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IMPLEMENTING DISCRETE EVENT SIMULATION TO IMPROVE OPTOMETRY CLINIC OPERATIONS

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ABSTRACT

As the tempo of military operations slows, Army Medical Facilities are faced with a need to improve the efficiency of their clinics to provide timely service to the growing population of Soldiers who are spending more time at home station. Discrete event simulation was used to examine six scheduling and staffing policies for the Womack Army Medical Center's Optometry Clinic with a goal of increasing the daily patient throughput of the clinic with consideration to patient waiting times. The best policy increased clinic throughput by eight patients a day, generating an additional $314,000 in Relative Value Units (RVUs) annually, while only increasing patient wait times by 26%. As a minimum, increasing the walk-in provider's scheduled patient load by two enables the provider to optimally treat both scheduled and walk-in patients, with a $94,000 annual RVU increase. Implementation of these results will improve clinic performance, revenue, and increase Soldiers' access to care.

1 INTRODUCTION

Fort Bragg, located in Fayetteville, North Carolina, was established as an artillery training camp in 1918 and has grown to be one of the largest installations in the United States (US) Army, serving as the home of the Army's Airborne and Special Operations Forces. Fort Bragg's Womack Army Medical Center (WAMC) is the largest medical center in the Army, residing in a one million square foot facility. The four thousand member staff provides quality, cost-effective inpatient and outpatient care to over 225 thousand beneficiaries in the area including 57 thousand active duty personnel (US Army 2013). Medical beneficiaries include active duty, reserve, and national guard Soldiers and Airmen, family members of active duty Soldiers, and military retirees and their family members. On an average day Womack has 3,350 clinic encounters, 190 emergency room visits, nine babies are born, 23 surgeries are performed, and 6,580 prescriptions are filled (Womack 2011). In addition to the hospital complex, WAMC has seven unit level primary care facilities under its command.

The Womack Optometry Department is comprised of five clinics located throughout the installation. Four of the clinics are collocated at unit level primary care facilities and one is located in the main hospital to maximize accessibility of their services to beneficiaries. As a result of the large patient population, improvements in policies at an optometry clinic can enhance the patient care and the patient satisfaction for the Fort Bragg community. As several Army training schools, to include the US Army Ranger School, require soldiers receive eye screenings as a prerequisite to advanced training, the intrinsic motivation for implementing better policies to serve this important patient base is obvious.

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This research tests six provider scheduling policies to increase patient throughput and therefore clinic revenue. The results of this research show that an increase of eight scheduled patients per day will yield a 17% increase in revenue ($314,000 increase per year) for the clinic with less than a 20-minute increase to the total time a patient stays in the clinic. Additionally, the research identified an increase of two scheduled patients per day for the walk-in provider yields a $94,000 annual increase in clinic revenue with no impact to patient time in the system.

2 LITERATURE REVIEW

As healthcare facilities strive to provide timely patient care, they turn to the scheduling and optimization techniques employed by Industrial and Systems engineers and Operations Research professionals. When faced with large and complex healthcare systems, engineers will enlist the aid of simulation to conduct analysis and test proposed changes. A discrete event simulation is a representative model that incorporates variability and uncertainty into the system processes. The simulation views the facility as a dynamic system where discrete events such as patient arrival, treatment time, and laboratory processing times are measurable, finite, and occur in a prescribed sequence, (Villamizar 1997). This flow is similar to jobs moving through a manufacturing facility where a job routed to a process station cannot be worked on until the preceding job has completed the process at the station.

A discrete event simulation uses defined probability distributions such as exponential or beta to account for the variation in the processing time a patient experiences at each station in the clinic, (Villamizar et al. 1997). The probability distributions are determined through a combination of direct observation of patient flow, clinic records, and staff input on averages processing times. The distributions are evaluated in the simulation and results are compared to actual clinic performance in order to validate the overall model.

A discrete event simulation can be formulated to model a diverse array of entity types, who use a range of different services, and then provide analysis as entities move through a complex network of processes. This technique of modeling different entity types can be easily applied to patients who arrive to a clinic which provides a diverse range of services; which is the case in larger healthcare facilities. In a study of a mammography clinic, (Coelli et al. 2007) utilized this method in a simulation model which tracked the travel times of both patients and their radiological films throughout the clinic system. The patients and films only shared a couple of common processes before traveling in different directions through the system. The simulation was ultimately able to identify optimal resource-provider ratios to minimize patient wait times.

