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USE OF SIMULATION TO EVALUATE RESOURCE ASSIGNMENT POLICIES IN A MULTIDISCIPLINARY OUTPATIENT CLINIC

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ABSTRACT

Advances in facility design and technology are leading to novel uses of healthcare delivery space including flexible and shared clinical space increasing collaboration and communication in multidisciplinary care settings. With new outpatient care delivery facilities and plans emerging, the need to evaluate how flexible and shared resources are assigned arises. We present a discrete-event simulation model based on the daily operations of an outpatient clinic where multiple specialties share resources including support staff, exam rooms, and ancillary providers. Being a new clinical space, the primary objective is to design resource assignment and staffing policies which maximize the use of the new facility. While resource utilization is the primary objective, the simulation model results and analysis incorporate other competing performance criteria including patient waiting, provider idleness, and clinic length of day. Results are presented based on a multidisciplinary clinic at the University of Minnesota.

1 INTRODUCTION

Efficient management of outpatient care delivery continues to be a priority area for improving the quality, coordination, and cost within healthcare systems (Kaplan et al. 2015; Kaplan 2015). More specifically, specialty care practices play a pivotal role in the continuum of health services in the U.S. healthcare system. Specialists provide diagnostic capabilities and advanced therapeutic care in clinical and procedural settings. Managing complex acute and chronic conditions positions specialty care practices in between the roles of providers in primary care and resource-intense inpatient care. This provides the specialty care practices a unique opportunity to provide advanced care in cost-effective outpatient settings.

Given the desirable value proposition specialty care practices provide, they are naturally inundated with competing operational objectives and are often in high demand from patient populations. Such objectives include maintaining high occupancy of their resources, meeting patients' needs and expectations for timely access, keeping patient wait times while in the clinic setting low, and coordinating multiple patient-provider interactions during a single patient's visit. While many of these factors have received previous attention in the design and evaluation of operations for single silo-functioning outpatient clinics, the growth of interdisciplinary and multidisciplinary care settings has led to new operational settings with greater flexibility and shared resources. These novel care settings require the development and evaluation of new operational polices to achieve their goals.

The aim and contribution of this paper is to address two primary concerns: 1) How should outpatient delivery systems with flexible and shared space staff providers if maximum utilization of exam rooms is sought? 2) What are the implied trade-offs with respect to other performance metrics when exam room utilization is prioritized? These questions are motivated by the operational capabilities afforded by new building designs and advances in technology, such as real time locating systems (RTLS). These recent and growing trends in outpatient infrastructure create the opportunity for new shared and completely flexible spaces, such as exam rooms. To evaluate the design and impact of staffing and shared resource policies in such novel outpatient delivery systems, we developed a discrete-event simulation model using data from a shared clinical space at the University of Minnesota's Clinics and Surgery Center (CSC). The simulation model allows for accurate representation of clinic activities in order to identify a staffing and resource configuration which maximizes exam room utilization subject to providers experiencing minimal blockage, which is a greater risk in a shared space. Further, we quantify the trade-offs in competing performance measures necessary to achieve this operational requirement.

The remainder of this paper is organized as follows. In Section 2, we briefly review previous work related to flexibility of resources in outpatient delivery systems. We describe the clinical design and patient flow processes in Section 3, and the associated discrete-event simulation model in Section 4. Numerical experiment and results are presented in Section 5 and we make concluding remarks in Section 6.

2 RELATED LITERATURE

Outpatient delivery systems, and in particular specialty clinics, have a multitude of operational goals and objectives, some of which are often competing (Gupta and Denton 2008). Depending on the clinical context, operational goals for outpatient systems may differ. Common performance measures include patient waiting time (both direct and indirect), length of stay or flow time, patient volumes, usage of overtime, resource utilization, and provider utilization or idleness. With respect to outpatient systems delivering specialty care, ensuring high utilization of both resources such as exam rooms and specialists are common priorities as opposed to minimizing patient wait time in settings with higher volumes of patients with lower acuity (Froehle and Magazine 2013).

Regarding exam room utilization and provider utilization, identifying appropriate ratios (Exam Rooms : Providers) has been examined in a number of outpatient contexts. This question is commonly examined within two different operational schemes. One is the historically traditional approach of assigning specific exam rooms to providers (Cote 1999) or outpatient procedure rooms to surgeons (Berg et al. 2010). While higher ratios of rooms to providers improves performance measures such as patients waiting to be roomed and reduces provider idleness, it also comes at a significant cost of lower room utilization rates and perhaps lower patient volumes, depending on the number of providers allocated exam rooms. Alternatively, the use of shared exam rooms has also been evaluated where multiple providers utilize exam rooms within the outpatient facility (Santibáñez et al. 2009; Norouzzadeh et al. 2015; Rohleder et al. 2007). The aim of many of these studies is often patient focused in reducing waiting and length of stay (LOS) times while simultaneously improving exam room utilization.

