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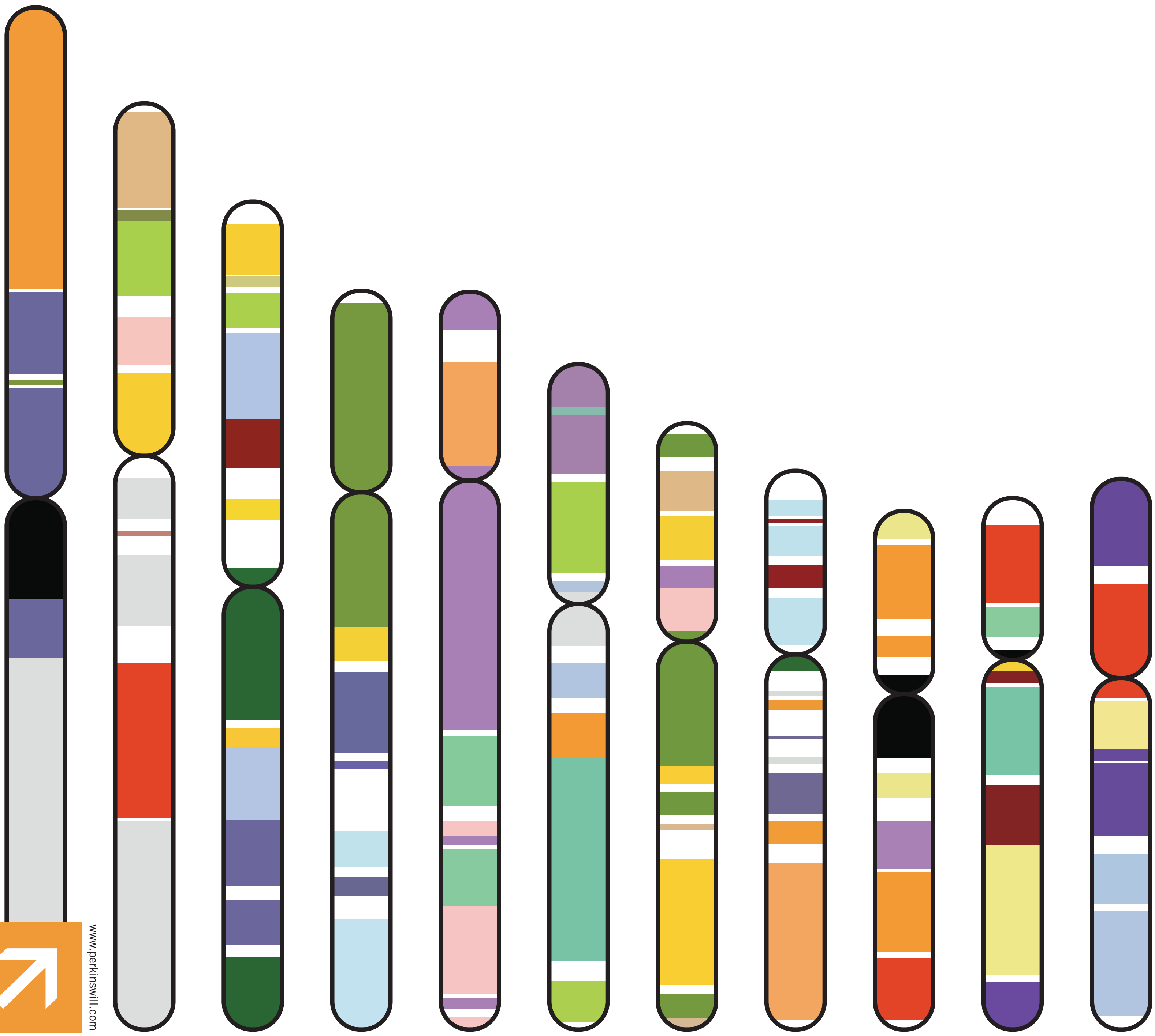

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04.
SIMULATION MODELING AS A METHOD FOR DETERMINING FACILITY SIZE OF AN EMERGENCY DEPARTMENT USING LEAN DESIGN PRINCIPLES

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ABSTRACT
This article outlines the use of a Lean design process, enabled by simulation modeling, to determine the appropriate size of an emergency department based on current patient volumes and projected patient volumes in 12 years. In its most recent year, the emergency department hosted 67,000 patient visits within 34 exam rooms. Projections estimate that almost 74,000 annual patient visits within 56 exam rooms will be needed in this emergency department in 12 years. This study began with a process map of the patient flow within each acuity level. Thereafter, a simulation model was built to mimic the patient flow in the design of the new emergency department. Patient wait times were the key metric to assess the efficacy of the facility design. The results of this study revealed that the planned facility size was bigger than necessary and rooms could be eliminated from the plan and design, thus providing savings in construction.