Healthcare facilities also have well-defined locations for reception, patient waiting, screening, and treatment to occur which is directly adaptable to the model construction. In study of a physiotherapy clinic, the stochastic and non-linear construct of the discrete event model enabled (Villamizar et al. 1997) to identify a decrease in clinic efficiency despite an increase in the total number of providers due to competition over limited resources.

The dynamic environment of an emergency department (ED), and requirement to rapidly provide for lifesaving care showcases the advantages of utilizing discrete event simulation to test system processes and performance against various scenarios, including mass casualty events such as multi-car accidents. While most healthcare simulations focus on patient wait time and length of stay in the facility, the study by (Abo-Hamad and Arisha 2013) of an ED in North Dublin included analysis of additional key performance indicators such as provider utilization and productivity. (Lal, Roh, and Huschka 2015) used simulation to test provider scheduling policies minimize the impact of patient wait time. The addition of these performance indicators highlights impacts on the clinical staff and administration; expanding the simulation formulation from a purely patient focused approach.

Simulations are similarly employed to assess the potential impact of costly facility upgrades to the efficiency of the system before they are implemented. In the study of an ED by (Ahmed and Alkamis 2009), a discrete event simulation determined the optimal staffing ratios (doctors, nurses, lab technicians) which maximized patient throughput while reducing wait times. The new policy achieved a 28% increase in throughput and 40% reduction in wait times while working with existing resources. (Margareidge 2015) applied simulation results to recommend policy changes regarding military healthcare facility design, development, and management. Results and analysis from discrete event simulations provide clinic leadership with vital insight useful in their decision analysis process.

Healthcare systems modeled with discrete event simulations focus on either walk-in patients, modeled exponentially as in (Ahmed and Alkamis 2009) and (Robinson and Chen 2003), or in the case of (Coelli et al. 2007) patients with scheduled appointments. (Walker et al. 2015) explored a multispecialty clinic with multiple providers by developing a patient appointment scheduling integer program to handle both scheduled and walk-in patients. The paper focused on minimizing system congestion at the front desk while assessing the comparative impact of new and existing patients.

In this research, the discrete event simulation of the optometry clinic will implement a mixture of entity types which arrive to the clinic based on determined probability distributions or specific schedules. A unique aspect of this study is the simulation of both scheduled and stochastic patient arrivals seeking appointments with the walk-in optometrist resource. This clinic presents similar patient-provider scheduling complexities as the healthcare systems discussed by (Gupta and Denton 2008). The clinic leadership is faced with the challenge of ensuring they have an optometrist available to treat acute care walk-in patients while maximizing the effectiveness of the provider. The simulation allows the decision makers to identify the risks and rewards for different patient appointment schedules and determine an optimal course of action.

3 PROBLEM DESCRIPTION

3.1 Description of Clinic Processes

In a recent change, the Army Medical Department now considers optometry services as primary care. Patients schedule routine eye exams on their own without the need for a primary care provider (Family Practice Doctor, Pediatrician, Physician's Assistant) to submit a referral. This opened and streamlined access of the clinic's services to the population of beneficiaries. Although a web-based appointment system exists, accessibility limitations result in patients scheduling optometry appointments up to three weeks out by contacting the hospital appointment call center.

The clinic has three full-time staff optometrists and an optometry resident focusing on fitting specialty hard contact lenses and treating acute care "walk-in" patients. The clinic is also staffed with four optometry technicians (one military, three civilian) and a Medical Support Assistant (MSA). One of the civilian technicians is assigned to fitting and processing eye glass orders but will occasionally see patients. The clinic MSA operates the clinic reception desk and manages the clinic appointment schedule.

The providers typically follow a constant schedule unless they will be unavailable due to planned leave or training commitments. Optometrists are directed to schedule twelve 30-minute eye wellness exams and two 15-minute follow-up appointments each day. The optometry technicians do not have scheduled appointments and are not assigned to support specific providers. They screen patients as they arrive and internally manage the division of labor.

The optometry clinic opens at 0730 during week days and scheduled appointments start at 0745. The clinic closes for lunch from 1130 to 1230. The MSA and the technicians take their lunch breaks during that time window. The optometrists have a delayed lunch break, from 1200 to 1300, so they are available to treat patients who entered the clinic prior to 1130. If a patient is in the interior waiting area, the staff will finish treating them before taking a shortened lunch break. The reception desk stops receiving patients at 1530 and the clinic closes at 1600, or until the last patient departs. The figure below depicts the layout of the WAMC optometry clinic which contains eight exam rooms, three screening rooms, an eyeglass ordering lab, and two rooms with specialty imaging equipment.

