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SIMULATION MODELING AS A LEAN TOOL FOR HEALTHCARE DESIGN:
Determining Room Utilization and Staffing in the Emergency Department

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ABSTRACT

This article outlines the use of operational planning and simulation modeling as a lean tool within Perkins+Will, to determine the room utilization and staffing for a large trauma center, based on current and projected volumes and turnaround times. A specific area of focus was the Resuscitation Rooms and their location within the emergency department (ED). In its most recent year, this facility had 64,000 patient visits. Projections estimate that approximately 75,000 annual patient visits within 63 exam rooms will be needed in this emergency department in 10 years. This study began with a process map of the patient flow within the ED. A simulation model was built to mimic the patient flow in the design of the new emergency department. Patient wait times, census, and staffing ratios were the key metrics to assess the efficacy of the ED design. The results of this revealed that the medical resuscitation rooms that were planned were better used when integrated with the emergent rooms in the main ED versus an area decentralized and adjacent to the main ED. The results also revealed that staffing of the ED within specific staff roles (RN's and Technicians) and specific ratios could reduce patient wait times.

KEYWORDS: simulation modeling, lean, process mapping, operational planning, staffing

1.0 INTRODUCTION

This article illustrates the use of operational planning and simulation modeling as lean tools to calculate the utilization of rooms and staffing for a large trauma center. Healthcare organizations are looking at lean systems for efficient care and to minimize waste. With the principles and processes of Lean, we know how to reduce and eliminate waste, including the reduction and eliminations of errors (defects)[1]. Simulation modeling is a great tool in lean practices to assess patient flow, wait times, and analyze capacity. Simulation analysis takes into account the inherent variability in patient arrival rates, process and turnaround times and provides a fairly accurate depiction of the process flow with the planned spaces. Simulation can inform key design/operational decisions by comparing the efficiency of various design and operational concepts.

The research problem that this article addresses is how to maximize the utilization of rooms for a trauma center, while understanding the relationship between staffing and turnaround times. It is possible to locate the medical resuscitation unit in a decentralized area adjacent to the main emergency department (ED) and staff the emergency department with specific staff members, but staff utilization may decrease and patient wait times may increase significantly. Conversely, having the medical resuscitation rooms integrated with the emergent beds in the main ED may cause an increase in staff utilization and an increase in specific staff coverage, which may reduce wait times, but increase operational costs. In addressing this problem, simulation modeling was used to analyze room utilization, patient flow with wait times, and staff coverage. The following sections describe the research methodology and results in detail.

2.0 METHODOLOGY

2.1 Data Collection

To complete the simulation modeling for the trauma center, the team gathered data on current patient census, as well as projected future patient census in the trauma center. Current staffing roles and ratios were also obtained. This facility utilizes the Emergency Severity Index (ESI) level 5 Acuity System[2], where Level 1 is the highest acuity level and Level 5 is the least acuity level. The Triage area prioritizes incoming patients and identifies the "walking wounded" from the "walking critical". In some low acuity cases, patients can be triaged, assessed, and seen as a "Treat and Street" cases. The Fast-Track rooms are for lower acuity patients, such as extremity fractures and lacerations. Emergent rooms are for the higher acuity patients, such as chest pain and abdominal pain, whereas the trauma and medical resuscitation rooms are for the highest acuity patients. Table 1 shows current turn-around-time (TAT) data and the projected turn-around-time goals that were obtained, including patient arrival time patterns.

Table 1: Client's current census and goals.

2008 Client Volume: 64,218	Current Turn-Around-Times (TAT's)
Triage	30 minutes
Fast-Track	2 hours
Emergent	9.1 hours
Trauma	6.5 hours

	Client Goals Turn-Around-Times (TAT's)
Triage	7 minutes
Fast-Track	1.5 hours
Emergent	4 hours
Trauma	4 hours

2.2 Tools and Techniques:

In developing the simulation model, a targeted workflow map for the patient flow through the trauma center, was created by areas of Triage, Fast-Track, Emergent, Medical Resuscitation, and Trauma, as shown in Figure 1. Observational studies were conducted to determine existing patient flow and processes. Process flow charts were developed to visualize the flow of patients through the various areas of the ED.

