Redesign of the University of Virginia's Emergency Department Waiting Room Layout to Optimize Patient Flow and Increase Satisfaction

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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***Abstract*—Increasing demands on emergency departments (EDs) due to rising patient volumes and operational inefficiencies necessitate innovative solutions to enhance patient flow and satisfaction. Data from UVA Health reveals substantial ED crowding, with a 12% increase in ED visits between 2022 and 2023, and a 25% increase from 2021 to 2023. To address these challenges, a simulated redesign of the waiting room at the University of Virginia (UVA) ED was completed to improve space utilization and streamline patient movement. Current designs, characterized by repeated patient returns to the waiting area, create congestion and hinder the perception of progress in care. This redesign aims to expand available space and create "progression areas" where patients can be effectively managed post-triage, reducing returns to the main lobby and thereby minimizing congestion.**

Utilizing FlexSim HC simulation software, both the current and proposed layouts are modeled to forecast key operational metrics. Validation was conducted by comparing simulation outcomes with UVA Health data on patient wait times, bed utilization, and throughput, ensuring the reliability of the proposed improvements. While the new waiting room is farther from the Patient in Triage (PIT) area, thus increasing patient travel time and the average total triage time by 2%, the variances of the arrival-to-roomed, arrival-to-triage, and triage-to-roomed times decreased by 57%, 83%, and 67% respectively. Additionally, the time taken to bring trauma patients from registration to a trauma bay decreased by 30%. Reducing the variance of wait times will increase patient satisfaction by eliminating the tail of unexpectedly long wait times. Reducing the variance enhances the reliability of wait time estimates, making actual experiences more aligned with expectations. Further research will focus on implementation challenges, including staff adaptation and continuous real-time assessment of operational performance.

***Index Terms*—Emergency Department Efficiency, Patient Flow, Waiting Room Design, Simulation**

I. Introduction

In the healthcare industry, emergency departments (EDs) consistently face challenges with patient throughput and efficiency, placing a significant burden on both patients and hospitals. EDs serve as critical points for immediate care, but they frequently face issues such as overcrowding, unpredictably long wait times, and reduced patient satisfaction. To address this, we observed patient flow at UVA's ED, aiming to optimize waiting areas and enhance the provider-in-triage model. Through direct observation and provider engagement, we collected quantitative and qualitative data to assess operational workflows and identify inefficiencies. A key finding revealed that patients are often returned to the waiting room after triage due to limited bed availability, creating unnecessary backlog and congestion. This cycle not only contributes to overcrowding but also impacts patient morale and satisfaction. Addressing these inefficiencies would be essential for improving both patient experience and hospital operations at UVA's ED.

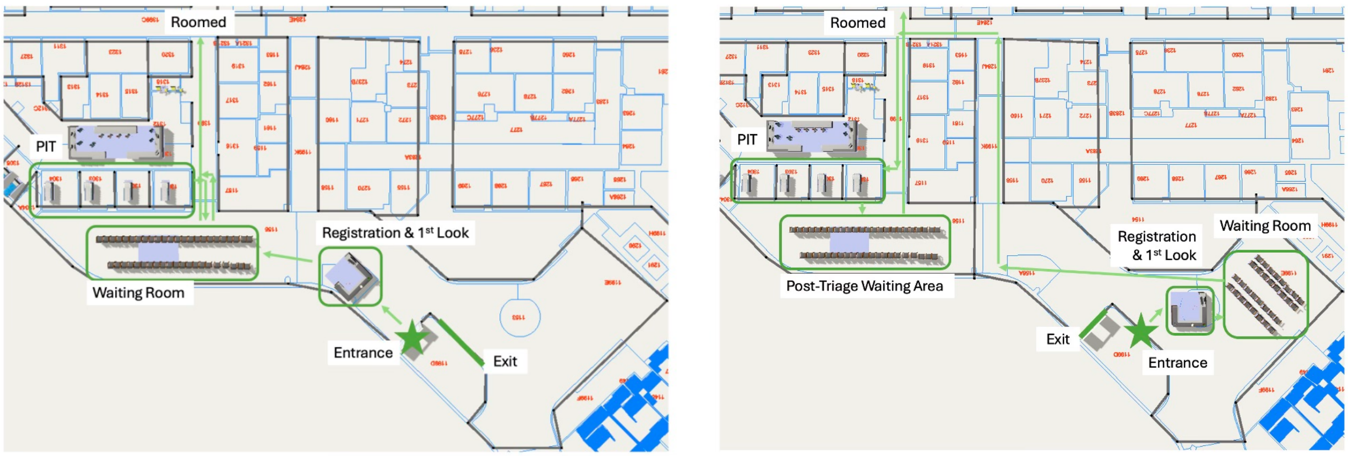
The proposed redesign is expected to improve patient satisfaction. Patients judge their perceived wait time with previous experiences in the ED. In addition, patients can experience a sense of forward progression in their care, which can positively influence their perception through the psychology of progress. If the experience appears to be shorter than expected, the patient satisfaction increases [1]. "One of the most frustrating aspects of waiting is the uncertainty of the wait length," and decreasing the variance of the wait times will lead to less wait time uncertainty [1].