However, as described in Norouzzadeh et al. (2015), implementing such shared exam room schemes is challenging in larger outpatient settings as inefficiencies resulting from providers finding and traveling to their patients reduce the intended benefits. To this end, Vahdat et al. (2017) focus on the benefits coming from using hybrid allocation schemes where exam rooms are assigned to a subset of providers. This frame work is also extended to the allocation policies of medical assistants to exam rooms in the cardiovascular clinic setting studied. A novel operational recommendation is made in the exam room allocation scheme being dynamic and becoming more flexible, depending on the state of the clinic. The authors report that a vast majority of the operational benefits can be realized by implementing a hybrid approach, which is particularly important for clinic settings where it is operationally difficult to implement full flexibility of exam rooms, or a pooled allocation scheme.

3 CLINICAL SETTING

The clinic space studied resides in the University of Minnesota's Clinic and Surgery Center (CSC). The clinic is comprised of three hallways containing 21 exam rooms. The clinic houses three primary specialties: cardiology, pulmonary, and multiple sclerosis. During the check-in process, the patient receives an RTLS tracking device which will accompany the patient throughout their appointment. The RTLS tracking device accurately monitors the patients location, space utilization, and time spent in various locations throughout the office space and building. The locating system also makes possible the implementation of a flexible exam room policy. As discussed by previous literature, operating a flexible policy with a larger number of rooms becomes prohibitive due to the logistics of providers finding their patients. However, the use of RTLS allows for such flexible policies in that providers return to central office spaces between patients and are able to quickly identify their subsequent patient and exam room via a large monitor with RTLS information overlaid on a clinic map. Use of this technology underpins the need for assessing exam room policies in this flexible environment.

Upon arrival to the CSC, the patient checks in with a receptionist using a tablet. Once the patient enters the designated waiting area near the clinic space, a certified medical assistant (CMA) receives an update on their computer that notifies the CMA that the patient is ready to begin the intake process. The CMA 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 CMA escorts the patient to the next available exam room, where the patient will remain for the entire clinic appointment.

While in the exam room, the CMA performs a standard CMA visit with the patient and records the patients health history. If the patient is scheduled for a nurse visit, a nurse will enter the exam room and conduct a standard nurse visit. If the patient is scheduled for a monitor visit, the CMA will remain in the exam room and perform a standard monitor visit. If the patient is not scheduled for a monitor or nurse visit, then the provider enters the exam room and conducts a provider visit. The provider visit duration is contingent on the patients appointment type.

Upon completion of the provider visit, the patient remains in the exam room and an ancillary provider enters the exam room to perform the ancillary visit. If the patient is scheduled for two ancillary visits, then the patient will remain in the exam room until the next ancillary provider enters the exam room and performs the second ancillary visit. After the scheduled ancillary appointment or appointments, the CMA escorts the patient to the checkout desk where a receptionist will schedule additional follow-up appointments if needed. After the patient completes the checkout process, then the patient returns the RTLS badge and departs the CSC. An overview of the clinic layout and patient flow are depicted in Figure 1.

4 SIMULATION

The simulation model of the multidisciplinary clinic was developed using Arena (Kelton et al. 2007). Patients arrive to the system based on a stationary random rate with each provider having their own stream of assigned patients. Though patients are scheduled in advance, the combination of early arrivals, tardiness, and variability in provider appointment templates creates an arrival process which can be modeled as a random rate. Arrivals occur between 7AM and 4PM with the planned clinic closing time at 5PM. No-shows are accounted for at the beginning of the model based on the clinic's historical no-show rate. Upon arrival, patients check in with one of three receptionists. When an exam room becomes available, a CMA does intake and rooms the patient. Depending on the type of visit, the patient spends time with a nurse for a nurse visit or monitoring visit, or proceeds to the CMA visit. If the patient has an appointment with their provider, this follows the CMA visit. Following the provider's exam, multiple ancillary visits may occur. Finally, the CMA takes the patient to the check out desk where one of the same three receptionists at check in proceeds to check the patient out. We note that while the patient may see multiple staff in addition to their provider, each of these visits occurs in a single room. That is, the patient stays in the room while the

