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USING SIMULATION TO EVALUATE PROVIDER SCHEDULING HEURISTICS IN SPECIALTY OUTPATIENT CLINICS

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ABSTRACT

Scheduling providers in outpatient specialty clinics is often done in a non-systematic fashion as a result of providers having varying clinic time assignments. This is particularly challenging in academic medical centers and large health systems where providers have responsibilities outside of clinical duties. This leads to inconsistent use of clinic space, staff, and other fixed resources in addition to high variability in operational performance measures. In this paper we present a discrete-event simulation model used to evaluate heuristics for scheduling providers within a specialty clinic. The simulation model is developed and validated based on a specialty clinic within University of Minnesota Health. The scheduling heuristics are evaluated across multiple operational performance measures based on relative improvements compared to test cases from actual schedules used in practice.

1 INTRODUCTION

The extent to which health care services are delivered in outpatient settings is growing (MedPAC 2017). This trend is a result of various factors including technological advances leading to more procedures being done in ambulatory settings, lower costs associated with services in outpatient facilities as compared to hospitals, higher safety measures in outpatient settings, and outpatient facilities being more convenient for patients (Deloitte 2019). As the emphasis placed on value across health care continues to mature, it can be expected that the growth in outpatient care delivery will also continue.

The increase in demand for specialty outpatient services (Barnett et al. 2012), in addition to existing health systems and hospitals responding with new facilities, has led to changes in the operational structure of how outpatient care is delivered. In response to meeting the preferences for patients with work or school schedules that conflict with traditional clinic hours, more outpatient facilities are maintaining longer clinic days (e.g., 12 hour days) resulting in more efficient use of physical resources as there is less time the facility and equipment sit idle. Depending on affiliations with hospitals, health systems, or larger medical centers, providers will not necessarily be scheduled in a particular clinic full time. Rather, a portion of their day or work week will be spent in a specific outpatient facility.

However, there is a continued need for administrative decision-makers to maintain adherence toward traditional performance measures. Specifically, outpatient facilities continue to aim for high patient experience levels while maintaining high patient visit volumes and clinic activity (Froehle and Magazine 2013). Investments in expensive resources (facilities, equipment, highly-trained specialists, etc.) continue to drive productivity benchmarks and efficient use of resources. Further, patient and staff satisfaction give impetus to the design and operationalization of balanced and efficient practices. The effects of poor operational

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design can lead to both operational and clinical impacts including poor quality, high stress, burnout, and low patient satisfaction as a result of the chaotic setting which may ensue.

Prior research related to physician scheduling is largely characterized by inpatient settings such as hospital units and emergency departments where problems are often categorized as staffing (long term), rostering (medium term or operational), and dynamic rescheduling in their decisions (Erhard et al. 2018). The aims of physician rostering problems, which are most closely related to this paper, focus on maintaining adequate coverage in a unit (e.g., emergency department) (Ferrand et al. 2011; Beaulieu et al. 2000) to meet uncertain demand and providing equity in the schedule with respect to physician preferences, night shifts, or weekend schedules (Gunawan and Lau 2013; Bard et al. 2013). Research focused on physician scheduling in outpatient settings has been concentrated on medical resident scheduling, particularly related to specialty rotation scheduling (Franz and Miller 1993; Bard et al. 2014; Cohn et al. 2009; Smalley and Keskinocak 2016). While there exists a broad literature related to physician scheduling, little is known regarding the design of physician schedules in outpatient clinic settings where physicians only spend a portion of their time seeing patients (vs. time allocated to research, education, and administrative duties).

In this paper we present a simulation model developed to evaluate provider scheduling heuristics. Specifically, provider schedules are sought which better level the clinic activity across the entire clinic day, thereby decreasing times during the day where either no providers are in the clinic or all providers are scheduled at the same time. In practice, the clinic's provider schedules often result in many providers being in the clinic during the middle of the day and few providers seeing patients at the beginning and end of the clinic day. The operational performance measures resulting from the heuristics are compared to test cases derived from actual clinic schedules and are presented in terms of relative improvements. Because the daily clinic activities are complex, provider clinic shift durations vary, service times (and arrivals) are stochastic and heterogeneous, evaluating operational performance measures resulting from heuristic schedules is challenging. Simulation provides an opportunity to accurately model specialty clinic activities and evaluate performance measures for given schedules.