II. Background and Motivation

Over 90% of EDs are regularly crowded [2]. When patients are admitted during periods of ED crowding, the chance of inpatient death increases by 5% [3]. Crowding can also result in decreased patient privacy, longer wait times, and poorer evaluation and treatment [4].

EDs have implemented various strategies to reduce crowding and improve patient flow. Easter et al. found that creating internal waiting areas for patients who have started the treatment process but do not need a bed allows resources to be used more efficiently [5]. Separating patients into parallel streams after they have been triaged, using quick tests, conducting rapid assessment, and having a primary care physician available have also been shown to improve patient flow [6].

Kamali et al. estimates that the longest time patients will wait in an ED waiting room before leaving is 3.7 hours [7]. 58% of their survey respondents said that they would consider leaving the ED without being seen if wait times increased. They also found that many patients do not understand why they have to wait, and over 70% of patients want improved wait time estimates.



a. Initial Waiting Room Design

b. Updated Waiting Room Design

Fig. 1: Waiting Room Designs

In 2023, UVA Health had 659 beds, 26,400 inpatient admissions, 72,153 emergency visits, and 1,052,452 outpatient visits. There are 1,098 full-time faculty, 793 residents and fellows, and 2,598 professional nurses [8]. The UVA ED is a Level 1 trauma center, one of only five in the state of Virginia [9]. There are 70 beds in the ED, including four operating rooms, 12 Rapid Medical Evaluation (RME) area beds, and 8 beds for behavioral and mental health emergencies [10].

Patient satisfaction and perceived wait time in the ED were the two main metrics of success for our project. After months of observation, we concluded that the area within the ED that would benefit the most was reconfiguring the waiting room and related process flows.

Our goal was to redesign the ED and model it through simulation to improve patient experience. We created a simulation model based on the current flow of the ED waiting room as seen in Figure 1a. We reorganized the format of the hospital to use the space more optimally. The new layout as seen in Figure 1b gives patients the perception that they are progressing through the ED to new spaces rather than the present model of returning to the same waiting room as the hub. The break-up in the spacing allows for patients to first enter a registration waiting room, then after the patient has been triaged, to an internal waiting room. Prior research suggests that a continuous sense of movement increases patient satisfaction in EDs [11]. We expect the updated waiting room to improve patient satisfaction and reduce patient wait times from each point within the process. The new design should also make the system more robust to extreme changes in the rate of patient arrivals due to the increased total capacity of the waiting room.

III. Literature Review

It is well-established that patients' perceptions of service quality are strongly influenced not only by actual waiting time but also by the way waiting is experienced, particularly when patients feel like they are moving forward through a system [11]. Research in queue management and simulation modeling shows the importance of perceived progression, the efficacy of simulation tools, and the need for innovations that address patient flow holistically.

One of the most significant determinants of patient satisfaction in EDs is the waiting experience. Researchers assessing the effect of a queue management system on patient satisfaction found that patients in the intervention group reported a perceived waiting time significantly shorter than their actual waiting time, while control group patients overestimated their waiting time. Additionally, the intervention group demonstrated higher satisfaction levels [12].

The distribution of waiting time across a service system also impacts customer satisfaction. Research has shown that long waits at a single point in multistage service networks, such as EDs, can severely impact perceived service quality, even when overall waiting time is minimized [13].

Simulation allows healthcare systems to forecast the effects of process changes without disrupting actual operations, and to identify scenarios that balance cost, resource use, and patient satisfaction [14], [15]. One comprehensive approach is SIMPFED, a hybrid simulation model combining discrete-event simulation and agent-based simulation to address key factors influencing patient throughput time in EDs [14]. This model analyzes patient flow - specifically waiting time, length of stay, and decision-making - and helps ED administrations identify cost-effective ways to reduce throughput time.