KEYWORDS: operations planning, process modeling, right-sizing, space requirements, modeling, simulation

1.0 INTRODUCTION
This article demonstrates the use of Lean process mapping and simulation modeling to calculate the recommended number of exam rooms by care intensity in an emergency department. A Lean system allows for an efficient response to fluctuating customer demands and requirements[1]. In healthcare, Lean is about shortening the time between the patient entering and leaving a care facility by eliminating all non-value added time, motion, and steps; it all leads to providing a quality healthcare system[2].

The research problem that this article addresses is how to optimize space requirements for an emergency department, while balancing relationship between the number of exam rooms and patients' wait times. It is possible to maintain the number of emergency department visits with very few exam rooms, but the patient wait time may increase significantly. Conversely, having many exam rooms and staff may result in short patient wait times, but very high costs to build and operate the facility. In addressing this problem, simulation modeling was used to assess patient flow, wait times, and analyze capacity[3]. 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 emergency department, the Perkins+Will team gathered data on current patient volumes, as well as projected future patient volumes for each acuity level. A five-level emergency department triage algorithm provides clinically relevant stratification of patients based on patient acuity and resource needs. The purpose of triage is to prioritize incoming patients and to identify patients that cannot wait. There has been a trend to standardize triage acuity scales that have 5 levels (e.g., 1-resuscitation, 2-emer-

gent, 3-urgent, 4-less urgent, 5-non-urgent)[4]. Additionally, length of stay data by acuity level and patient arrival pattern data was also obtained. Planned counts for exam rooms by traditional programming methods was provided based on input from the client. The critical care rooms were for the highest acuity patients such as Trauma, resuscitation and acute Myocardial Infarction, while the emergent rooms were designated for chest pain patients, stroke and abdominal pain. The Express Care rooms were for lower acuity conditions such as lacerations, and fractured extremities, while the Intake rooms were used for triage/assessment and in many cases as a "treat and street" area. Figure 1 provides an overview of sample data.

2.2 Tools and Techniques

The first step in developing the simulation model was to create a process map for the patient flow through the emergency department, by acuity level, as shown in Figure 2. Some of the acuity levels had patients that need to be lying down while others could remain upright or vertical.

As shown in Figure 3, this process flow also reflected the percentage of patients following each pathway through the process, and these percentages served as probabilities in the simulation model.

Fiscal Year 2011 Data	Fiscal Year 2024 Projections
Visits: 67,000	Visits: 74,000
Critical Care & Emergent Rooms: 28	Critical Care Rooms: 4
Express Care Rooms: 6	Emergent Rooms: 27
Total Exam Rooms: 34	Express Care Rooms: 20
	Intake Rooms: 5
	Total Exam Rooms: 56

Figure 1: Sample data overview.

