Designing Patient Throughput and Task Management Innovations in Orthopaedics

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Abstract - **The Orthopaedic and Sports Medicine Clinics of the University of Virginia Health System are collocated in the Fontaine Research Park. The two departments operate in separate clinics, but share a Radiology Department. Collectively, the clinics serve about 42,000 outpatient visits annually. With patient visits projected to increase substantially in the coming years, the clinics seek process improvements that will accommodate growth and sustain strong patient satisfaction well into the future. This paper describes a simulation study of patient flows in the clinics under various future demand scenarios, including alternative patient volumes and no-show rates. The study explored the impact of best practices for in-clinic task management, patient and staff scheduling, and patient communications. Key performance measures included patient waiting times, total time in clinic, facility utilization, and on-time clinic closings. The model was developed based on patient schedule and tracking data. The results of the simulation model and clinic observations provided evidence to support multiple process improvements within the clinics. Introducing an additional front desk attendant in each clinic during busy times to assist with incoming phone calls and patient check-ins will allow for patients to be seen sooner and for more efficient appointment scheduling. Altering appointment time slots from 15 minutes to 10 minutes and distributing scheduled appointments more evenly throughout the day will allow providers to see more patients and reduce the need for overbooking, effectively decreasing patient waiting time. Based on the results of our analysis, implementing these changes to the clinics may allow for future growth while preserving patient satisfaction.**

Index Terms – Discrete-event simulation, healthcare systems, outpatient clinic, patient flow, scheduling

INTRODUCTION

Because of growing patient populations, many clinics in the United States experience issues regarding treatment efficiency and long waiting times. In addition, a lower proportion of U.S. patients are satisfied with their healthcare than many other developed nations [1]. This indicates a general need for systematic changes to streamline healthcare processes and improve patient flow. *Patient flow* is the efficiency and volume at which patients move through a healthcare setting. This issue has implications for both staff, who would like to see as many patients as possible without getting backlogged, and patients, who would like to be seen in the shortest amount of time possible without sacrificing quality of care. Thus, patient flow improvement projects must consider multiple stakeholder groups. Operational decisions should therefore seek to balance optimizing patient volume and patient satisfaction, while reducing provider overtime and patient waiting times.

This paper discusses how simulation modeling was used to evaluate strategies to improve patient flow at the Orthopaedic and Sports Medicine Clinics of the University of Virginia (UVA) Health System. The project involved a (1) review of relevant literature, (2) on-site clinical observations, (3) analysis of historical data, (4) and system modeling via a discrete-event simulation (DES). This combination of methods allowed for a thorough understanding of the current patient flow situation and provided evidence for changes to their current resource management and scheduling processes.

BACKGROUND AND LITERATURE REVIEW

We conducted an extensive literature review to better understand the issue of patient flow and how to resolve potential problems. The literature review involved investigating best practices for relevant aspects of the project. The sections below demonstrate multiple topics related to this project and clinics of interest, along with the evidence-based practices used in similar patient flow improvement undertakings.

I. Patient Flow Modeling

Patient flow modeling is often employed for process improvement in healthcare. One such study successfully utilized simulation to identify a list of common bottlenecks in orthopaedic practices: congested waiting rooms, patient no-shows and late arrivals, walk-ins, initial visit patients, and patients who need imaging [2]. These are all components that influence patient flow at the UVA clinics, so we sought to yield similar results. The same study describes the power of DES in the healthcare industry. It is an ideal method for evaluating and improving systems that exhibit a high level of complexity and uncertainty. Furthermore, the study exhibits the extent to which animation and data recording capabilities of simulation software allow healthcare professionals to visualize the impact of potential changes prior to implementation.

Another study conducted in 2014 proposed a simplified modeling approach, in which patients were able to take one of three possible trajectories through the clinic. The trajectories were determined probabilistically and then used to create an accurate simulation with reasonable assumptions. The authors found that the optimal scheduling for the clinic depended on the percentage of patients in each defined trajectory [3].

II. Optimal Scheduling for Outpatient Clinics

It is common for clinics to *overbook*, or schedule multiple patients in the same time slot, to mitigate the potential financial loss resulting from a patient unexpectedly cancelling or failing to show up for an appointment; however, it may also lead to congestion and occasionally provider overtime [4]. Kaandoorp and Koole conducted a simulation study in 2007 that reinforced the trade-off associated with optimal scheduling: maximizing patient throughput versus meeting the interests of both patients and providers [5].