The remainder of this paper is organized as follows. Section 2 provides a detailed description of the problem context and simulation model. The heuristics evaluated with the simulation model are described in Section 3. Results are presented in Section 4 and concluding remarks are made in Section 5.

2 PROBLEM DESCRIPTION AND SIMULATION MODEL

Specialty providers' duties are often spread across multiple care settings or entail various non-clinical activities. This is particularly the case in large health systems or academic medical centers (Aron and Papp 2000). Depending on the specialty and health system context these activities may include inpatient (hospital) service time, procedures or surgeries not done in the outpatient clinic, teaching and other didactic responsibilities, research time, or administrative obligations. Further, as health systems continue to grow, many providers often rotate their presence between multiple sites through out the week. In combination with outpatient clinics maintaining longer days, allocating provider time within clinic hours is a formidable task for many managers as most providers are assigned only a portion of their time as spent seeing patients in the clinic. Other portions of their time spent outside of the clinic include research, education, and administrative responsibilities. As a result, on a given day the variability of provider shift durations can be high. Figure 1 illustrates the range of provider clinic shift durations based on the outpatient specialty clinic we studied. While the most common clinic shift duration was between 8-9 hours, Figure 1 illustrates a wide range of shift durations in the provider schedules.

Further complicating the provider scheduling process is the variability of exam durations across between different providers. The differences in the time spent with patients across providers is due to a number of factors and has been observed in various settings (Guy Jr and Richardson 2012; Blumenthal et al. 1999; Mechanic et al. 2001). Each provider has their own examination style and pace with which they interact with patients. Further, each provider within specialty disciplines is likely to have different case mixes of patients with respect to patient characteristics, illness severity, comorbid conditions, and general health

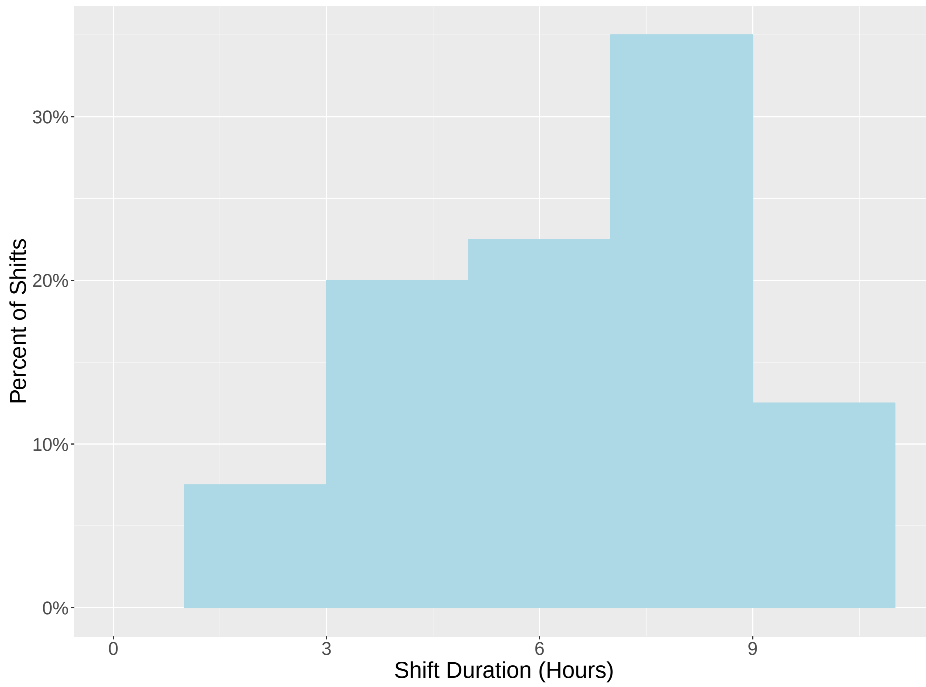

Figure 1: The distribution of provider clinic shift durations is variable due to providers having different levels of their time allocation dedicated to clinic responsibilities (vs. research, education, and administrative duties).

states which contributes to the duration of exams. As a result of these differences, both the arrival and service rates for each provider's patients are heterogeneous in the distributions. Figure 2 illustrates the patient exam duration distrubutions for five providers in the specialty clinic studied using box plots.