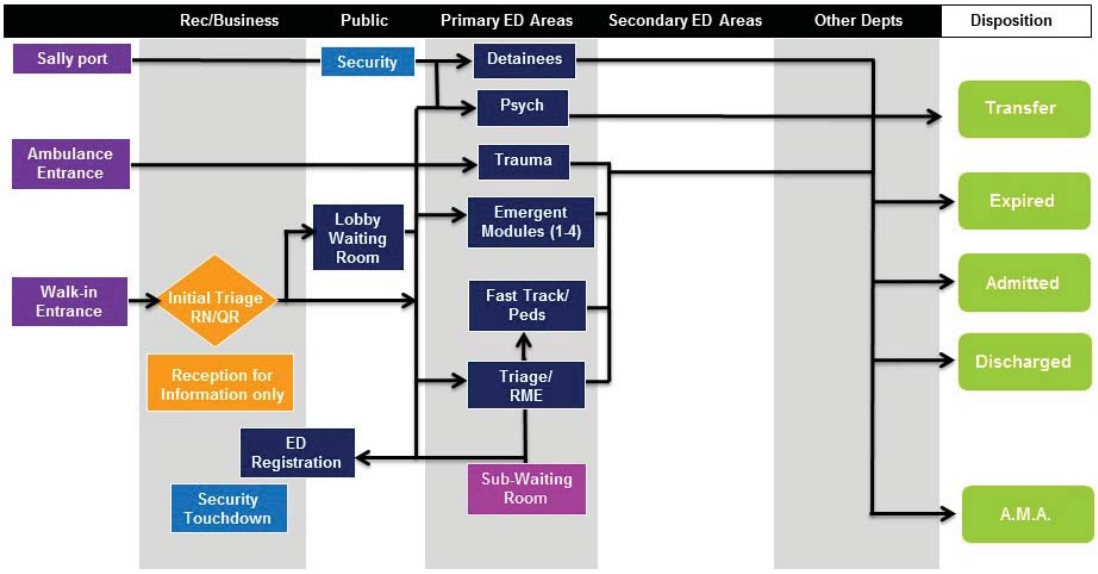

Figure 1: Targeted work flow map.

Table 2: Client 2017 Emergency Department space need projections for 74,958 visits.

Primary ED Area	Client TAT Goals (hrs.)	Projected Visits	% of Census	Reg No. of Rooms
Trauma	4 hrs.	7,496	10%	10
Med Resuscitation	2 hrs.	750	1%	4
Emergent	4 hrs.	46,474	62%	34
Fast-Track	1.5 hrs.	8,995	12%	5
Pediatrics	1.5 hrs.	7,496	10%	4
Behavrioral Health	8 hrs.	3,748	5%	6
			TOTAL	63 Rooms

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Table 2 above shows process flow, and also the percent of patients following each pathway through the process. These percentages served as probabilities in the model for simulation.

Further calculations included the time involved with movement from one area to the next based on the planned physical layout of the department.

The team determined the variables that would best represent whether the design of the emergency department would accommodate the various utilization of the rooms and staffing coverage. The team elected average patient wait time for a room by acuity, patient census, and staffing ratios as the variables for optimization in the model. Next, simulation models were built in ProModel's MedModel software[3]. The models simulate patient flow and provide statistics on the chosen variables, which can be used to measure process efficiency. In this particular simulation, the levels of acuity and staffing play a major role in the placement of patients. For the highest acuity level 1 patient, there can be no waiting time. These patients must be seen immediately by staff and placed in the trauma unit, medical resuscitation unit, or emergent rooms. In the space programming of this department, a breakdown of room requirements with their function and adjacencies was previously established with the client. All acuities had specific rooms or areas where patients were placed. The simulation model handled all "if, then" logic and provided statistics based on the patient flow.