It is known that the professionals who manage patient scheduling receive appointment requests over time and must accommodate patients within an ever-growing schedule. This makes the effective prediction of demand and appropriate scheduling more complicated [6]. Demand and service times typically vary by the specialty of the provider. Patient visit attributes such as visit type (e.g., initial versus follow-up) may also impact service times [7, 8].

III. General Best Practices

Since patient flow is such a prominent issue in outpatient clinics around the country, there are a variety of ways to make improvements beyond scheduling changes. A study on the use of SMS text message reminders, as opposed to calling or mailing patients, was found to significantly reduce the rate of no-shows and late arrivals [9]. The Orthopaedic and Sports Medicine Clinics at UVA currently only send letters and make phone calls to patients, so this study is strongly suggestive that an SMS reminder system could result in more consistent patient arrivals. Another study examined the turnaround time in imaging departments, which is a common bottleneck in clinical care. The issue is often made worse due to overtreatment, which can result in many requests for imaging services that may be unnecessary [10].

An important aspect of this type of project is to maintain frequent communication between the team and clinics. This allows clinical staff to be up-to-date on proposed changes and leads to more effective implementation [11].

METHODOLOGY

DES is one of the most effective methods to analyze patient flow and assess what-if scenarios for producing evidence-based changes. Given the nature of outpatient clinics, patients are typically moved through multiple independent clinical processes during their short stay. This makes identifying and remediating bottlenecks in the system a complex process. DES is powerful for its ability to accurately model and validate the current scenario and then see how various systemic changes affect patient flow. In particular, it is useful for observing the impact of manipulating system resources, such as introducing additional staff or imaging machines, or testing various scheduling techniques, such as changing the allotted time per patient and distributing scheduled appointments more evenly rather than staggering appointments with overbooking [2].

I. Clinic Observations

An essential part of simulation modeling is a having a thorough understanding of the system to be modeled. To reach this understanding of the clinics, multiple rounds of clinical observations were conducted on varying days and times. Discussion with clinical staff provided indications of where the current system may be falling short. In-clinic observation also allowed for a comprehensive understanding of the various paths a patient may take throughout their visit to the clinic.

Figure I represents possible patient paths through the two clinics. The flow diagram provides a basis for the DES model. The two major processes that occur for patients are examination and imaging. The primary resources that these processes utilize include facilities and staff. When resources are tied up due to multiple patients existing in the system, queues form, which are represented by the various waiting rooms at the facility. There are four typical patient scenarios for both orthopaedic and sports medicine patients:

- **Trajectory 1:** Patient does not require imaging and proceeds directly to examination. Leaves clinic.
- **Trajectory 2:** Patient requires imaging immediately then proceeds to examination. Leaves clinic.
- **Trajectory 3:** Patient proceeds immediately to examination, is determined to require imaging, and returns to examination. Leaves clinic.
- **Trajectory 4:** Patient proceeds immediately to examination, is determined to require imaging, and leaves clinic without further examination.

The frequency at which these different trajectories occur in the model is decided probabilistically, based on historical data kept by the clinics' patient tracking system. This approach is similar to the one utilized by Baril, Gascon, and Cartier in 2014 [3]. They found that the optimal scheduling rule for the clinic was based on the percentage of patients following each trajectory. The number of patients who require same-day imaging is uncertain and subsequently can cause delays. This is a large factor in the UVA clinics because of their shared Radiology Department, which is a suspected bottleneck resulting from resource limitations.

II. Results of Clinic Observations

While in isolation it is not an effective tool for analysis, in-clinic observation was valuable for gaining a qualitative understanding of the system. In order for simulation