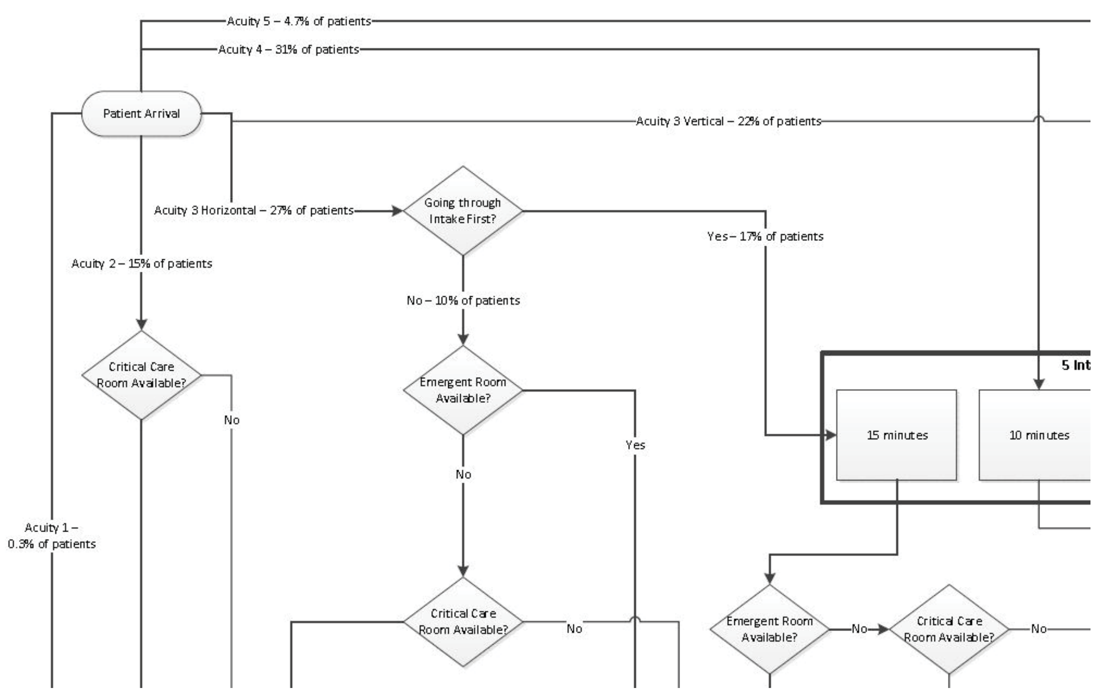

Figure 2: Patient flow process map.

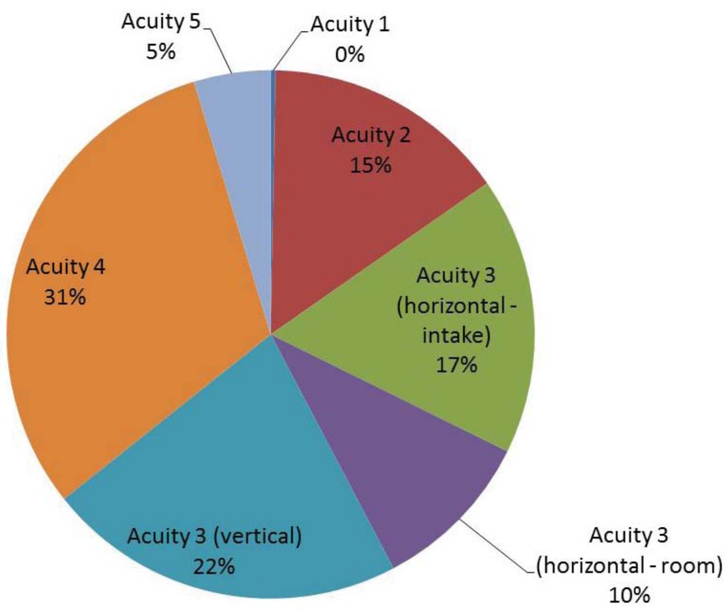

Figure 3: Percentage of emergency department patients by acuity level.

Additional calculations included the time involved with movement from one location to the next, based on the planned physical layout of the department.

Next, the team determined the variables that would best represent whether the design of the emergency department could accommodate the expected increase in patient visits. The team selected average patient wait time for a room by acuity level and the utilization percentage by room type as the variables for optimization in the model.

Observational studies were conducted to determine existing patient flow and processes. Process flow charts were developed to visualize the flow of patients through various areas of the clinic. These flow charts were overlaid with statistical analyses to determine the probability of patients flowing through each pathway.

Next, simulation models were built in ProModel's MedModel software[3]. The models simulate patient flow and provide statistics on the two chosen variables, which can be used to measure process efficiency. In this particular simulation, the levels of acuity play a major role in the placement of the patients. For the acuity level one patient, there can be no waiting time. These patients are at risk of death, and must be seen immediately, so they are placed in the critical care rooms. A breakdown of room requirements, their functional intent and their required adjacencies had been established within the space programming of the department. Certain acuities had specific rooms where patients would be placed first and if those areas were not open, patients could be seen in other areas or experience time in a waiting room. Some may go first to seek an emergent bed while others may first seek an express care room. The models can respond to "if, then" logic. For example, if an acuity three vertical patient arrives, the first choice is to place the patient in an intake room. However, if an intake room is not available, then the patient will be placed in an express care room. If an express care room is not available, then the patient will be placed in an emergent room. If none of these room types are available, the patient will wait in the waiting area. The simulation model handles all of this logic, and provides statistics based on the patient flow.

The treatment room projections assumed that a room would be available 99% of the time. This will be well noted in the average waiting time results for a room.

2.3 Simulation Results

Four different scenarios were simulated, which are described in more detail in this section.

Scenario One

The first simulated scenario considered the projected patient volumes for 12 years from present (see Table 1).

With wait times less than one minute, the increased volumes expected in 12 years are manageable with the environment as designed. Average wait times less than one minute may actually represent excess capacity, or more exam rooms than necessary.