3.0 SIMULATION RESULTS

This section describes the two scenarios simulated for room utilization, Scenario A and Scenario B:

Scenario A:

The first simulated scenario considered the medical resuscitation and emergent rooms separated, with the medical resuscitation unit in a decentralized area adjacent to the main ED. The medical resuscitation rooms and staff were drastically underutilized and may actually represent more rooms and staff than necessary (Table 3A).

Table 3A: Room utilization simulation input summary for Scenario A

Type of Room	Annual No. of Patients	Number of Rooms	TAT (hours)	Utilization
Trauma	7,496	10	4	39%
Med Resus.	750	4	2	5%
Emergent	46,474	34	4	71%
Fast-Track	8,995	5	1.5	61%
Pediatrics	7,496	4	1.5	81%
Behavioral Health	3,748	6	8	49%

Scenario B:
The next scenario integrated the medical resuscitation and emergent rooms. The integrated simulation model combining emergent and medical resuscitation areas provided flexibility for staffing purposes and improved utilization (Table 3B).

Table 3B: Room utilization simulation input summary for Scenario B.

Type of Room	Annual No. of Patients	Number of Rooms	TAT (hours)	Utilization
Trauma	7,496	10	4	39%
Combined Emergent	47,224	38	4	65%
Fast-Track	8,995	5	1.5	61%
Pediatrics	7,496	4	1.5	81%
Behavioral Health	3,748	6	8	49%

The medical resuscitation unit for the 10 year projections was simulated with current staffing ratios of 2RN's and 1 technician. The lower staff utilization with current staffing ratios shows the scope for improving staff utilization. The current staffing numbers indicated that staffing the medical resuscitation unit as a separate entity provided ample potential for flexing of staffing hours with other areas of the ED. As expected, the patient waiting times for the unit are zero to minimal owing to the abundance of staffing hours along with low utilization numbers for both RNs and technicians. However, it was noted that ESI acuity level 1 patients should never have to wait for staff due to the severity of their illness/injury. The results are shown in Table 4.

Table 4: Census with current medical resuscitation staffing ratios.

Time of Day (hours)	Average Number of Patients	Maximum Number of Parients	RN	Tech	Patient waiting time for RN or Tech (mins)	RN Utilization	Tech Utilization
7-10	1	1	2	1	0	2%	3%
10-12	1	1	2	1	0	1%	3%
12-14	1	1	2	1	0.1	5%	8%
14-16	1	1	2	1	0.28	7%	11%
16-17	1	1	2	1	0.13	6%	8%
17-19	1	1	2	1	0.12	6%	11%
19-23	1	1	2	1	0.38	5%	9%
23-1	1	1	2	1	0	4%	7%
1-3	1	1	2	1	0	3%	5%
3-4	1	1	2	1	0.14	5%	8%
4-7	1	1	2	1	0.03	3%	4%