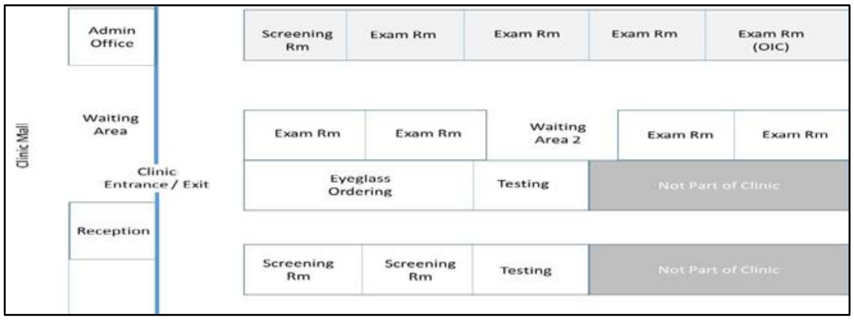

Figure 1: Diagram of Womack Army Medical Center optometry clinic.

Patients arrive to the clinic and check in with the MSA at the reception counter, where their current medications are screened and staff is notified of the arrival. The clinic receives scheduled patients for routine eye wellness exams and for appointment follow-ups. They also treat patients with acute care issues on a walk-in basis. In the mornings, the clinic technicians provide medical readiness screenings for Soldiers to fulfill a requirement of their annual physical exam which is tracked through the Medical Protection System (MEDPROS). The MEDPROS system provides unit leaders with the medical readiness and deployability status of the Soldiers under their command. Eye screening are also conducted in the afternoon for Soldiers applying to attend physically demanding training or technical programs such as Ranger school, flight school, or Special Forces assessment and selection. Additionally, the reception station receives a variety of visitors whose inquiries vary from requesting copies of eye glass prescriptions and scheduling appointments to seeking directions to other clinics in the hospital. These visitors typically depart the clinic after speaking with the receptionist but their presence impacts the wait time of the scheduled and walk-in patients waiting to receive clinical services.

Following check in, patients sit in the entrance waiting area until an optometry technician escorts them to a screening room. Scheduled patients with wellness exam appointments are asked about their medical history and receive a standard battery of testing which includes the eye pressure (air puff) test. They are then directed to the interior waiting area until the doctor is ready to see them. Patients with follow-up exams will have their health history verified and then directed to the waiting area. If the follow-up is for an eye dilation exam, the optometry tech will apply the dilation drops and the patient will sit in the waiting area for the drops to take effect prior to seeing the provider. Figure 2 provides a flowchart of patient movement through the clinic.

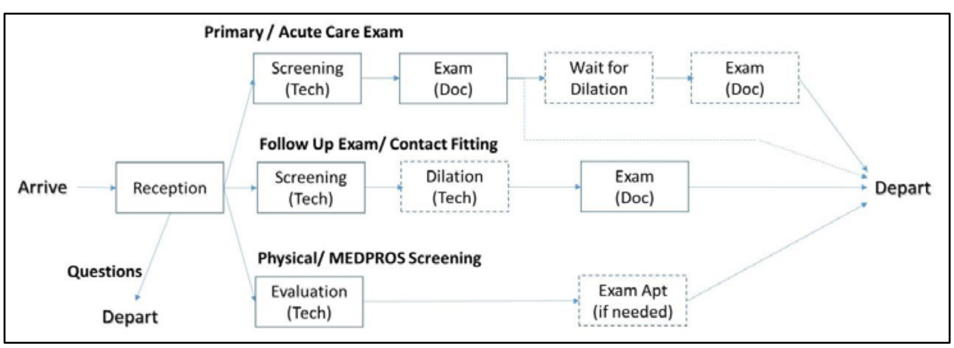

Figure 2: Patient movement through clinic.

The MEDPROS and Physical exam screenings are conducted by the optometry technician. Uncorrected and corrected vision is recorded, eye pressure tested, and some physical exams require tests for color blindness. If the technician identifies issues with the patients' vision, they are directed to schedule an appointment for an exam with a provider, otherwise, they depart the clinic. The physical exam and MEDPROS results are updated by the technician in the patient's digital medical record.