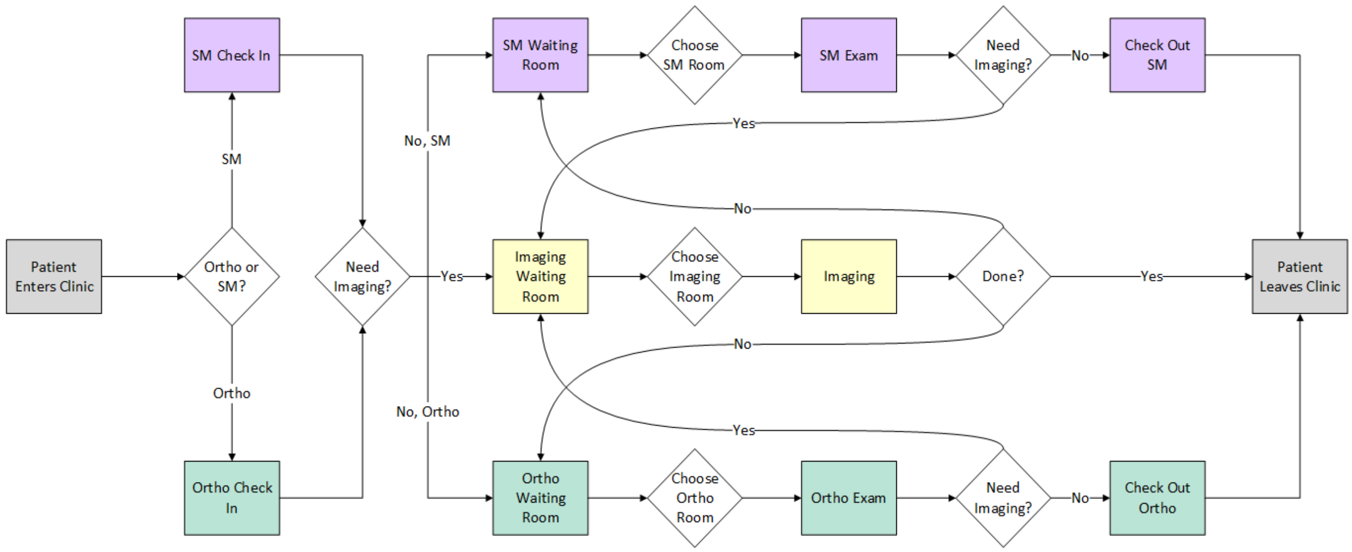

FIGURE I
SIMPLIFIED FLOW DIAGRAM OF POSSIBLE PATIENT TRAJECTORIES

modeling to be useful, alternative schemes must be developed in advance. These alternatives can then be tested and compared with the current scenario via certain performance measures. In-clinic observations revealed several points of interest that warranted further investigation within the simulation model. These points of interest included:

- Variable service and waiting times
- Busy front-desk staff
- Providers not adhering to schedule templates
- Patients not arriving at scheduled appointment times

All of these factors likely influence and complicate the patient flow problem. Variability in service and waiting times is dependent on many other factors, such as the particular provider (e.g., physician, physician assistant), the visit type (e.g., initial or follow-up), need for same-day imaging, and if the patient is scheduled for an overbooked slot.

In-clinic observations revealed that the front-desk receptionists were often too busy handling phone calls and scheduling new appointments to admit the next patient in a timely manner. This has an impact on the processing time of patients and is significant for patient satisfaction.

The lack of consistency regarding the schedule templates suggests that providers may not be satisfied with their established schedules. The current system utilizes 15-minute time slots and allows providers to customize a quota of patients to see during each slot. Initial visit patients typically take longer, thus it is common for providers to dedicate two of 15-minute slots for initial visits, and only one 15-minute slot for follow-up visits. It is also common for providers to overbook slots in order to reduce potential downtime and see a higher volume of patients. The simulation model allows us to analyze the impact of altering this scheduling system on patient waiting times and facility utilization.

Through in-clinic observations and discussion with clinical staff, we determined that timely arrival of patients is predominantly an issue of communication. This may be alleviated by introducing a more effective reminder system, such as the aforementioned text message-based reminders utilized by Downer *et al.* [9].

DATA

The Orthopaedic and Sports Medicine Clinics use multiple technologies to handle appointment scheduling and patient tracking. Patient appointments are made using a software system, A2K3. This system also aggregates appointments by provider for providers to use as a daily schedule. This daily schedule is typically inconsistent with the aforementioned provider templates. Upon arrival at the clinics for their appointments, patients are registered into patient-tracking software, Tracks.

The data utilized for analysis included two datasets retrieved from these systems. A2K3 provided a one-year historical record from 2015 containing the following attributes of interest for individual patient visits: appointment date, appointment time, provider, visit type, and patient type. From Tracks, we obtained two months of tracking data with the following factors of interest: clinic arrival times, time spent in various clinical rooms, and whether or not X-rays were taken. In this paper, we focused our analysis on Mondays from October to November in 2015 because both observation and data analysis showed that Monday is typically the busiest day of the week. Therefore, subsequent statistics and figures are generated from data gathered on Mondays.