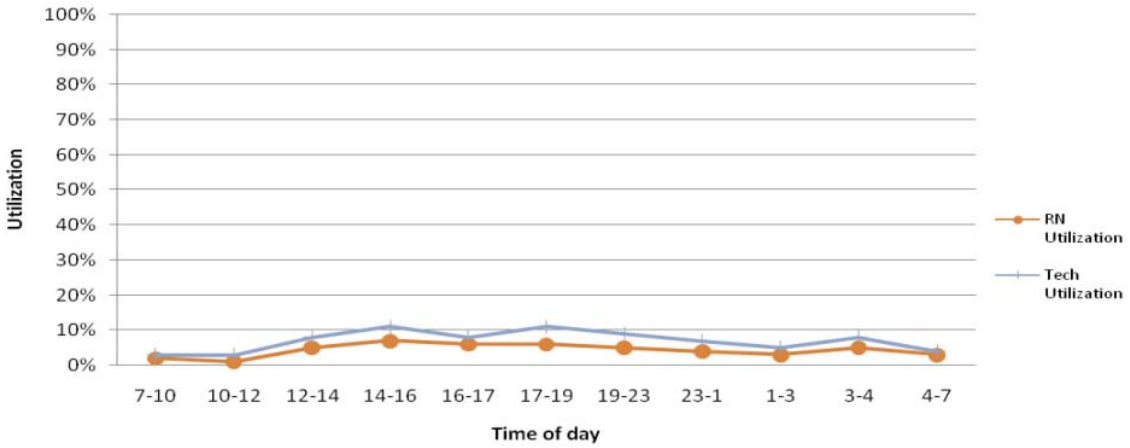

Figure 2: Resource utilization for 2017 census with current medical resuscitation staffing ratios.

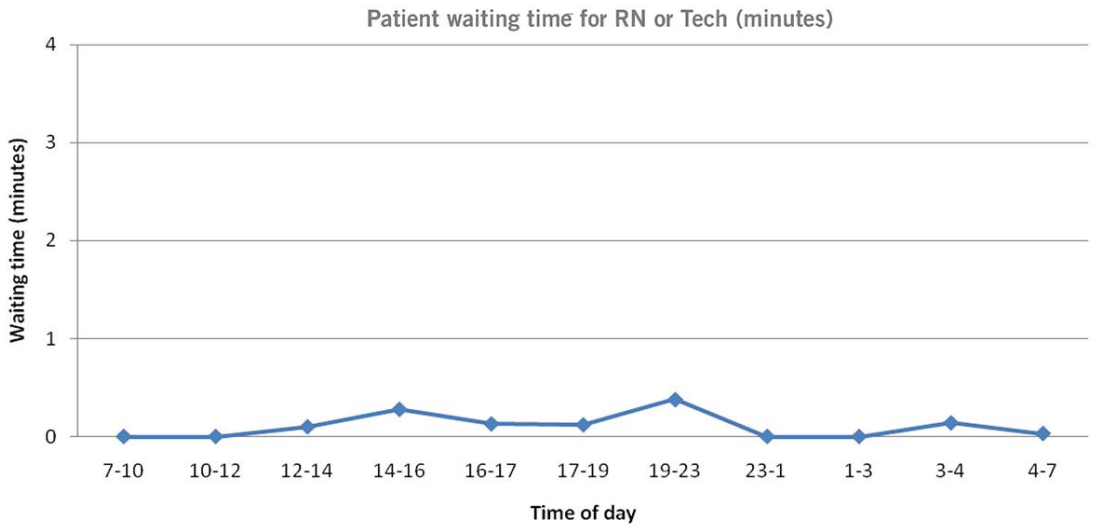

Figure 3: Patient waiting time for 2017 census with current medical resuscitation staffing ratios.

3.1 Results for Scenario 1

In this scenario, the medical resuscitation unit and emergent beds were integrated with current staffing ratios of 1 RN: 4 patients and 1 technician to 5 patients. Combining the emergent and medical resuscitation unit with staff flexing reduced the excessive waiting times and staff utilization numbers for the emergent beds. The patient waiting times were found to be significantly reduced for the combined unit dropping from an average of 112 minutes to 20 minutes. Results are shown in Table 5.

Table 5: Combined emergent and medical resuscitation unit staffing: Scenario 1.

Time of Day (hours)	Average Number of Patients	Maximum Number of Parients	RN	Tech	Patient waiting time for RN or Tech (mins)	RN Utilization	Tech Utilization
7-10	9	12	3	3	19.34	78%	72%
10-12	14	18	5	4	24.71	79%	82%
12-14	21	26	7	6	25.33	80%	80%
14-16	29	33	9	7	23.7	83%	87%
16-17	33	35	9	7	20.68	83%	88%
17-19	33	35	9	7	18.14	83%	83%
19-23	30	33	9	7	15.62	82%	85%
23-1	31	33	8	6	18.97	86%	89%
1-3	26	29	7	5	14.13	82%	87%
3-4	22	25	5	4	17.04	84%	83%
4-7	15	21	4	3	20.31	70%	70%