The aim of the analysis presented in this paper is to evaluate provider scheduling heuristics which lower the volatility of activity within a clinic setting during a given clinic day. This goal is complicated as a result of the provider heterogeneity discussed above. Specifically, the provider heterogeneity induces varying clinic shift durations, arrival rates, and exam duration distributions which make balancing the clinic activity across a 12 hour day, for example, difficult. Due to the complexities associated with accurately modeling the clinic operations, we evaluate and compare multiple heuristics used to schedule providers to clinic shifts during the day using a discrete-event simulation model.

2.1 Simulation Model and Clinic Flow

A discrete-event simulation model was developed to evaluate the variability in clinic metrics associated with physician scheduling approaches. The model was built within Arena simulation software to reflect the patient flow process of the prostate urology outpatient clinic at the University of Minnesotas Clinic and Surgery Center (CSC) (Kelton et al. 2007). Patients' flow through the clinic is determined based on the assigned provider. Each provider has their own clinic flow, with the arrival rate of patients as well as exam time distribution determined by actual operational data from the CSC's real time locating system (RTLS).

For each clinic day, the clinic was open for 12 hours. During this time, the supporting staff resources were kept constant. The provider shift durations have varying lengths due to full time equivalent (FTE) clinic assignments as well as the nature of the duties within an academic medical center described above. Schedules within the clinic were based on ad hoc and preferential bases.

Upon arrival to the CSC, the patient checks in with a receptionist using a tablet and is given a RTLS badge. Once the patient enters the designated waiting area near the clinic space, a licensed practical nurse

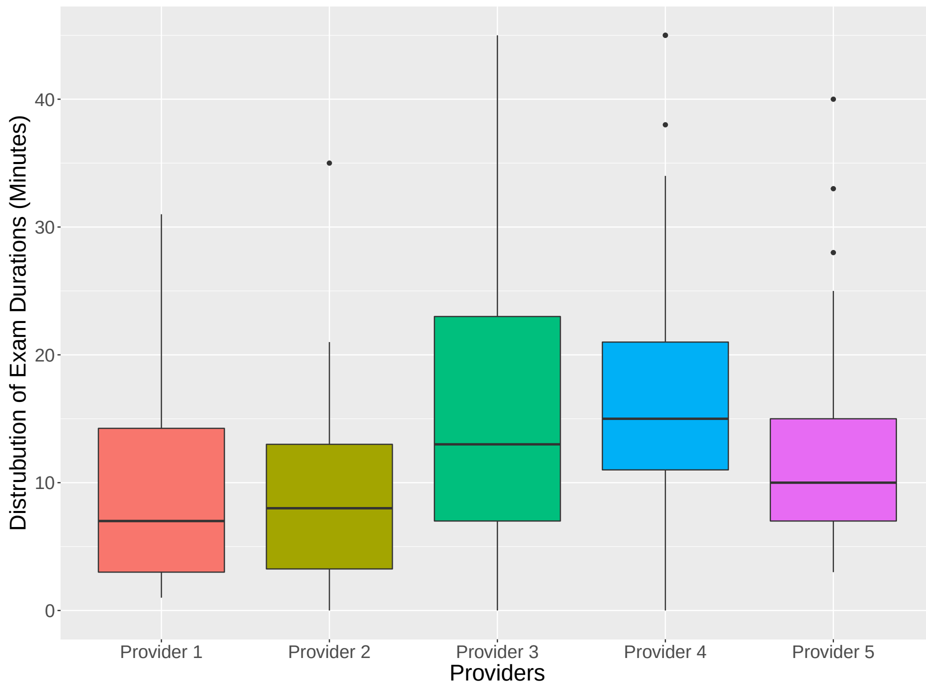

Figure 2: Distributions of time spent with patients during an exam vary by provider as a result of factors such as different practice styles as well as patient case mixes.

(LPN) receives an update on their computer that notifies the LPN that the patient is ready to begin the intake process. The LPN identifies the patient in the waiting area using a digital map with the patients location and photo and escorts the patient to the intake area within the clinic space. Upon completing the intake process, the LPN escorts the patient to the either the next available exam room or to a procedure room, depending on the appointment type, where the patient will remain for the entire clinic appointment. We note that both exam and procedure rooms are flexible and are allocated based on a *first room up* policy and are not dedicated for use by a specific provider.