Figure II shows overlaid histograms of each visit type. As can be seen in the figure, follow-up visits represent a greater proportion of all visits than do initial visits and on average take less time (72.73 minutes compared to 86.88 minutes). With this in mind, visit type was considered as an important factor in analysis of service times.

Table I below shows 25th, 50th, and 75th quartile values for various de-identified physicians (PHYS) and physician assistants (PA). From this table it can be confirmed that follow-up visits generally take less time than initial visits. Service times for each provider are calculated based on patient type: initial visit vs. follow-up visit. These times are represented by random variates that were fitted with the list of actual process times. Additionally, the proportion of patients who must receive imaging has a large effect on overall patient flow. This proportion was calculated for each provider, since different specialties will send patients to radiology with a different frequency.

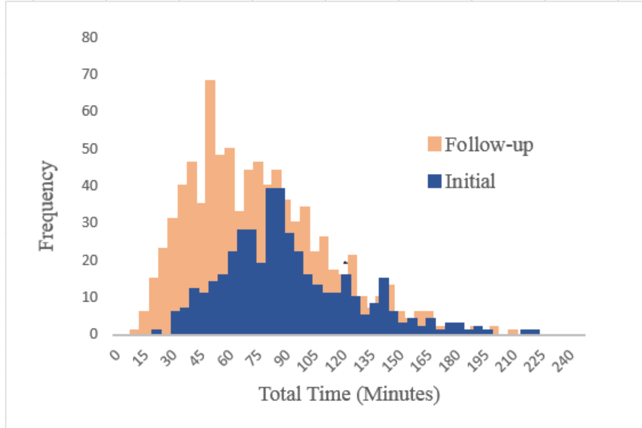

FIGURE II
HISTOGRAM OF TOTAL TIME BY VISIT TYPE

DISCRETE EVENT SIMULATION

I. Modeling Decisions

Despite fairly robust datasets and analysis, it was necessary to make some assumptions to perform the DES. All modeling assumptions were validated by comparing the simulation results to the actual system and consulting with clinical staff. Key assumptions used in the simulation model include:

- Small sample sizes for providers who do not see many patients were adequate to characterize the behavior of these providers.
- Initial visits and follow-up visits were the primary types of patients for determining process times.
- Distributions of process times varied only by provider and type of patient.
- The amount of time in exam room was an adequate surrogate for process time, rather than time spent with provider.
- Offset times showed that about 84% of patients arrive within 5 minutes of the scheduled appointment time, so no offset times were required in the model.
- If initial visit or follow-up visit is not specified on schedule template, the patient type alternates starting with initial visit.

A crucial aspect of creating evidence for improvement is having clearly defined performance measures. These are the metrics by which the simulation model will be evaluated, and show the effect of any changes introduced in the model. To optimize the tradeoff between efficiency for clinical staff and quality service for their patients, a diverse set of performance measures should be used. The following indices of performance were selected based on a simulation study by Bhattacharjee and Ray [12] and the specific goals of the clinics:

- Utilization of exam rooms
- Utilization of X-ray rooms
- Number of patients (throughout)
- Total time in clinic (cycle time)
- Time in queues (waiting rooms)

The primary interest of the Orthopaedic and Sports

TABLE I
PROVIDER SERVICE TIME AND X-RAY PROPORTION

		Initial Visit Service Time (minutes)			Follow-Up Visit Service Time (minutes)		
Provider	**X-Ray %**	**25th Quartile**	**Median**	**75th Quartile**	**25th Quartile**	**Median**	**75th Quartile**
SM-PHYS 1	25.80	31.75	49.38	61.22	19.90	32.30	48.85
SM-PHYS 2	35.90	29.98	51.69	69.98	18.88	31.07	43.35
ORTHO-PHYS 1	43.82	41.73	58.33	72.64	23.00	37.77	55.14
ORTHO-PHYS 2	53.06	45.28	51.19	81.63	23.12	33.65	43.40
ORTHO-PHYS 3	67.80	43.88	52.82	73.37	32.30	42.11	52.75
SM-PA 1	48.91	11.52	17.23	24.53	16.10	22.02	27.48
SM-PA 2	49.18	17.75	23.21	34.27	17.95	25.38	29.93
ORTHO-PA 1	44.71	44.31	56.67	62.40	18.13	24.54	35.33
ORTHO-PA 2	20.59	43.68	47.22	59.58	21.20	32.24	51.50
ORTHO-PA 3	65.00	36.21	40.02	51.60	19.76	33.43	52.66
ORTHO-PA 4	52.63	39.86	47.26	55.76	33.45	43.60	53.95