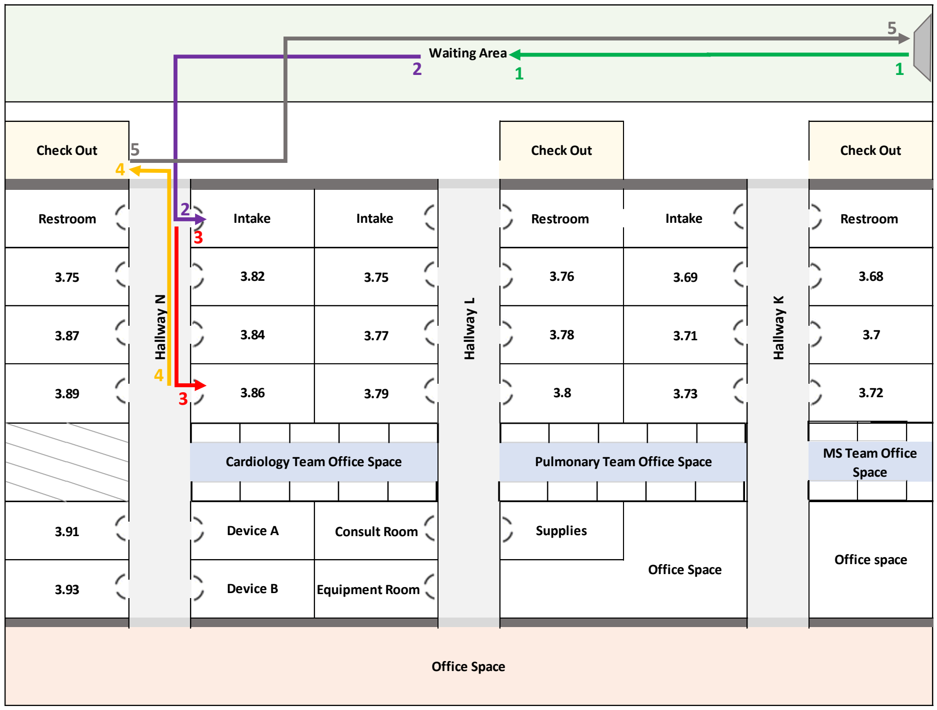

Figure 1: Overview of patient flow in clinical setting.

provider and staff come to them. The simulation model's logic is presented in Figure 2 where historical data refers to data collected from systems within the clinic.

Input parameters and distributions were collected based on historical data as well as expert opinion. Patient volumes and arrival rate were calculated based on the historical daily patients per provider average where the random arrival rate during the 7AM to 4PM arrival period allowed for variability in both interarrival times and daily patient volumes. Check in, intake, nurse visit, monitor visit, CMA visit, ancillary visit, and check out times were each modeled as having triangular distributions where clinic staff provided estimates for the respective minimum, maximum, and most likely durations. Provider visit durations were modeled as a discrete distribution as different providers allocate different appointment durations for both new and returning patients. New patient visits had durations of 40, 60, or 80 minutes while returning patient visits had durations of 20, 30, or 40 minutes. Unless noted otherwise, the simulation model includes five CMAs and four ancillary staff. Model parameters are described in detail in Table 1.

While the simulation model was developed to closely mimic the clinic's operations, modeling assumptions were also made for abstraction and generalizability. For example, the simulation model presented here assumes that each ancillary visit and ancillary provider provides the same service. In reality, there are multiple types of ancillary providers such as dietitians, nutritionists, social workers, and more each providing unique services. However, since these providers are often shared across multiple clinics and we do not have ancillary-specific data available, we assumed a single ancillary provider type. While this is reasonable as there is rarely a wait for ancillary services, we do explore the effect of such limited resources in our experiments. Further, we also assume that providers are in clinic all day. In reality, the clinic day is divided into two shifts: AM and PM. While there is likely a small disruption as the AM shift ends and the PM shift begins, this was not explicitly modeled in our simulation.