If escorted to an exam room, the LPN performs a standard LPN visit with the patient and records the patients health history. If the patient is scheduled for a nurse-only visit, a nurse will enter the exam room and conduct a standard nurse visit. If the patient is scheduled for a provider visit, the provider will enter the room following the intake process and conducts an exam. If the patient is present for a procedure, the provider will then enter the room to perform the procedure. We note that procedure rooms can be used for both exams and procedures while exam rooms are only used for exams.

Following exam or procedure, some patients will require a follow-up nurse visit to discuss next steps regarding treatment and education. Finally, the patient is escorted by the LPN to the checkout desk where a receptionist will schedule additional follow-up appointments if needed. After the patient completes the checkout process, the patient returns the RTLS badge and departs the CSC. Figure 3 illustrates the flow of patient activities in the clinic.

2.2 Model Validation

Calibration of the simulation model was based on an outpatient specialty clinic at the University of Minnesota's Clinics and Surgery Center. Historical durations of patient and clinic activities from two months of the clinic's RTLS data were used to identify arrival rate, no-show, intake, exam, procedure and check out process distributions used as inputs in the simulation model. Simulated patient length of stay and patient wait times were compared to the same durations as measured by the RTLS data. The results

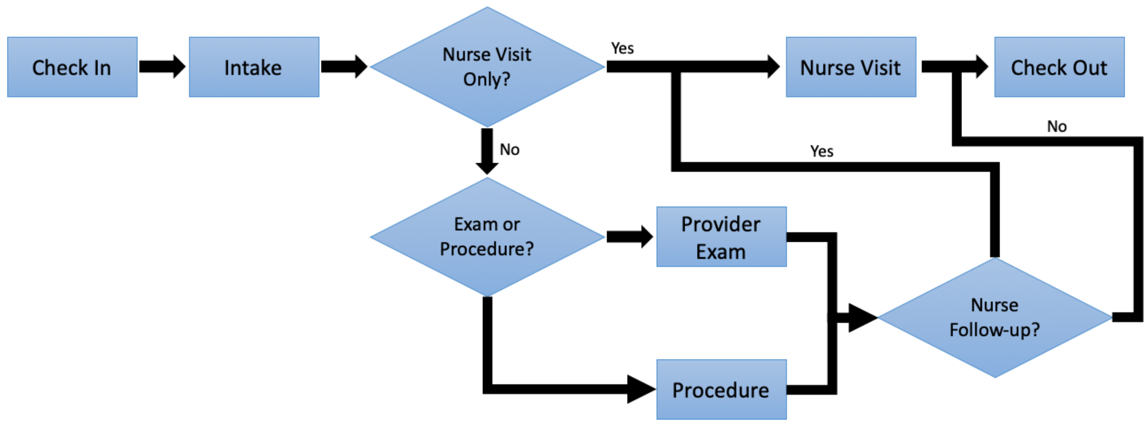

Figure 3: Patient flow and activities in the clinic studied.

from the simulation model were found closely match those of the RTLS data. The simulation model was also verified with clinic staff in its logic, visualization, and output.

3 PROVIDER SCHEDULING HEURISTICS

Two scheduling heuristic frameworks for provider clinic shift assignment were developed and evaluated. Each of the scheduling heuristics were developed based on the objective of spreading out clinic activity throughout the entire day. The intuition behind both of the scheduling heuristics is that current capacity should be used to the greatest extent (minimize amount of time when no providers are scheduled) while also scheduling as few providers concurrently as possible (minimize clinic congestion). The first heuristic attempts to balance the clinic activity during the day by alternating scheduling clinic shifts at the beginning and end of the clinic day until all provider shifts are scheduled. The second heuristic schedules provider shifts at the beginning of clinic day until a shift is able to follow a previously scheduled shift with no overlap or scheduled overtime. Within each of these heuristics four variations were developed based on two schedule attributes. The first attribute was the inclusion (or absence) of a *break* in the middle of the clinic day which facilitated a time for the clinic to catch up with any delays accrued during the morning potion of the clinic day. An hour-long break in the middle of the day was considered to allow time for providers to catch up and to have personal time for lunch, administrative work, etc. If the provider was scheduled during this hour, the providers shift was extended by one hour in order to keep the clinics patient capacity equal to what it would be with a continuous shift. The second schedule attribute was how the list of provider shifts to be scheduled was sorted prior to applying each heuristic. Two sorting procedures were evaluated based on the durations of the provider shifts to be scheduled and the patient arrival rate associated with each provider's clinic shift. For the former sorting procedure, we assumed that shift durations for each provider and each clinic day were predetermined.

