision nodes
 - o Determine the demand at each service station given a nonhomogenous patient flow
- Queuing models:
 - o Build a multiphase queuing system, without and with staff pooling
 - o Determine total weighted waiting time and understand the impact of staffing levels
 - o [optional] Ability to manipulate a queuing model and its assumptions to represent various decision-making scenarios
- Discrete-event simulation [optional]
 - o Build a DES simulation
 - o Determine total weighted waiting time and understand the impact of staffing levels
 - o Explain the difference in results between DES and queuing models
- Critical thinking

Regarding the last item, the case encourages students to verify the impact of different assumptions by intentionally providing a range of patient arrival rates. The students must identify a reasonable maximum arrival rate the clinic can serve, which requires a good understanding of the process map (specifically the second visit required by a portion of the patient population). Furthermore, knowing that the arrival rate selected is but an assumption, the students should also perform a sensitivity analysis to discover the impact of their assumption on the results. Finally, students

can be encouraged to explore alternative process improvements with the model they have built. In class, student proposals have included tele-consulting for the second doctor consultation or reserving slots for appointments.

3. Experience in Class

This case has been taught twice in an undergraduate elective class on healthcare operations. Most students are in their third or final year. About half of them are in the Bachelor of Business program with a major in operations management; slightly over a quarter comes from other management schools, such as economics, social sciences and computer science, and take a second major in healthcare economics; and the remaining students are international students on exchange. Because this course does not have any prerequisites, the case is introduced after a review of process mapping and queuing in two preceding classes. Therefore, all students have practiced drawing process maps. Furthermore, they understand the tradeoff between utilization and waiting time and the impact of variability and can analyze simple M/M/n queues using the QMacro extension for Excel (Groenevelt 2021) or other online queuing calculators.

The case discussion uses an entire class when following a student-led approach, in which students are challenged to identify the right questions to ask and answer rather than being given a series of questions to answer. To kick off the case discussion, the class is asked what they would do if they were in Sara's position. Individual students are invited to share their initial idea with the class on the white board. Rather than focusing on the analysis, the students typically come up with different proposals to change the patient flow. The students are then asked how they can evaluate which idea is more promising. At that point in time, the students realize they must perform an in-depth analysis of the patient flow and queuing system to be able to choose and prioritize the different ideas presented.

3.1. Process Mapping

The students typically simplify the patient flow and omit some of the details described in the case; furthermore, they may come up with several alternative representations of some of the more complex steps in the process (such as the second consultation after the doctor recommended additional tests during the first visit). Incomplete representations, for example, representing registration as a single process even though there are different ways to register, will lead to incorrect analysis and must be addressed. However, different representations are not necessarily incorrect if they capture the relevant details needed.

3.2. Queuing Analysis

When the students are challenged to fill out the details such as resource availability and arrival rate in preparation for the queuing analysis, they realize that the arrival rate is a range. Because undergraduate students are used to receiving all the data, they may feel uncomfortable with the uncertainty around the arrival rate. A discussion can ensue about how to make, justify, and test modeling assumptions.

The students proceed to the queuing analysis once the necessary parameters have been identified. Upon identifying the performance of the “base case,” the students can be asked to verify the impact of their arrival rate assumption and to evaluate some of the ideas that were initially proposed at the beginning of the class for their implications on staffing, waiting time, and patient experience. Alternatively, the instructor can request all students to focus on the evaluation of the two following process improvements: staff pooling and technology adoption.

Although DES is arguably superior for the complex queuing network found in healthcare facilities, that methodology is beyond the scope of my course. I choose to briefly present the simulation model and its results to the students but do not ask them to build their own simulation or discuss the results of the simulation separately.

Finally, the case study could be used to investigate strategic questions about the impact of long-term trends on the polyclinic’s operations. Possible questions relate to the increase in chronic diseases and the use of laboratory services, an aging population leading to a higher number of doctor visits for a constant population size, or the preferred size of the clinic patient pool.

4. Student Learning

The students were asked for feedback outside of class. I managed to collect 32 responses (out of 42 students) after reminding the students one week and two weeks after class. They answered the following questions (on a scale of one to five in Table 1):

Table 1. Student Feedback

Question	Average	Minimum	Maximum
I feel more confident in my ability to structure a complex process.	3.97	1	5
I know better how to examine the impact of process changes.	4.00	2	5
I feel more confident in building and analyzing queuing models	3.75	2	5
I have a better understanding of the operations of a healthcare facility	4.03	2	5

The students also reflected on the key takeaways from the case. I have reproduced a sample of responses below:

- “Understanding of Queuing Models: Learned how queuing theory applies to real-world healthcare settings, specifically optimizing patient wait times. Importance of Process Mapping: Gained insights into the value of process mapping for identifying inefficiencies and bottlenecks in clinic operations.”

- “I learn how to break down the steps, taking information and processing it in smaller part then put them together as a bigger picture.”

- “I have a better understanding of operations in healthcare facilities and where it could go wrong”

- “Better understood how to map the process flow diagram when it is more complex and the thought process behind the sensitivity analysis”

- “I enjoyed the case study and the way you brought us through the thought process. My key takeaway is learning how to work around missing information and still draw valid conclusions.”

The students were also asked for feedback on how to improve their learning experience. They highlighted that they struggled with identifying and finding the missing information and would have appreciated more guiding questions along the way. This can be addressed by following the suggested case study questions more closely rather than asking students to identify the problem statement themselves. They also requested whether a semiblack template of the mathematical workings in Excel could be shared ahead of time to help those who are less familiar with Excel and QMacro.

5. Conclusion

This case is a tool for instructors who wish to discuss healthcare operations, with a focus on patient flow analysis and queuing or discrete event simulation. The case aims to teach the students about the complexities of healthcare operations by staying close to the experience of the intern at the polyclinic. The case can be used solely as a guided exercise of operations management theories and tools or can be discussed with a greater focus on generating and evaluating possible process improvements. The second approach fosters greater critical thinking by the students on top of cementing their operations and analytical skills, but is more suitable for students in their final year who are more confident in their ability to make and defend assumptions to support their ideas.

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