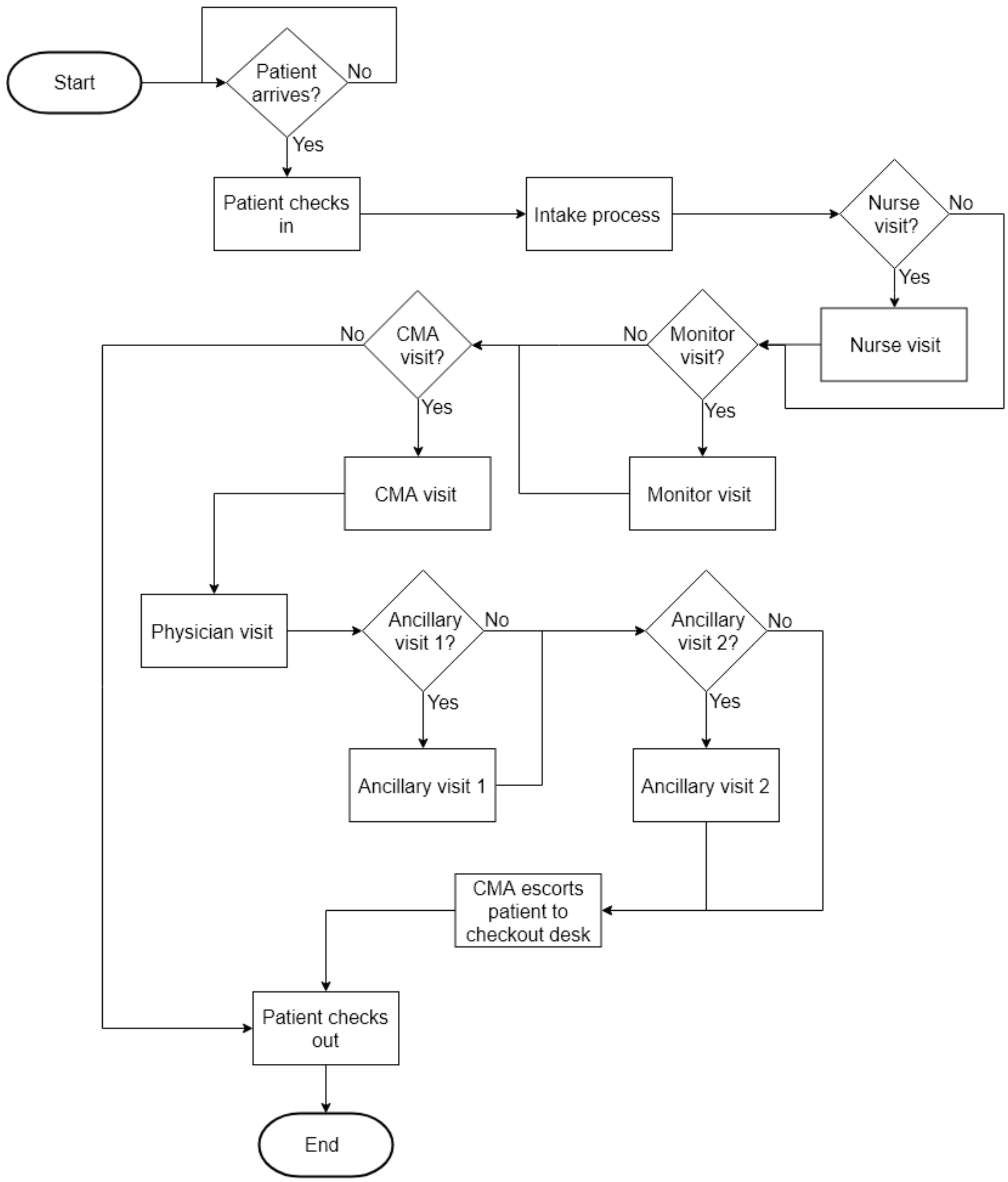

Figure 2: An overview of the simulation model of the multidisciplinary clinic demonstrates the patients' flow through the system.

Table 1: Model parameters were estimated based on historical data and expert opinion.

Parameter	**Value or Distribution**	**Source**
Arrival Rate	Poisson (1.22/hour/provider)	Historical Data
Check In	Triangular (0, 0.5, 1) minutes	Clinic Staff
CMA Visit	Triangular (2, 5, 10) minutes	Clinic Staff
Nurse Visit	Triangular (10, 35, 60) minutes	Clinic Staff
Monitor Visit	Triangular (10, 20, 30) minutes	Clinic Staff
Provider Visit	Discrete (20, 30, 40, 60, 80) minutes	Historical Data
Ancillary Visit	Triangular (5, 15, 20) minutes	Clinic Staff
Check Out	Triangular (1, 5, 7) minutes	Clinic Staff
Room Turn Over	Triangular (3, 4, 5) minutes	Clinic Staff
No-show Rate	6.5%	Historical Data
Patient Mix	25% New Patients	Historical Data
Ancillary Visits	80% have 1, 20% have 2	Clinic Staff
Nurse Visits	9.5% of patient visits	Historical Data
Monitor Visits	4.3% of patient visits	Historical Data