Algorithm 1 and Algorithm 2 illustrate the steps in each of the heuristic frameworks. Algorithms 1 and 2 are implementations of each heuristic where the sorting procedure is based on provider shift duration and there is no break scheduled in the clinic day. Minor alterations to each of these heuristics were made to implement each heuristic where the provider shifts were sorted by decreasing patient arrival rates in addition to including an hour-long break in the day. Implementing the two scheduling heuristics with two sorting procedures and two alternatives for including a break resulted in eight schedules being evaluated. These schedules are enumerated in Table 1 and Figure 4 illustrates the structure of resulting provider schedules compared to an actual schedule. As seen in Figure 4, one of the actual schedules from a test case has all five providers scheduled during the same time in the middle of the day and no providers scheduled at the end. In contrast, the heuristic schedules aim to better balance the providers across the clinic day.

Algorithm 1: Heuristic 1 applied where shifts are sorted by duration and no break is scheduled.

Data: List of provider shifts to be scheduled and duration of each shift.
Result: Schedule of provider shifts for a single clinic day.

```
Initialization;
Sort list of provider shifts by shift duration with the longest first and shortest last;
while not at the end of the provider shift list do
    Schedule the shift at the top of the list to begin at the beginning of the clinic day;
    Remove scheduled shift from list;
    Schedule the shift at the top of the list such that it ends at the time of clinic closing;
    Remove scheduled shift from list;
end
```

Algorithm 2: Heuristic 2 applied where shifts are sorted by duration and no break is scheduled.

Data: List of provider shifts to be scheduled and duration of each shift.
Result: Schedule of provider shifts for a single clinic day.

```
Initialization;
Sort list of provider shifts by shift duration with the longest first and shortest last;
while not at the end of the provider shift list do
    if shift at top of list is less than or equal to the remaining time between the end of a previously
      placed shift and clinic closing then
        Schedule shift to begin at end of previously scheduled shift such that the time until closing
          is minimized;
        Remove scheduled shift from list;
    else
        Schedule shift to begin at the beginning of the clinic day;
        Remove scheduled shift from list;
    end
end
```

4 RESULTS

In this section we present numerical results comparing the performance measures obtained from simulating the provider scheduling heuristics. Seven test case days were identified and used for experiments where the actual provider schedule is compared to the schedules resulting from the heuristics using the simulation model. The test cases are representative of schedule changes that occur on a monthly or quarterly basis due to changes in clinic, research, education, and administrative responsibilities of the providers. The numerical results presented in this section are based on applying the eight provider schedule heuristics to each of the seven test case instances resulting in 63 experiment models (including the actual schedules from the seven test cases). Each schedule model was run for 100 replications. Results for average patient waiting time, average patient flow time, and average exam room utilization rate are presented for each schedule as a relative improvement from the actual schedule in the test case.

4.1 Patient Wait Time

Patient wait time was measured as the cumulative time spent waiting across activities throughout a patient's visit. Average patient wait times varied between the test cases and schedules with a range from approximately 10 minutes to nearly 40 minutes with an average half-width of 3.35 minutes. The patient wait time results

Table 1: Provider schedules evaluated with the simulation model were defined based on the heuristic applied, sorting procedure, and whether or not a break was included.

Schedule Name	Heuristic Used	Sorting Procedure	Break
1A	1	Shift Duration	No Break
1B	1	Patient Arrival Rate	No Break
1C	1	Shift Duration	Break
1D	1	Patient Arrival Rate	Break
2A	2	Shift Duration	No Break
2B	2	Patient Arrival Rate	No Break
2C	2	Shift Duration	Break
2D	2	Patient Arrival Rate	Break