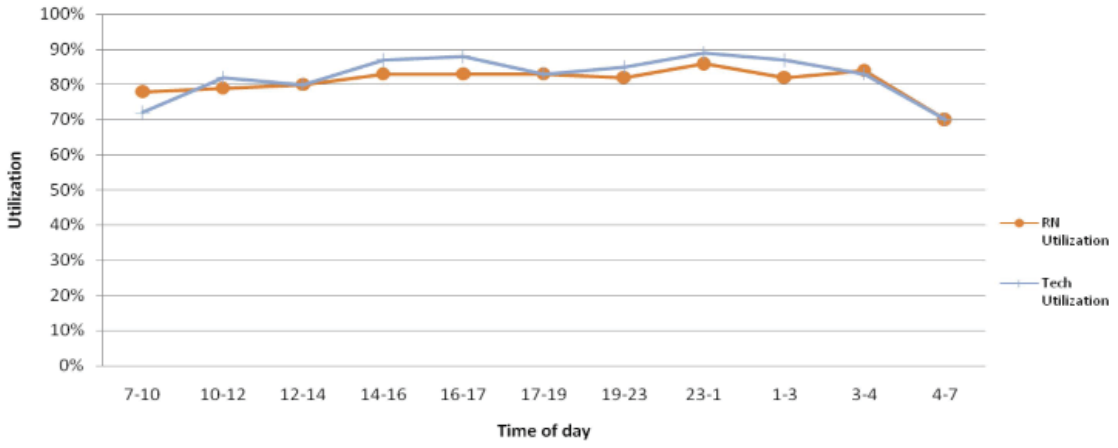

Figure 4: Emergent and medical resuscitation staffing combined: Resource utilization in Scenario 1.

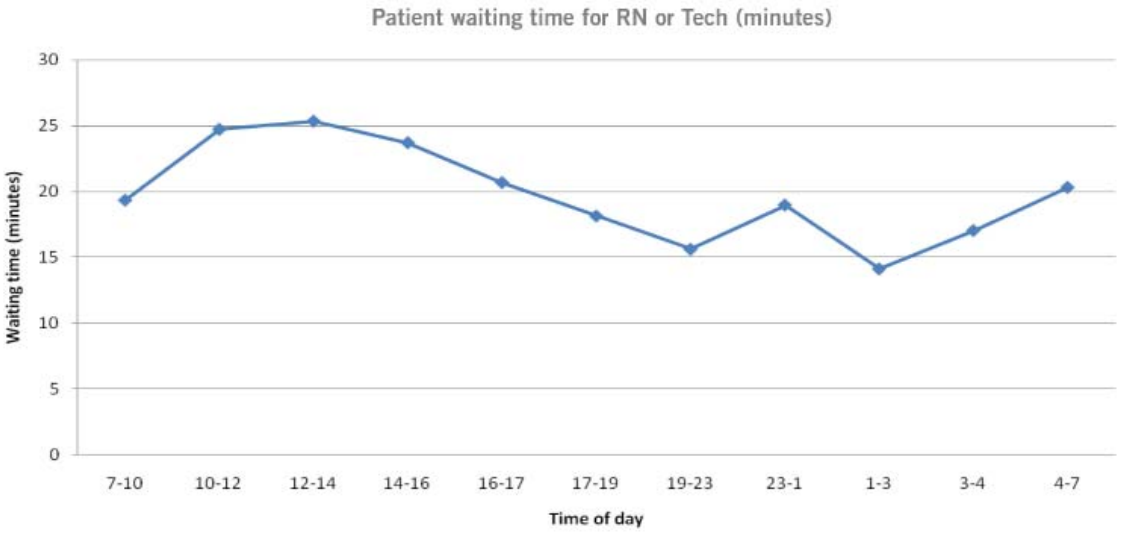

Figure 5: Emergent and medical resuscitation staffing combined: Patient waiting time in Scenario 1.