Medicine Clinics is achieving improved patient flow through optimized scheduling and resource utilization. Therefore, we developed alternatives regarding these interests. It was important to address the true causes of inefficiency while ensuring that proposed solutions were actually viable for implementation. The following alternatives were tested to analyze their expected impact if implemented in the clinics:

- **Alternative 1:** 10 min schedule slots rather than 15, with appointments distributed more evenly
- **Alternative 2:** Adding an additional X-ray resource
- **Alternative 3:** Adding additional receptionists

II. Results of Simulation Modeling

The simulation model was used to test the three aforementioned alternatives, and compare these to the current scenario at the clinic. Comparisons were based on the defined performance measures, with the goal of maximizing patient volume without sacrificing patient waiting times and provider overtime. For each scenario, 10 replications were run to further validate and increase confidence in the results. Analyzing multiple replications reduces the uncertainty of the simulation outputs due to the randomness of process time distributions. Conclusions were then drawn based on these results.

Implementing 10 minute rather than 15 minute schedule slots showed a decrease in the total time patients who see physicians spend in the clinics by roughly three minutes. There is no significant decrease in total time for patients of physician assistants, which is likely due to their smaller patient volume. An additional X-ray resource did not significantly decrease total time patients spend in the clinic and did not have a high utilization. This is likely attributed to the clinic's recent expansion to their imaging services, which lessened the need for additional physical resources. By adding a receptionist in each clinic, the total time spent by patients in the clinic was reduced by an average of roughly two and a half minutes. Queue lengths and waiting times similarly decreased by adding these staff members. These model results validate the clinic's decision to hire additional front-desk staff.

Conclusion

To combat the issues of congestion and patient throughput within the Orthopedic and Sports Medicine Clinics of the UVA Health System, operational changes are recommended. These changes were hypothesized based on researched best practices in clinic flow and related fields, data analysis, and in-clinic observations. The hypothesized changes were then tested using a DES model designed to reflect both the current clinic condition and future scenarios for comparison. The simulation model results indicate the following:

- Ten minute schedule slots may improve physician patient throughput but may not have an effect on physician assistant patient throughput.
- An additional physical X-ray resource may not decrease total patient time at the clinic at this point in time.
- Adding a receptionist may improve patient flow in each clinic.

In addition to findings based on the simulation model, general takeaways were garnered throughout the course of the project. Better data collection and storage will help future analyses. Many assumptions and limitations of the model resulted from the lack of volume or organization of data. The inability to separate provider time from time in examination room prevented an optimal representation of the time providers spent with the patient. Therefore, provider utilization could not be calculated and patient service times were dependent on the service of other patients. An increased volume of data would provide a larger sample size of patients for each provider, which would better predict the number of expected patients each day. Predicting patient volume allows for the development of more effective schedule templates for providers.

Other takeaways included the possible use of an automated text-messaging reminder system, which would likely decrease clinic costs and failure-to-attend rates. Using provider templates to create daily schedules will decrease the variability in patient waiting times.

Implementing operational changes based on model and general takeaways will likely result in increased patient throughput while maintaining if not improving patient satisfaction. Further, these operational changes will facilitate future works of similar nature in these clinics.

Future Works

The nature of this project supports future analysis to track the effectiveness of operational changes made and discover new innovations in patient throughput. The DES model can be easily used in future projects with little to no adjustment depending on the operations of the clinic relative to those employed in 2015. With better data collection in the future, fewer assumptions and limitations will be necessary and more factors can be investigated and understood. A major limitation of this study was the inability to separate provider service times from the amount of time patients spent in the exam room. Additional factors not addressed in the scope of this project include potential seasonality and variation among days of the week, as well as analysis of different visit types beyond follow-up and initial visits. More complete data would allow better assessment of operational changes with fewer limitations and assumptions applied to the model.

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