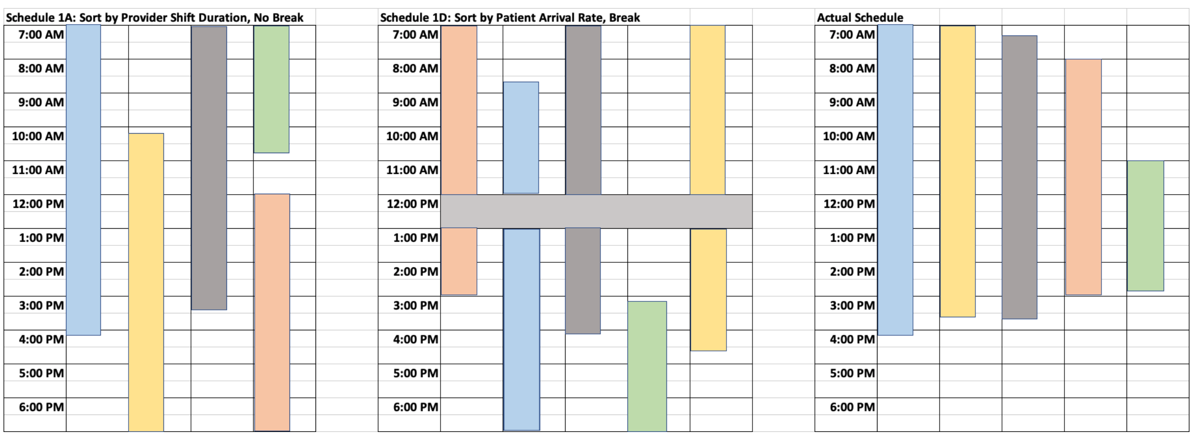

Figure 4: Schedules 1A and 1D are presented for illustration with a schedule used in practice with the same shift durations.

for the eight provider scheduling heuristics were analyzed based on relative improvements to the results of the actual schedules from each of the seven test cases. Figure 5 presents the percentage improvement in patient wait time of each of the scheduling heuristics over the actual schedule averaged across the test cases. We note that all eight of the provider scheduling heuristics resulted in lower average patient wait time with Schedule 1D resulting in a more that 30% improvement on average. All of the provider scheduling heuristics resulting in lower patient wait time is likely due to the heuristics' attempt at balancing the provider shifts across the clinic day, thereby spreading out patient arrivals and clinic congestion. Further, we note that the heuristic which resulted in the largest improvement with respect to patient wait time (Schedule 1D) is a heuristic which directly incorporates the heterogeneity of providers' patient arrival rates.

4.2 Patient Flow Time

Patient flow time was measured as the duration of time between the patient's arrival and check out at the end of the visit. Similar to patient wait time, patient flow time results for the eight provider scheduling heuristics were analyzed based on relative improvements to the results of the actual schedules from each of the seven test cases. Average patient flow times ranged between 29 and 62 minutes depending on the test case and schedule evaluated with an average half-width of 3.53 minutes. A similar trend of relative improvements can be seen in Figure 6 for patient flow time as was observed for patient wait time. This is likely explained by the reduction in flow time largely being accounted for by the reduction in patient wait time. However, the magnitude of the improvements for patient flow time were not as great as they were for patient wait time (Schedule 1D had the largest relative improvement at more that 15%). In general, we