3.2 Relative Value Units

The Military Health System (MHS) utilizes a system of Relative Value Units (RVU) to quantifiably assess provider performance. Each patient encounter, defined as a face-to-face interaction, is assessed a value based on the specific type of procedure or testing conducted. Follow-up appointments do not count as another encounter, but any new procedures conducted would be added to the total RVU of the encounter. If a patient has an eye wellness exam and returns to have their eyes dilated during a follow-up appointment, the follow-up is part of the same patient encounter but the encounter RVUs increase to account for the "cost" of the dilation procedure.

A per RVU value is applied to the total RVU for each encounter to generate a "billable" value of the services that were provided. Members of the armed services receive health care insurance through the MHS so the "billable" value is a comparative estimate of the cost a civilian provider would charge for the same service. MHS uses these values in budget planning and assessing the utility of the hospitals under its charge. Additionally, within a hospital, clinics and individual providers' RVUs are totaled and converted to equivalent values to assess productivity.

Under the standard operating guidelines for the Womack Optometry Department, each staff optometrist is directed to support a daily schedule of twelve wellness examinations and two follow-up examinations. The average RVU for all patient encounters in the Womack Optometry clinic was 4.74 from June 2013 to May 2014. During this time period, the providers averaged 162 encounters per month. The generic RVU rate of $34.02 per RVU is applied to clinical services yielding an average equivalent value of $26,100 per provider per month.

An improvement of one additional eye wellness exam each day to the scheduling process of the Optometry Clinic would increase the number of monthly encounters by 20. Expanding this value by 4.74 RVU per encounter and $34.02 per RVU yields a monthly equivalent value increase of $3,225 per provider. The addition of one appointment to the schedule has the potential for an eight percent increase in the provider's assessed productivity. A feasible scheduling policy which increases the number of patients served also needs to minimally impact the wait times experienced by patients in the clinic. This analysis will use increases to patient wait times as a metric to compare and assess the policies.

4 MODEL CONSTRUCTION AND EXPERIMENTAL DESIGN

4.1 Clinic Arrivals

The model of the Womack Optometry clinic was built using Rockwell Automation Technologies' Arena Simulation software, version 14.7. A logical, source code, model was built to generate key performance parameters to support statistical analysis of the system. The Arena simulation model uses six entity types to represent the flow of various patient types who enter into the clinic. Entities for patients who have a scheduled appointment (wellness exam or follow-up exam) are generated based on the planned appointment slots for their specific provider. The entities are then assigned a provider specific attribute to ensure each patient receives care from their scheduled optometrist.

Walk-in patients arrive to the clinic based on an exponentially distributed arrival rate with an average inter-arrival time between patients of 95.5 minutes. The simulation does not generate arrivals during the staff lunch hour between 1130 and 1230 since they would not be able to enter the clinic. Walk-in patients with non-emergent ailments will return to the clinic following the lunch time closure to see the on call provider.

The Optometry clinic conducts screening exams for military school physicals in the mornings and annual health assessments during the afternoons with average patient inter-arrival times of 89.6 minutes and 95.4 minutes, respectively. Both of these entities are serviced by available optometry technicians and depart the clinic. People with questions for the receptionist arrive to the clinic on average every 16 minutes which follows an exponential distribution. These patients are serviced by the receptionist and then leave.

The model focuses on the performance of the clinic system and therefore assumes every scheduled appointment is filled by the patient. Allowing for patient cancellations will only reduce the load on the system and will not aid in our analysis. In addition, Fort Bragg leadership place a tremendous level of emphasis and have highly detailed oversight on appointment no-show rates; this stymies patient no-shows and motivates our patient arrival assumption. Patients are instructed by the hospital to arrive at least ten minutes prior to their scheduled appointment time. A patient who arrives to the reception queue significantly after their appointment time will be considered a missed appointment and rescheduled for a later date. Allowing for variance in arrivals, it is assumed patients will arrive no earlier than 18 minutes prior to their appointment and no later than five minutes after their scheduled appointment time.

4.2 Clinic Staff

The Optometry clinic employs three types of staff members who are simulated as resources in the model. The MSA serves as the clinic's receptionist, charting when scheduled patients arrive, answering phone calls, and notifying the staff when walk-in patients arrive. The MSA also builds the weekly schedule of available appointments four weeks in the future based on projected provider availability. This task does not involve patient interaction and is prioritized lower than servicing patients and will therefore not be studied in this model. However, this task should be considered when analyzing resource utilization for the receptionist.

Optometry technicians assist optometrists by screening patients prior to exams and conducting routine tests such as eye pressure measurements. Technicians also conduct routine vision assessments for physical exams, administer dilation drops, and conduct instruction on the use and care of contact lenses. The clinic employs three technicians who, when idle, are able to service any patient after they have been checked in by the receptionist, giving priority to those with scheduled appointments.