3.2 Results for Scenario 2

The team questioned the peak times in the emergency department for the combined emergent and medical resuscitation beds. Staffing in this scenario was RN/patient ratio 1:4, technician ratio 1:5, additional RN/tech during peak hours. This scenario was aimed at reducing patient waiting times for the combined model by providing additional staff hours during peak hours of demand. The drop in staff utilization was not significant compared to Scenario 1. Compared to Scenario 1, a significant drop in patient waiting times was observed with additional staffing hours (patient waiting times was an average of 10 minutes in Scenario 2 compared to 20 minutes in Scenario 1). *Note:* Considering, there is never a wait time for initial medical resuscitation assessment in clinical practice, it therefore reflected as such in the simulation. Results are shown in Table 6.

Table 6: Combined emergent and medical resuscitation unit staffing: Scenario 2.

Time of Day (hours)	Average Number of Patients	Maximum Number of Parients	RN	Tech	Patient waiting time for RN or Tech (mins)	RN Utilization	Tech Utilization
7-10	9	11	4	3	6.79	60%	67%
10-12	15	18	5	5	10.15	81%	73%
12-14	21	25	7	7	11.08	81%	70%
14-16	29	33	9	9	12.69	85%	72%
16-17	33	35	9	8	11.94	84%	77%
17-19	31	34	9	8	11.16	83%	73%
19-23	29	33	9	8	11.36	82%	75%
23-1	30	32	9	8	8.51	79%	70%
1-3	25	29	7	6	8.13	81%	74%
3-4	21	23	5	4	7.23	81%	78%
4-7	13	19	5	4	8.54	56%	51%

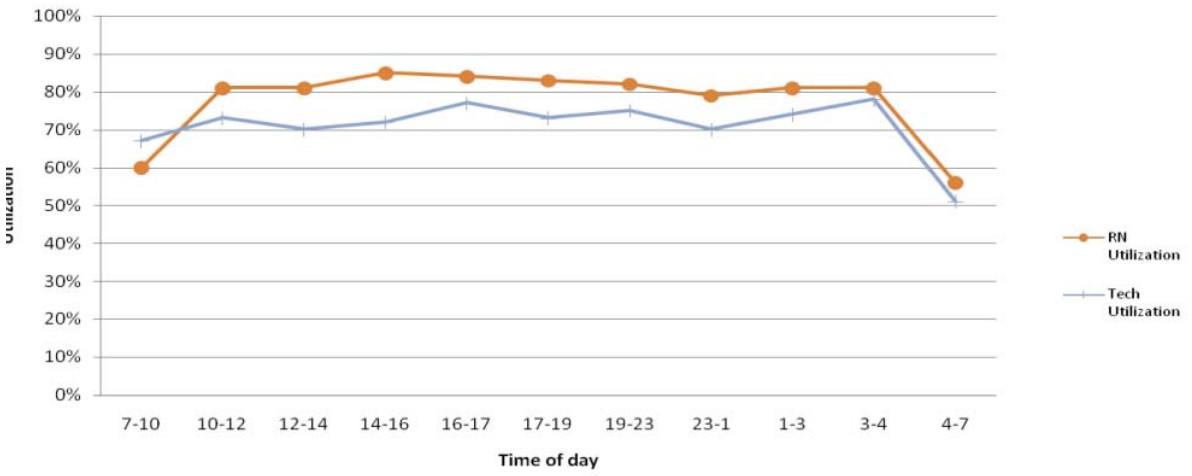

Figure 6: Emergent and medical resuscitation staffing combined: Resource utilization in Scenario 2.