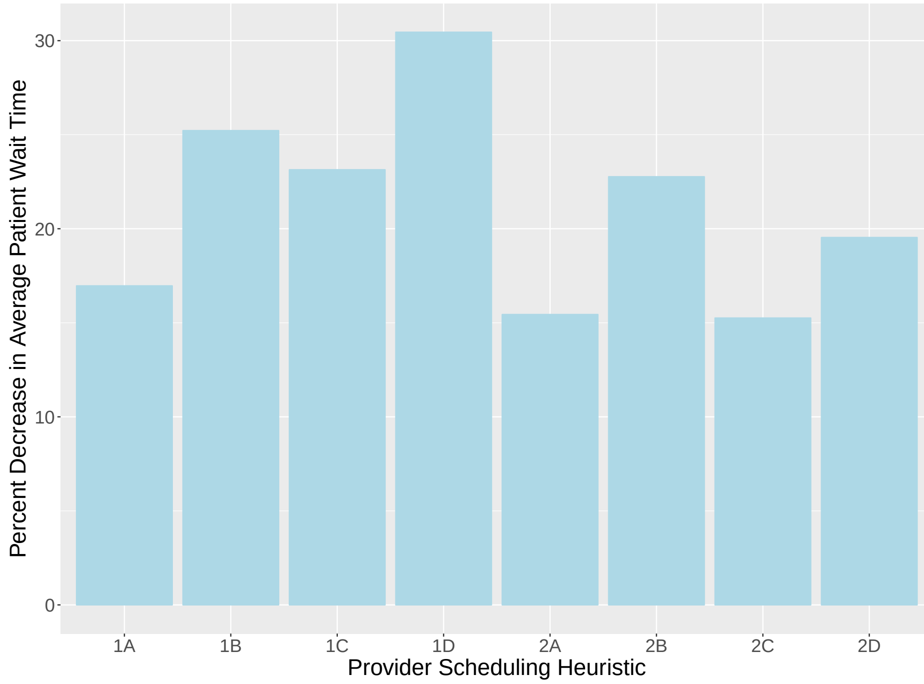

Figure 5: The average percent decrease in average patient wait time relative to the actual schedule across the seven test cases is presented for the eight provider scheduling heuristics.

observe that the provider schedule heuristics which account for the variability in providers' patient arrival rate as well as those based on applying Heuristic 1 tend to perform better with respect to both patient flow and patient wait time. Less clear is the overall benefit of including a break in the clinic day to catch up on any backlogs.

4.3 Exam Room Utilization Rate

Average exam room utilization rates were also analyzed across the provider scheduling heuristics. Exam room utilization is determined as the portion of time during the clinic day of which an exam room is occupied by a patient. We note that an exam room is considered utilized even if a patient is in the room waiting for their provider. Average exam room utilization rates for the test cases and schedules ranged between 33% and 62% with an average half-width of 2.35%. Figure 7 presents the average percent decrease in exam room utilization rates for each provider scheduling heuristics relative to the actual schedules' exam room utilization rates. The decreases in exam room utilization rates appear to be more uniform as compared to the decreases in the previous performance measures. While higher utilization rates are desirable when analyzing systems with expensive resources, we interpret the decreases in exam room utilization rates as a measure of improved efficiency and a potential opportunity to schedule more providers within the clinic day. While not presented here, we note that an increase in the range of exam room utilization rates was observed. That is, while average exam room utilization rates decreased with each of the provider scheduling heuristics analyzed, the range between the average minimum and the average maximum increased as compared to the actual schedules of the test cases. This indicates that more day-to-day utilization volatility may be experienced despite obtaining an average exam room utilization rate decrease.

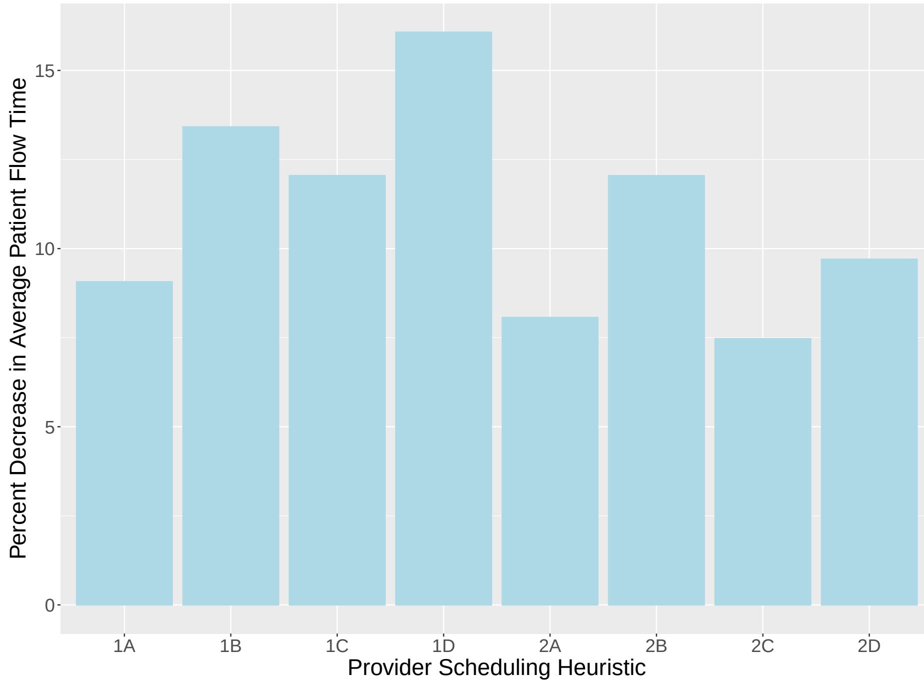

Figure 6: The average percent decrease in average patient flow time relative to the actual schedule across the seven test cases is presented for the eight provider scheduling heuristics.