The number of optometrists working in the Womack Optometry clinic varies based on residents, optometry student interns, and providers in administrative positions who will log limited clinical hours. This simulation model assumes the clinic has four full-time staff optometrists, one of whom serves as the on-call acute care (walk-in patient) provider. The clinic rotates the acute care duty so each provider serves this capacity one day a week and one provider (typically the resident) for two days. Regardless of the amount of available providers, there is always one optometrist on call when the clinic is open. The simulation lists each of the four doctors as a single resource. Patients with a scheduled appointment will call upon their assigned doctor for wellness exams, follow-up visits, and dilation exams. If a doctor administers dilation drops to a patient, while the drops take effect, he will see the next patient if they have arrived. The provider will prioritize evaluating a patient who is ready for a dilation exam over one who just arrived.

4.3 Model Development

Model input values for patient arrivals and processes throughout the clinic were primarily based on data collected through direct observation of patient movement through the Optometry clinic. Service times for the clinical processes were recorded as patients departed the station. Patient wait times were also recorded at each of the queue locations for use in validating the simulation model. Inspection of digital medical records provided insight into the number of acute care (walk-in) patients, school physical and medical readiness screenings conducted, and even the probability of follow-up patients who receive dilation exams. Interviews with the clinic staff provided generalized parameters for processes that occurred less frequently or were unobserved, such as school physical exam screenings and technician dilation.

A "baseline" scenario where each staff optometrist is scheduled to see 12 wellness exam patients and two follow-up patients each day is assumed to create the model. The walk-in provider will be scheduled to see seven wellness exam patients and no follow-ups each day. Optometrist appointment times for the baseline model are listed in Table 1. The model simulates one work day for the clinic from 0730 to 1600 or until the last patient departs. Assuming 20 work days a month, the model was replicated for 60 iterations to simulate clinic averages over a three month period.

Table 1: Baseline scenario appointment times.

Appointment Type	Appointment Times
Follow-up (all 3 doctors)	0730, 1300
Wellness Exam (all 3 doctors)	0745, 0815, 0845, 0915, 0945, 1015, 1045, 1115 1315, 1345, 1415, 1445
Exams assigned to Walk-in Doctor	0800, 0900, 1000, 1100, 1300, 1400, 1500

4.4 Validation

The parameters measured in the "baseline" scenario are compared to the data collected in the actual system in order to validate the output of the model. The clinic stops receiving new patients at 1530 and closes as early as 1600 or until the last patient is completed, which is typically around 1630. The model results mirror these times with an average end of day time, estimated by a 95% confidence interval, 1623 ± 6 minutes and a minimum value of 1550. No more than one patient per provider was observed waiting for an eye exam or dilation exam and the model output coincides. Table 2 below highlights some of the key measures used to validate the model and illustrates how closely the model matches the real system. Further analysis will be conducted by instituting changes to the baseline model whose results are inferred to be valid in practice.

Table 2: Validation of model parameters.

Parameter	Model Output Value	Observed Value
End of Day [Expected, Minimum] (time)	1623 ± 6*, 1550	1630, 1600
Total Number of Scheduled Patients	43 Wellness, 6 Follow-up	43 Wellness, 6 Follow-up
Wait Time in Receptionist Queue (min)	0.246 ± 0.06*	0.54
Waiting Time for Exam (min)	10.8 ± 1.2*	9.8
Number of Walk-in Patients	4.083 ± 0.49*	4.085
* 95% confidence interval for expected value		

4.5 Experimental Design

In this study, six separate alternative patient schedules were created to evaluate against the current (base) clinic policy, see Table 3. These alternative policies resulted from working groups conducted with the client and comprise policies the clinic determined to be feasible to implement. Policy A is the same as the base model except one of the three dedicated wellness exam doctors (Doctor C) has all of their appointments scheduled 15 minutes offset from the other two doctors; the adjusted wellness appointment times begin at 0800 and 1330 with the associated two follow-up appointments adjusted to 0745 and 1315. This policy tests the system to see if any efficiency can be gained through scheduling manipulation by offsetting some of the patient arrivals. Policy B is also similar to the base schedule, except the walk-in provider is scheduled to see two additional scheduled patients; increasing his patient load to nine. The new appointments are scheduled for the 0930 and 1330 which increases the total number of appoints in the clinic to 51.