5 RESULTS

In this section we present the results of experiments based on the simulation model. We begin with the performance measures under the policy where specific exam rooms are assigned to providers. This represents the status quo for many practices and serves as a reference of expectations for providers and staff when transitions to new exam room policies are made. Next we present performance measures for a flexible exam room policy which is made possible through the use of RTLS data within the CSC. Performance measures are compared over a range of providers utilizing a shared set of exam rooms. Finally, to further evaluate the impact of other important operational decisions, the effects of the number of available ancillary staff is analyzed as well as the impact of using standardized appointment templates. All performance measure results in this section are presented as averages based on 100 replications using the simulation.

5.1 Assigned Exam Rooms

Two scenarios were examined where providers were assigned specific exam rooms. In the first scenario 10 providers are assigned two exam rooms each and in the second scenario seven providers were assigned three exam rooms each. While the two scenarios differ in the total number of exam rooms assigned (20 and 21), they represent realistic assigned exam room policies based on the number of exam rooms in the clinic space. Performance measures analyzed include provider utilization, exam room utilization, percent of patients completing their visit by 5PM, patient total visit time, and patient waiting time. The results for the assigned exam room policy are presented in Table 2.

Table 2: Performance measures for the assigned exam room policy.

Performance Measure	**2 Rooms per Provider (10 Providers)**	**3 Rooms per Provider (7 Providers)**
Provider Utilization	55.4%	58.6%
Exam Room Utilization	62.7%	49.9%
Completion % by 5PM	86.0%	90.7%
Patient Total Visit Time (minutes)	88.6	84.6
Patient Waiting Time (minutes)	27.3	22.8

As shown in Table 2, provider utilization for the assigned room policies ranges between 55.4% and 58.6%. In moving to a more flexible exam room policy, one important question is at what number of providers staffed in a flexible exam room scheme results in similar provider utilization rates. Further, what are the impacts on the other performance measures when similar provider utilization is obtained under a flexible exam room policy? Maintaining similar provider utilization while improving the utilization of the available exam rooms is an underlying objective for practices transitioning to more flexible facilities and is examined in the next subsection.

5.2 Flexible Exam Rooms

Next we present results for a flexible exam room policy where all providers can use all of the 21 exam rooms available in the clinic space. The same performance measures are examined as for the assigned exam room policy. The number of providers ranged from 4 to 18. The results are presented in Table 3. We note that while half widths are not included, they were approximately 1% for the utilization measures and completion percent and approximately 2 minutes for the total visit time and waiting time measures.

Table 3: Performance measures for the flexible exam room policy.

Number of Providers	**Provider Utilization**	**Exam Room Utilization**	**Completion % by 5PM**	**Patient Total Visit Time (minutes)**	**Patient Waiting Time (minutes)**
4	58.6%	27.9%	92.8%	84.0	22.0
5	58.1%	35.0%	91.3%	83.3	21.0
6	57.4%	40.2%	92.3%	82.1	20.1
7	58.5%	49.7%	92.4%	83.7	21.7
8	59.1%	57.6%	91.9%	85.3	23.6
9	58.4%	61.6%	91.9%	84.4	22.5
10	57.4%	67.5%	91.2%	84.6	22.9
11	57.9%	75.1%	89.9%	87.3	25.2
12	57.4%	80.1%	89.7%	89.4	27.4
13	56.3%	82.6%	88.6%	92.1	30.3
14	55.0%	86.5%	86.7%	94.9	33.2
15	53.7%	89.2%	83.0%	100.8	39.5
16	52.4%	91.2%	80.9%	107.2	46.2
17	50.4%	92.3%	78.6%	110.6	49.3
18	48.8%	93.4%	76.2%	118.4	57.3

In comparing the results of the flexible exam room policy in Table 3 with those of the assigned exam room policy in Table 2, it can be seen that provider utilization for the flexible policy remains above the lower provider utilization from the assigned room policy of 55.4% (2 rooms per provider) up until there are 14 providers using the 21 flexible exam rooms. That is, in order to maintain similar provider utilization in a flexible exam room policy, as many as 14 providers could be staffed in the clinic space. However, this provider staffing level also affects the other performance measures. Specifically, by maintaining a similar provider utilization rate of 55-58% as in the assigned exam room policy, the flexible exam room policy with 9-14 providers results in substantially increased exam room utilization rates of 61.6-86.5% as compared to 49.9-62.7%. While the percent of patients completing their visit by 5PM is approximately the same for the assigned exam room policies and the flexible exam room policies with 9-14 providers, both patient total visit time and patient waiting times increase as a trade-off for higher exam room utilization rates. For example, patient waiting time ranges between 22.5-33.2 minutes for flexible exam room policies with similar provider utilization rates, while the assigned exam room polices resulted in patient wait times of 22.8 and 27.3 minutes.