A study using the FlexSim 6.0 software found that adding a resource at a high-utilization registration counter reduced wait times by over 80% [15]. Another group of researchers utilized discrete-event simulation to analyze the effects of bed capacity, operating hours, and patient acuity routing on length of stay and door-to-doctor time in an ED [16].

Collectively, these studies reveal that patient satisfaction is not solely dependent on the duration of waiting, but is heavily influenced by perceived progression and the structure of the care environment. Moreover, simulation tools have proven effective in identifying and validating process improvements that enhance patient flow and satisfaction. While current literature addresses queue management, throughput time, and system optimization, there is still scope to explore how physical space design and movement cues influence perceived progression and satisfaction, warranting further research in this area.

IV. Methodology

A. Observations

To understand the operations and patient flow within UVA's ED, our team conducted 66 hours of direct observation. To maintain a focused scope, we limited our study to weekdays during normal operating hours, as the ED operates differently from 11 PM to 7 AM due to lower patient volume and reduced staffing. Observations were conducted in 2- to 3-hour sessions, primarily between 8 AM and 8 PM. 38% of our observation time was spent in the Provider in Triage (PIT) and Rapid Medical Evaluation (RME) areas, while the remaining 62% was spent in the main ED. These observations provided insights into how patients navigate the ED and enabled us to engage with providers, technicians, and nurses. This combination of qualitative and quantitative data collection helped us identify inefficiencies and critical pain points affecting patient care.

We shadowed and interviewed a diverse group of healthcare professionals, including doctors, nurses, and technicians, to understand their perspectives on operational challenges. Our observations consistently pointed to patient congestion as a major issue. Many providers and patients expressed frustration with delays, which we linked to a lack of spatial design promoting a sense of movement through the care process.

Through in-person observations, we documented patient flow from arrival through registration, first-look assessment, triage, and placement into emergency room pods. When patients first arrive, they check in at the registration desk and are assessed by the first-look nurse. Patients are then triaged in the PIT area. During triage, they are assigned an acuity score and the PIT physician determines the next steps. Depending on availability and patient needs, they are assigned to RME, a pod in the main ED (a grouping of beds within the ED based on care needs), or patients are discharged. Figure 2 presents a flowchart of the patient throughput process we documented during observation.

In addition to our observations, the hospital provided us with ED patient tracking data from October 2023 to September 2024. This dataset, generated through the Electronic Medical Record (EMR) system, contained timestamps for each stage of care, patient room assignments, and disposition decisions. Any identifying information or protected health information was removed by the hospital before it was provided to us. To ensure data accuracy, we cleaned the dataset by removing redundant columns and validating calculated times.

We developed initial data visualizations focusing on patient wait times by acuity level, which helped us identify bottlenecks in patient flow. In one visualization we were able to identify the waiting room as a critical site for intervention based on the average time between triage and placement in the emergency department based on ESI. While high-acuity patients (ESI 1–2) are placed in treatment areas with minimal delay, our visualization showed us that lower-acuity patients (ESI 3–5) face average delays of 17 to 25 minutes between triage and placement. These patients are often left waiting back in the initial waiting room, creating congestion and contributing to dissatisfaction and perceived stagnation in care.