Policies C and D modify the base schedule to create one hour where wellness patients are scheduled to arrive twenty minutes apart, generating a thirteenth appointment for each of the staff doctors and 52 for the clinic. The three twenty minute appointments are placed in the beginning of the day (0745, 0805, and 0825) to allow the system to work through any patient congestion created. Policy D uses the thirteen patient schedules developed in Policy C and adds two additional scheduled appointments for the walk-in provider, as was done in Policy B, increasing the total scheduled patients in the clinic to 54.

Lastly, Policies E and F modify the base schedule to create two hours where wellness patients are scheduled to arrive 20 minutes apart, generating fourteen appointments for each of the staff doctors and 55 for the clinic. Twenty minute appointments are placed in the beginning of the day (0745, 0805, and 0825) and the other hour immediately follows the lunch break (1315, 1335, and 1355) to allow the system to work process any congestion. Policy F uses the fourteen patient schedules developed in Policy E and adds two additional scheduled appointments for the walk-in provider; as was done in Policy B; increasing the total scheduled patients in the clinic to 57.

Table 3: Appointment breakdowns for each policy.

	Total Appointments	Total Scheduled Patients	Scheduled Pts/ Staff Doctor	Scheduled Pts / Walk-In Doctor	Follow-up/ Staff Doctor
Base	49	43	12	7	2
Policy A	49	43	12	7	2
Policy B	51	45	12	9	2
Policy C	52	46	13	7	2
Policy D	54	48	13	9	2
Policy E	55	49	14	7	2
Policy F	57	51	14	9	2

5 RESULTS

5.1 Patient Length of Stay

The total time a patient spends in the clinic (length of stay) is calculated from the difference in the time the entity arrives to the reception station queue and when they depart the clinic. The simulation determined the average length of stay for each patient type under each policy and is depicted in Figure 3 below. Patients arriving to receive a vision screening have average lengths of stay that are consistent across all policies and are within the confidence interval of the baseline. The length of stay for walk-in and follow-up patients increases in Policies D-F, however, the times are within the 0.95 half width of the baseline average for both patient types and therefore not statistically different from the base model.

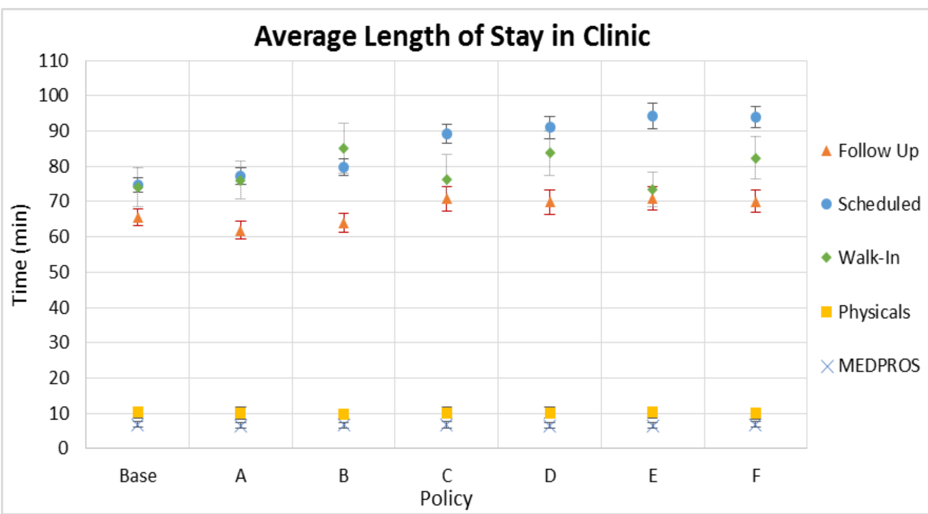

Figure 3: Average length of stay by patient type.

The length of stay for scheduled patients in the baseline scenario is 74.69 minutes ± 2.08 minutes. The average times for the other two 12 wellness appointment policies (A and B) fall within the same confidence interval as the baseline results. This suggests that an offset to one of the provider's schedules or an increase of two additional scheduled patients has no impact to a patient's average length of stay. This is a positive result for Policy B, since the clinic can serve two more scheduled eye wellness exam patients each day with no impact to the total time a patient is in the clinic.

The average length of stay values for Policies C, D, E, and F are not statistically different from each other but the four policies are all statistically different from the base model. Implementing these policies and increasing the number of wellness appointments for the staff optometrists yields 20% to 26% increases in average length of stay. If the clinic was to increase the number of scheduled appointments Policy F should be implemented as there is no difference to a patient's total time in the system whether the clinic serves 46 scheduled patients under Policy C or 51 patients under Policy F.