5.3 Impact of Ancillary Staffing and Standardized Appointments

While the number of providers is one of the most influential variables affecting provider utilization and exam room utilization, we also present results on the impact of other operational factors which may influence these measures. First, we present results where the number of ancillary staff ranges between 1-7. Second, we provide a comparison of performance measures under the hypothetical scenario where appointment durations are standardized to 30 minutes for returning patients and 60 minutes for new patients. This is currently a discretionary decision made by providers. For both of these analyses, we present results based on 11 providers being staffed within the 21 exam rooms with a flexible exam room policy. The results for the ancillary staff levels are included in Table 4 and the results where standardized appointment durations are used are presented in Table 5.

Table 4: Performance measures for the flexible exam room policy where ancillary staffing levels are varied.

Number of Ancillary Staff	Provider Utilization	Exam Room Utilization	Completion % by 5PM	Patient Total Visit Time (minutes)	Patient Waiting Time (minutes)
1	35.2%	88.8%	44.9%	166.8	111.2
2	53.2%	84.4%	75.1%	119.2	58.6
3	57.4%	75.8%	89.1%	91.6	29.4
4	57.9%	75.1%	89.9%	87.3	25.2
5	58.2%	74.7%	89.8%	87.4	25.2
6	58.3%	75.0%	90.1%	87.7	25.5
7	58.0%	74.7%	90.0%	87.3	25.0

Table 5: Performance measures for standardized appointment duration templates where 30 minutes are allocated to returning patients and 60 minutes are allocated to new patients.

Provider Utilization	Exam Room Utilization	Completion % by 5PM	Patient Total Visit Time (minutes)	Patient Waiting Time (minutes)
57.4%	72.4%	91.0%	84.8	23.0

The results in Table 4 show that for three or more ancillary staff, performance measures are unaffected. However, at levels of one or two ancillary staff, the shortage leads to a bottle neck in the system causing low completion by 5PM rates, high patient total and wait times, and low provider utilization. While exam room utilization rates are higher for lower ancillary staffing levels, this is a result of patients spending substantial time in the exam room waiting for an ancillary staff member to become available.

In Table 5, it can be seen that reducing the variability of appointment durations by standardizing appointment templates, provider utilization remains approximately the same while exam room utilization declines, the percent of patients completing their visit by 5PM remains the same, and patient visit and waiting times both decline. While these changes appear to be marginal at most, this is likely a result of assuming the patient arrival process would remain the same. However, it is conceivable that standardized appointment duration templates would lead to different patient arrival patterns which we are unable to model at present.

6 CONCLUSIONS

In this paper we presented a simulation model to evaluate the effects of using a flexible exam room policy in a multidisciplinary outpatient clinic setting. Underlying the capability of the flexible exam room policy was a real time locating system (RTLS) infrastructure which allowed providers and supporting staff to locate patients in an open and flexible clinic design. The results of the simulation analyses demonstrate the benefits and economies of scale in implementing a flexible exam room policy with a larger number of exam rooms resulting from sharing resources across disciplines. Specifically, the results show that more providers, and thereby more patients, can make use of the space while maintaining similar provider utilization rates as those associated with an assigned exam room policy. In fact, as a result of increased provider staffing levels, the utilization rate of exam rooms increases with marginal trade-offs in terms of patient visit and waiting times. In addition, the results include an analysis of the effects of ancillary staffing levels on clinic performance measures, as ancillary staff spend a significant amount of time with patients and have the potential to impact clinic performance. Finally, we presented results demonstrating the expected performance of transitioning to a standardized appointment duration template.

Future work associated with this analysis of the multidisciplinary clinic includes evaluating RTLS data to directly support operational decision making for staffing and clinic flow design. Further, while this simulation model and resulting analysis captures the complexity of a multidisciplinary clinic, this multidisciplinary practice is still intrinsically tied to the operational design of the rest of the CSC. Expanding the simulation model and analysis to incorporate a broader scope of operations in the CSC leads to future work in designing operational recommendations in novel outpatient healthcare delivery settings.

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