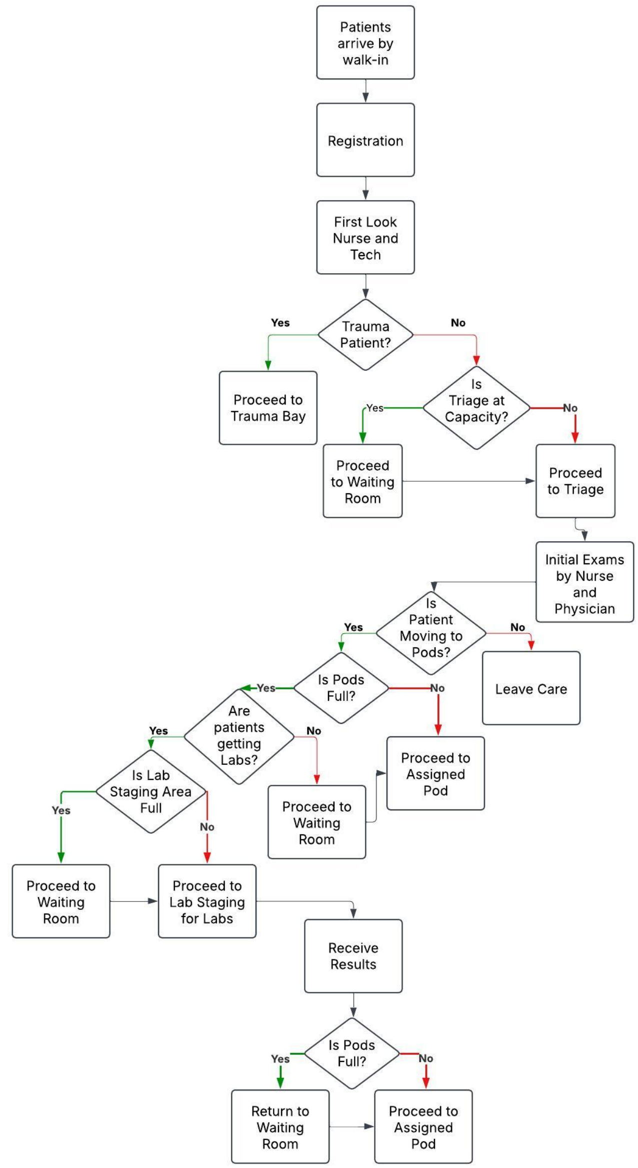


Fig. 2: Patient Flow Diagram

We initially used a map of the UVA ED, then created a flow map by overlaying the paths of patients and providers. These visualizations supported our hypothesis that redesigning the waiting room layout could improve the perception and efficiency of patient progression through the ED. Currently, patients return to the same waiting area after their initial check-in, which undermines the perception of movement through the care process. With stakeholder inputs, it was also revealed that there were challenges in communication and navigation, as both patients and providers struggled with inefficient pathways through the ED. From these findings, we proposed an expanded waiting room layout that introduces a progression area for patients who have been seen by a provider, leading to our decision to improve the waiting room layout as seen in Figure 1.

B. Simulation Development

To further evaluate our solution for reducing overcrowding, we utilized simulation modeling. Given its cost-effectiveness and ability to test new processes without disrupting real-world operations, we chose FlexSim HC, a user-friendly simulation software tailored for healthcare environments [17].

Utilizing a detailed map of UVA's ED, we created a digital model in FlexSim to simulate a patient's journey through the ED waiting room. The model included spatial components such as beds, walls, waiting areas, and hallways to closely replicate the existing physical layout. We also incorporated patient process flows to help define patient movement patterns and provider interactions based on observed behaviors and collected data.

To ensure a high-fidelity simulation, we programmed Task Sequences for key roles, including nurses, technicians, and physicians. These sequences determined when and how each provider interacted with patients, capturing real-time constraints such as triage delays, room availability, and treatment times. With the data, we calculated the distribution of patient arrival into the ED and determined that the average distribution of arrivals was a Poisson distribution of $\lambda = 6.83$ per hour. Additionally, we implemented Resource Constraints to reflect staffing levels and room utilization patterns accurately. The simulation was built on both data provided by UVA and stakeholder input.

To validate the accuracy of our simulation, we compared key output metrics against historical data from the UVA ED, as recorded in EPIC. Using Welch's t-tests, we found no statistically significant differences at the $\alpha = 0.05$ level between the simulated and real data for arrival-to-roomed time ($p = 0.17$) and arrival-to-triage time ($p = 0.10$). Although there was a statistically significant difference in total triage time between the two datasets, this discrepancy likely stems from underreporting in the real data due to delayed or inconsistent documentation. Such variability is not present in the simulation, which assumes complete triage processes and models them more comprehensively. Taken together, these results affirm the model's accuracy and reliability as a faithful representation of existing ED operations.

We ran the simulation representing patient flow over a one-month period. A one-month simulation period was deemed sufficient to analyze patterns of congestion and inefficiencies, particularly in the waiting room. The simulation confirmed that patients were frequently sent back to the waiting area, leading to a perceived lack of progress through the care process.

Informed by stakeholder input and our observational findings, we proposed a redesigned ED waiting area aimed at alleviating congestion and improving patient flow. The new design leverages additional space at the ED entrance to establish dedicated progression areas, allowing patients to advance more smoothly through the care process. These modifications were incorporated into our FlexSim model, which was subsequently subjected to stress testing under varying patient arrival rates and acuity distributions to assess the design's performance and robustness.

V. Results

Simulations for both the original and redesigned waiting room layouts, as seen in Figure 1, were run 30 times each. When assessing the time taken to get trauma patients from registration to a trauma bay, each simulation was run only 10 times. Due to limited disk space on the computer that runs the simulations, the trauma patient scenario was only simulated 10 times instead of 30. However, because the variance in trauma patient times was low for both simulations, since both were less than 0.005, it was determined that additional runs were unlikely to significantly affect the outcome. All discussions of statistical significance use an α value of 0.05. Each simulation run was 1 month long. Each simulation included a one-week warm-up period before data collection began. This was done to represent continuous movement within an ED, as there are always patients within the hospital.