5.2 Patient Wait Time

Patient wait times are derived by the simulation, which averages the sum of the total time each entity type spends waiting in a queue to see a staff member. The average wait times across the 60 runs are analyzed by Arena and statistics with 0.95 confidence intervals are reported. The wait times for patients receiving eye screenings for physicals or MEDPROS were similar across all policies. Entities arriving for eye screenings only experience queues at the reception station and waiting for the technician. These results suggest changes to the number of scheduled appointments has no impact to the movement of entities through the reception or technician screening stations.

As depicted in Figure 4, the average wait times for walk-in patients are similar across all policies except in Policies B and F. The average wait time for Policies B and D are statistically different from the base model average with 95% confidence. In Policies B and F, where the walk-in provider has two additional scheduled appointments, the walk-in patients experience increases in the average wait time but the confidence intervals overlap the confidence interval for the baseline average. These results provide support for implementing policies which add additional scheduled appointments to the walk-in optometrist.

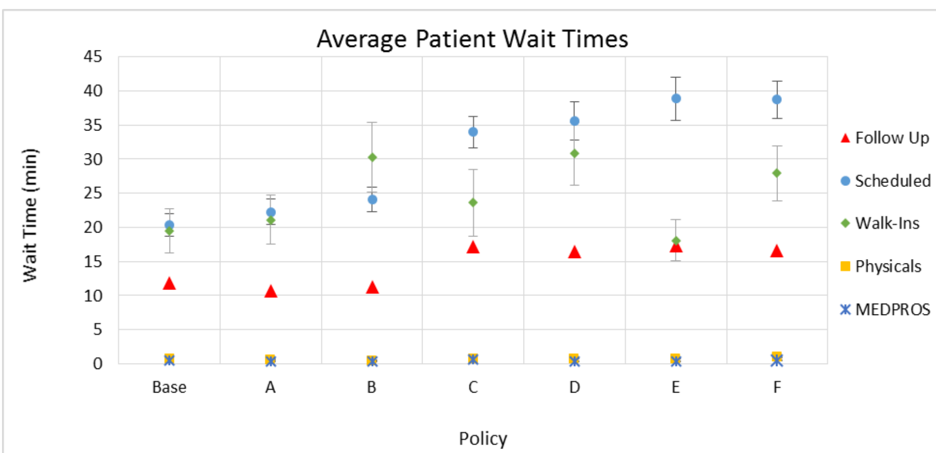

Figure 4: Average patient wait time by policy.

Scheduled patients do not experience increases in average wait times in Policies A and B. This result again supports increasing the walk-in provider's scheduled patient load by the implementation of Policy B. The simulation results for Policies C through F show a significant increase in average wait time for scheduled patients. Scheduled patients under Policies C and D experienced a 13-15 minute increase in wait times from the baseline scenario and an 18-minute increase with Policies E and F, nearly double the base case. This increase makes intuitive sense as the clinic has patients arriving faster than a doctor can service them at the beginning of the day. As the day progresses and inter-arrival times are longer than service times, patients will experience shorter wait times. Since there is no impact to wait times for the MEDPROS and physical screening patients, scheduled patients experience most of their time in queues waiting for the optometrist. This time is split between waiting for the initial exam and then waiting for the optometrist to perform the dilation exam. The clinic can help mitigate the impact on wait times by scheduling patients who do not need dilation exams during the 20-minute appointment slots, eliminating one cause of delays.

Although, the average wait times are statistically different from the baseline, the confidence intervals for the four policies (C-F) overlap. This suggests that if the clinic is willing to implement a scheduling policy which increases the total number of patients serviced each day, there is no significant impact to wait times between a 13 patient a day policy (C or D) and a 14 patient policy (E or F).

As discussed, the largest average patient length of stay time was only 26% increase over the baseline model. The average length of stay for Policy F is 93.98 minutes, which is 19.3 minutes larger than the baseline length of stay of 74.69 minutes, while the difference in scheduled patient wait times between Policy F and the base model is 18.3 minutes. Therefore, if the clinic implements a scheduling policy which causes the average wait time to double, the average total time a patient spends in the clinic will only increase by 26%. This direct relationship between wait time and length of stay provides clinic leadership with a framework to assess the risks and rewards of employing a scheduling policy to increase the number of patients served each day.