Scenario Two

The team questioned the busy times in the emergency department. While the wait times for all acuity levels are, on average, less than a minute, are there times when wait times would drastically increase? With this question in mind, the team explored patient wait times during peak periods, from 16:00 to 20:00 each day. The simulation model was rerun, and statistics were reviewed for the peak times. The results are shown in Table 2.

While several of the wait times increased, it is important to note that none of them are above one minute. Less than one minute wait in the emergency department during peak times is considered very acceptable to patients, and likely represent excess capacity.

Scenario Three

Next, the team questioned what would happen if the emergency department volumes were increased much further than the facility projected. The facility projected 74,000 visits per year in 12 years. However, if the projection was incorrect, and 90,000 visits were seen in one year, what would happen? Could the emergency department handle this volume? The model was re-run and wait times were reviewed.

Results are shown in Table 3. Again, wait times increased in this scenario, but all times were still less than one minute. This provided great confidence that the emergency department could handle even higher volume levels.

Next, the team questioned whether the number of planned rooms was too great. Statistics by room type for 90,000 visits were reviewed and are shown in Table 4.

The statistics indicate that room utilization is well within reasonable expectation of performance. In general, room utilization in excess of 80 percent is concerning, as there is time that each room must be out of commission for maintenance, as well as the time to clean the room between patients.

Table 1: Scenario 1 based on 12 year volume projection.

Patient Acuity	Length of Stay (minutes)	% of Total Emergency Patient Visits	Average Time Waiting for a Room (seconds)
1	160	0.3	2.3
2	220	15	5.3
3	220	49	2.3
4	90	31	4.5
5	30	4.7	7.1

Table 2: Scenario 2 based on patient volume during peak times.

Patient Acuity	Length of Stay (minutes)	% of Total Emergency Patient Visits	Average Time Waiting for a Room (seconds)
1	160	0.3	1.6
2	220	15	10.2
3	220	49	3.1
4	90	31	7.1
5	30	4.7	5.2

Table 3: Scenario 3 based on wait times and volume of 90,000 patient visits per year.

Patient Acuity	Length of Stay (minutes)	% of Total Emergency Patient Visits	Average Time Waiting for a Room (seconds)
1	160	0.3	44.3
2	220	15	46.6
3	220	49	4.6
4	90	31	15.1
5	30	4.7	14.9

Table 4: Scenario 3 based on number of rooms and volume of 90,000 patients.

Type of Room	Number of Rooms	Turn-Around-Time (minutes)	Utilization Percentage
Critical Care	4	160 - 220	37
Emergent	27	135 - 220	55
Express Care	20	80 - 220	48
Intake	5	10 - 30	35

Table 5: Scenario 4 based on 10 fewer rooms with volume of 90,000 patients.

Patient Acuity	Length of Stay (minutes)	% of Total Emergency Patient Visits	Average Time Waiting for a Room (seconds)
1	160	0.3	76.5
2	220	15	71.6
3	220	49	2.2
4	90	31	17.3
5	30	4.7	7.7

Table 6: Scenario 4 (effect of 10 fewer rooms on turn-around-times and utilization).

Type of Room	Number of Rooms	Turn-Around-Time (minutes)	Utilization Percentage
Critical Care	4	160 - 220	33
Emergent	17	135 - 220	50
Express Care	20	80 - 220	56
Intake	5	10 - 30	29

Scenario Four

After confirming that the planned size of the emergency department could accommodate many more patients than projected, the team altered the simulation model to review results with 10 fewer emergent rooms. The patient volumes were kept at 90,000 per year, even though estimates were for a maximum of 74,000 visits per year. The results are shown in Table 5. The results showed an increase in wait time for patients, above one minute, but none exceeded two minutes. Room utilization slightly increased for emergent care rooms and decreased for all other room types, as shown in Table 6. This revealed that the planned facility size was bigger than necessary and rooms could be eliminated from the plan and design, thus providing savings in construction and maintenance costs.

3.0 CONCLUSION

Simulation is a great tool to test facility plans and space programs prior to design and construction of new or renovated facilities. Simulation studies can be used in the Lean design process to understand space requirements during the programming stage. Results can be predicted, and facilities may be right-sized to achieve the desired results. This particular facility chose to keep the room numbers as previously planned and repurpose some of the rooms.

Since developing the simulation model for this Health System's emergency department, the Perkins+Will Healthcare Planning + Strategies team plans to further explore uses of simulation modeling as a lean tool to support healthcare facility planning and design.

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