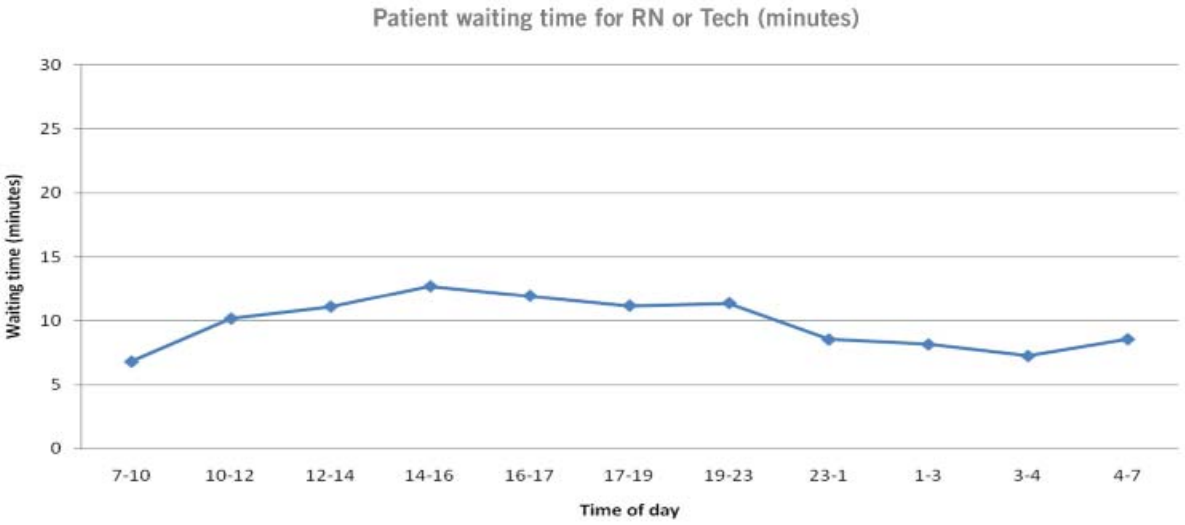

Figure 7: Emergent and medical resuscitation staffing combined: Patient waiting time in Scenario 2.

The emergent and medical resuscitation staffing simulation summary shown in Table 7 demonstrates the current staffing and results for Scenario 1 and Scenario 2. High staff utilization could lead to increased patient wait times, staff burnout, and poor retention.

Table 7: Summary of simulation results.

Scenario	Average time patient waits for RN or Tech (min)	Average RN Utilization	Average Tech Utilization
Current	112.9	83%	100%
Scenario 1	19.8	81%	82%
Scenario 2	9.78	78%	71%

CURRENT For Medical Resuscitation, 2 RN and I Tech for all time periods
For Emergent unit, RN ratio of 1:4 and Tech ratio of 1:10

SCENARIO 1. Emergent and Medical Resuscitation as one unit, with RN ratio of 1:4 and Tech ratio of 1:5

SCENARIO 2. Emergent and Medical Resuscitation as one unit, with RN ratio of 1:4 and Tech ratio of 1:5, addition of one RN or Tech during peak hours, (Example 7:00 AM-10:00 AM for RN and 2:00 PM -1:00 AM for Tech) to reduce patient waiting times.

NOTES: 1) There is no wait for initial medical resuscitation assesment.
2) Modules would open according to need.

4.0 CONCLUSION

Simulation modeling is a powerful tool for simulating design and operations of healthcare facilities and can aid the lean design process. It assists in developing a framework for effectively using planned spaces. Developed simulation scenarios can help to understand design and space requirements before construction. Simulation results can also help determine desired outcomes for efficiency and patient/staff satisfaction. In this particular study, simulations were used to analyze room utilization, patient flow, and staffing coverage. Integration of medical resuscitation and emergent rooms provides for staffing flexibility and improves room utilization. The staffing scenarios for those rooms demonstrates effects on wait times and staff utilization. Simulation is not always needed within projects, but it is particularly useful for areas with complex arrival and queuing, such as emergency departments, obstetric unit, and surgical suites. Results can help inform key design and operational decisions for healthcare facilities. Healthcare simulation over the past few years, is going beyond the traditional role of scenarios and visualizing workflows. A simulation model can be incorporated as a component of ongoing efforts to monitor and improve performance and increase efficiency[4].

Acknowledgments

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