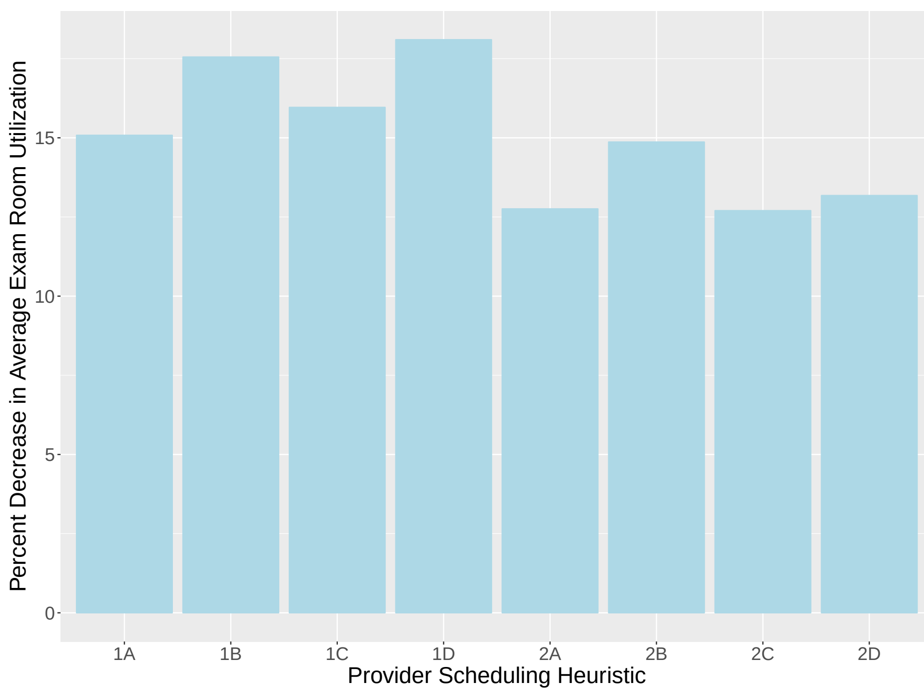

Figure 7: The average percent decrease in average exam room utilization relative to the actual schedule across the seven test cases is presented for the eight provider scheduling heuristics.

5 CONCLUSIONS

In this paper we presented a simulation model used to evaluate heuristics for scheduling provider shifts in a specialty outpatient clinic setting. The changing operational landscape of how specialty outpatient care is delivered, planned, and scheduled highlights the need for new approaches in managing clinical time. We developed eight provider scheduling heuristics which differed by the specific scheduling algorithm applied, how provider shifts were sorted, and whether or not a break was included in the clinic day. These eight heuristics were evaluated using a simulation model based on an outpatient specialty clinic at the University of Minnesota's Clinics and Surgery Center. Seven test cases were identified for validation and served as the base cases upon which improvements associated with the simulated scheduling heuristics were compared.

The results in this paper show that, in general, each of the eight provider scheduling heuristics evaluated improved the performance measures with respect to the test cases used. Trends in the results include provider scheduling heuristics which aim to spread out provider clinic shifts across the day and explicitly incorporate the heterogeneous patient arrival rates tend to perform better with respect to both patient flow and patient wait time. While each of the provider scheduling heuristics decreased the average exam room utilization (thereby increasing available capacity), specific hints toward which schedules are more successful in this regard are not as apparent.

There are multiple limitations which we would like to point out as opportunities for future research. First, the heuristics presented in this paper assume the shift durations are predetermined as inputs. This is due to various exogenous factors influencing the design of each provider's shift duration (e.g., clinical FTE, teaching schedule, hospital schedule, preference, etc.). However, expanding on the heuristics presented here within a broader scheduling scope (e.g., a week or a month) where shifts are allocated to specific days as well as times during a clinical day is a promising subsequent evaluation. Second, another assumption underlying our simulation model is that each provider's appointment template (i.e., the time each provider allocates to different patient types) is a fixed input based on how individual providers design their appointment templates. Coordinating appointment template design for providers scheduled during the same clinic day will likely impact various performance measures as each provider's stream of patient arrivals make use of multiple shared resources in the clinic. Both of these current limitations offer opportunities to expand the current analysis in broader clinic-level perspectives.

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