Four key metrics were captured during the simulation runs, and one additional metric was calculated. Captured metrics included the time between a patient's arrival and their room placement, total time spent in triage, and time between a patient's arrival and the start of triage. From these, we calculated the time between the end of triage and room placement. These metrics reflect the key stages of a patient's time in the ED waiting room, helping us assess both the total and segmented waiting periods. The time from registration to a trauma bay for a trauma patient was also captured. This metric was included to evaluate the performance of each design in accommodating trauma patients.

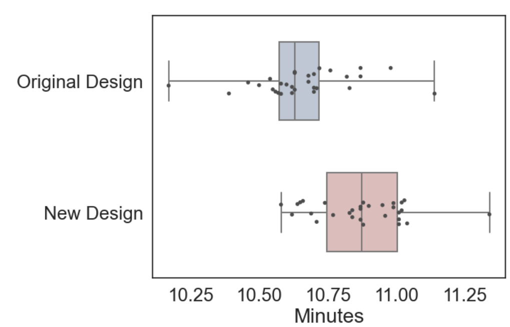


Fig. 3: Simulations Total Triage Time

As seen in Figure 3, the average total triage time in the redesigned waiting room simulation is statistically greater than the total triage time in the original waiting room simulation. The average time is 10.66 minutes in the original design and 10.87 minutes in the new design, an increase of 2%. While this increase is statistically significant, it is not materially significant. This difference is likely due to the total triage time metric including the travel time from the waiting room to the PIT, which is longer in the new design. The variance in triage time is not statistically different between the original and redesigned waiting room simulations. Although the total triage time is statistically greater in the redesign, we propose that the new model offers a better patient experience based on psychological research on patient satisfaction [12]. Enhancing the perception of reduced time was the primary goal of our study.

As seen in Figures 4, 5, and 6, the average times from arrival to room placement, arrival to triage, and triage to room placement do not differ significantly between the original and redesigned waiting room simulations. The variances of arrival-to-roomed time, arrival-to-triage time, and triage-to-roomed time are statistically different between the original and redesigned simulations.

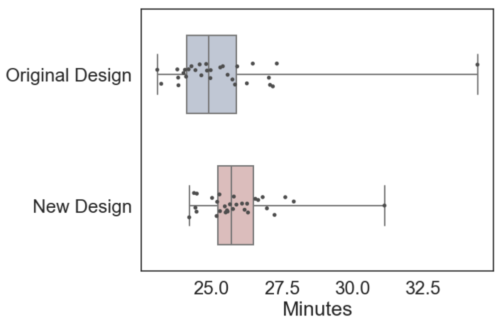


Fig. 4: Simulations Arrival to Room Placement Time

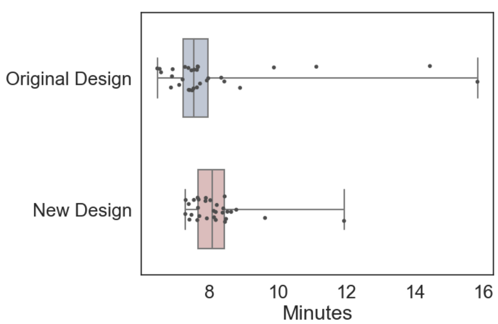


Fig. 5: Simulations Arrival to Triage Time

The variances are smaller in the new waiting room design. The variance of the arrival to roomed time is 4.31 minutes in the original design and is 1.86 minutes in the new design, a 57% decrease. The variance in the arrival-to-triage time is 4.52 minutes in the original design and 0.77 minutes in the new design, an 83% decrease. The variance of the triage to roomed time is 1.55 minutes in the original design and is 0.52 in the new design, a 67% decrease. These dramatic decreases in variance emphasizes the need for the new waiting room as it allows patients to accurately predict when they should be expecting their next steps of care. This smaller variance is also important because it validates the data to be more predictable for future simulations.