6 CONCLUSION

This research studied the optometry clinic system to establish a baseline simulation model and then tested six scheduling policies to improve the clinic's service capacity which in turn would increase the revenue generated. The baseline model uses observed data to implement stochastic variations in system processes, was verified, validated, and used as a representative benchmark for comparison with the six scheduling policies.

Policy A tested the system by having one staff provider see patients 15 minutes offset from the other two staff optometrists to minimize the "surge" of patients arriving to the clinic at the same time. Policy A had the same performance measures as the base policy, which illustrates that the reception and technician stations are adequately staffed and potential delays occur when the patient is with the optometrist. This result can be is expected since the exam accounts for the majority of the patient's time in the clinic. The simulation shows that under the current level of resources, there is no advantage to implementing a scheduling policy which simply offsets appointment times.

A focus of this research has been to determine the feasibility of the clinic leadership's desire to serve more patients each day by raising the number of appointments for staff optometrists. This parameter is tested in Policies C and E, which implemented schedules allowing optometrists to see 13 and 14 patients per day respectively. The results show that both policies dramatically increase the clinic's revenue but incur negative impacts to patient wait times. Under Policy C scheduled patient wait time is 34 minutes but is only five minutes longer in Policy E as seen in Figure 5. The simulation results infer that if the clinic is willing to implement a scheduling policy which increases the number of patients each staff optometrist sees, they should assume slightly more risk with Policy E in return for the significantly higher rewards.

The clinic provides an optometrist who is "on-call" to see walk-in patients with acute care eye issues, but also sees a limited number of scheduled patients. Policies B, D, and F analyzed the impact of increasing this number from seven to nine appointments each day. The results of Policy B, which only serves two more patients a day over the base model, yield a $392 increase in daily revenue while increasing the wait time of scheduled patients by less than four minutes. Under Policy B, the wait time for walk-in patients does increase by ten minutes but these patients are not suffering from urgent conditions. Typically, patients suffering from severe eye trauma enter the hospital through the Emergency Department (ED), where the ED staff treats their other wounds and contacts the optometry clinic to notify them of the patient. In the rare occasion a walk-in patient presents to the clinic with a severe condition, they are immediately seen by any available provider. The graph in figure 5 shows that adding ten minutes to the walk-in patient's overall wait time is a minor drawback compared with the potential gains for the clinic. However, if the walk-in provider served ten scheduled patients (increase of three) with an average of four walk-in patients, the average number of patients per day will exceed 14 and result in increased wait times for both types of patients. Under the current walk-in arrival rate, the clinic should implement a policy (B, D, or F), which schedules nine eye wellness appointments for the walk-in provider each day.

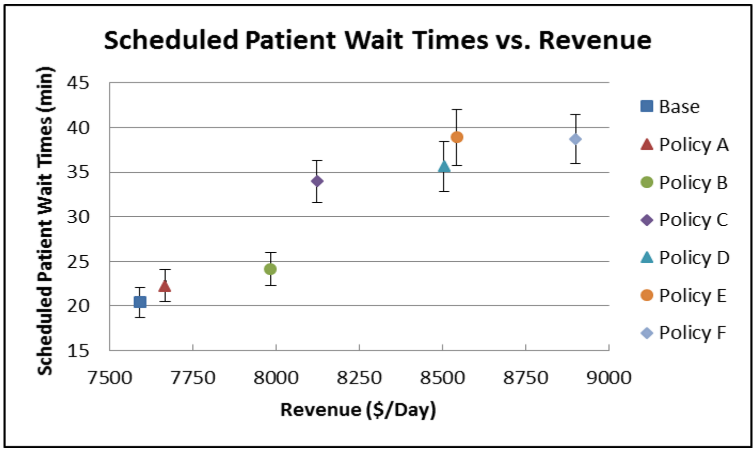

Figure 5: Graph of wait times for scheduled patients vs. daily revenue.

As discussed above, if the clinic is willing to assume the risk of slightly increased patient wait times, they should implement a policy where the staff optometrists see 14 scheduled patients a day. Increasing the number of scheduled patients has the potential to extend the work day. Since military clinicians are not authorized overtime compensation the leadership would need to shift the work day by an hour for a few staff members to ensure adequate coverage if patient care exceeds the regular clinic hours. Additionally, policies which increase the walk-in provider's scheduled patient load to nine generate significant revenue improvements over similar policies. Combining both of these findings supports the implementation of Policy F, which schedules 14 patients per day for staff optometrists and nine for the walk-in provider. This policy enables the clinic to serve and additional eight patients per day while generating over $314,000 in increased annual revenue.

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