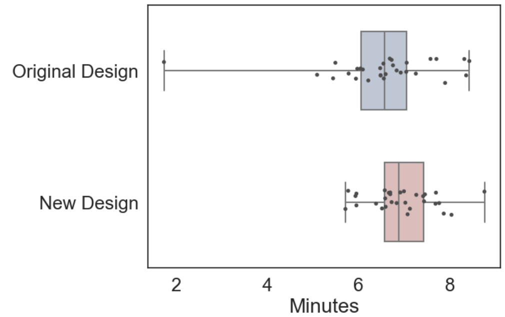


Fig. 6: Simulations Triage to Room Placement Time

As seen in Figure 7, the time from registration to a trauma bay is statistically different in the redesign versus the original. The variances for the registration-to-trauma times are not statistically different. The average time it takes for a patient to get from registration to trauma with the original design is 1.64 minutes and is 1.15 minutes in the redesigned waiting room, a 30% decrease. The increased efficiency for patients moving to trauma is essential, since these are patients with the highest acuity and in the most dire situations. It is beneficial for the wait time from registration to trauma to decrease, since we want to limit bottle-necks within the ED.

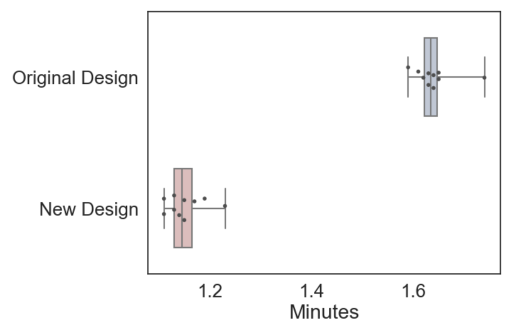


Fig. 7: Simulations Time of Registration to Trauma

VI. Discussion

Our FlexSim HC simulations, created using UVA's ED data from Epic and observational inputs, were able to show patient flow through both the existing and remodeled waiting room designs. Although the total triage time for patients marginally increases, the redesigned layout significantly reduced the variance in critical patient flow metrics, including arrival-to-roomed time, arrival-to-triage time, and triage-to-roomed time. Moreover, trauma patients experienced a decrease in time from registration to trauma bay, which showed the value of the redesign for high-acuity cases.

Since the redesign focuses on the patient experience, the variance of the wait times is extremely important. In this scenario, a high variance and extreme outliers means some patients are waiting a long time before receiving care, so reducing the variance is essential to improving their care and experience. While the average wait time may not change significantly, the range of possible wait times will be narrower, with fewer extreme outliers.

Given emergency rooms are a high-stress environment, patients want accurate information. Smaller wait time variances suggest the patient is less likely to experience wait times that are significantly longer than anticipated. While the actual average wait times are not significantly different, the smaller variance means that more patients will experience the average wait times. This will improve patient satisfaction as they are less likely to be waiting much longer than expected. The hospital will be able to provide more confident wait time estimates to patients and the confidence interval of the estimations will be smaller.

The redesigned waiting room is expected to enhance patient satisfaction by improving their perception of wait times. Although the average wait times between the two designs do not differ significantly, existing research has shown that implementing progression areas can lead to a reduction in patients' perceived wait time. Consequently, while the actual wait time may remain largely unchanged, the perception of a shorter wait is likely to contribute to an improved patient experience and increased satisfaction.

Limitations of this study arise from the inherent constraints of simulation modeling. Due to time and funding limitations, the proposed design was not physically implemented in UVA's ED, and the study relied on simulations to forecast outcomes. The use of simulation to validate expected results before disrupting live ED operations is prudent. Moreover, the scope of the simulation was limited to the patient flow up until bed assignment, excluding the remaining care process. While the simulation was rigorously verified and validated, it is important to note that simulations cannot replicate the full accuracy of real-world implementation and testing.

Future efforts will focus on the live deployment of the redesigned layout, including the integration of real-time location systems to dynamically manage space and patient routing. Continuous feedback from both patients and staff will be crucial to ensure that operational improvements translate into lasting enhancements in patient care and satisfaction. Additionally, incorporating patient satisfaction data and expanding the scope to include more of the care process will provide a more accurate model, offering further insights for the hospital team. A key limitation of implementing the redesign is the adaptation of staff to the new layout and processes. Changes in workflow and communication may require targeted training to ensure staff can effectively manage new patient routes and interactions. Addressing these challenges will be essential for ensuring the long-term success of the redesigned waiting room.

VII. Conclusion

Improvements in variance and potential perceived wait time suggest that the proposed layout could improve patient satisfaction by fostering a clearer, more predictable sense of forward movement through the care process. The redesign, featuring greater consistency and improved trauma bay access, marks meaningful progress toward a more operationally efficient and psychologically attuned emergency care environment.

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