Case II: *Emergency Room Staffing*

Executive Summary

A hospital's emergency department (ED) handles 145 people on average per day and collaborates with other hospital services to share resources. Receptionists, physicians, lab technicians, treatment room nurses, and emergency room nurses are the main resources available and are limited. Data on the arrival process, service timings, and routing probabilities have been gathered, and theoretical distributions have been established to characterize each stage of the process. The hospital wants to make the process efficient for Category 1 patients i.e., critical patients by determining the configuration of resources that maximizes patient throughput while keeping the average waiting time within 3.5 hours and a budget constraint of not more than 10 business units.

The simulation model, developed using ExtendSim, incorporated data collected from a comprehensive survey and interviews with medical personnel. The interarrival times of walk-in patients followed an exponential distribution, with the mean value varying throughout the day. Ambulance patient interarrival times were fixed at 30 minutes. Service time distributions were also considered for each stage of the patient flow process.

In Part 1 of the study, the simulation model was used to determine the minimum staffing levels required to keep the average cycle time for Category 1 patients under 3.5 hours. Through trial and error, it was found that one receptionist, six doctors, two lab technicians, one treatment room nurse, and seven emergency room nurses could achieve an average cycle time of 2.50 hours.
In Part 2, an optimization model was introduced using the Optimizer block in ExtendSim. The objective was to minimize the average cycle time for Category 1 patients while restricting the labor budget to 10 budget units (BU). The model was set up for a 30-day simulation run, with one sample per case. The optimization solution yielded the optimal staffing configuration of one receptionist, six doctors, one lab technician, one treatment room nurse, and five emergency room nurses. This configuration resulted in an average cycle time of 3.045 hours and adhered to the labor budget constraint. To evaluate the effectiveness of the optimized staffing solution, the simulation model was run for 100 days in Part 3. The average cycle time achieved was 3.15 hours, consistent with the previous 30-day simulation. This indicated the stability and reliability of the optimized staffing configuration over a longer time frame.

The optimized staffing solution provides a balance between resource utilization, patient throughput, and budget constraints in the ED. By maintaining appropriate staffing levels, hospitals can effectively manage patient flow, minimize waiting times, and enhance the quality of care provided to Category 1 patients. Additionally, the simulation-based approach allows decision-makers to make data-driven staffing decisions that consider both patient needs and financial limitations.

In conclusion, the simulation study presented an optimized staffing solution for the ED, considering Category 1 patient cycle time and labor budget constraints. By implementing the recommended staffing configuration, hospitals can improve efficiency and provide timely care to critically ill patients while managing costs effectively.

Introduction and Motivation

The emergency department of the hospital accommodates two types of patient arrivals: walk-in patients and ambulance patients. Walk-in patients follow a queue and undergo an activity before the receptionist is released through the resource pool. Both types of patients proceed to the queue of doctors for examination. Depending on the assessment, they may be directed for further tests. For patients requiring tests, doctors are released through the resource pool, and the patients enter the test queue. Subsequently, lab technicians are released through the resource pool, and the patients re-enter the doctor's queue for reexamination. Finally, all patients are categorized into two groups: Category 1, comprising critical patients who enter the queue for nurses to undergo major treatment administered by both doctors and nurses and Category 2, comprising non-critical patients who wait for minor treatment after doctors are released and nurses are assigned for their care. Category 3 patients receive medication, and doctors are released accordingly.

The figure below shows the service system map of the hospital's emergency room. Data regarding the mean interarrival times and distribution of each resource processing time were given.

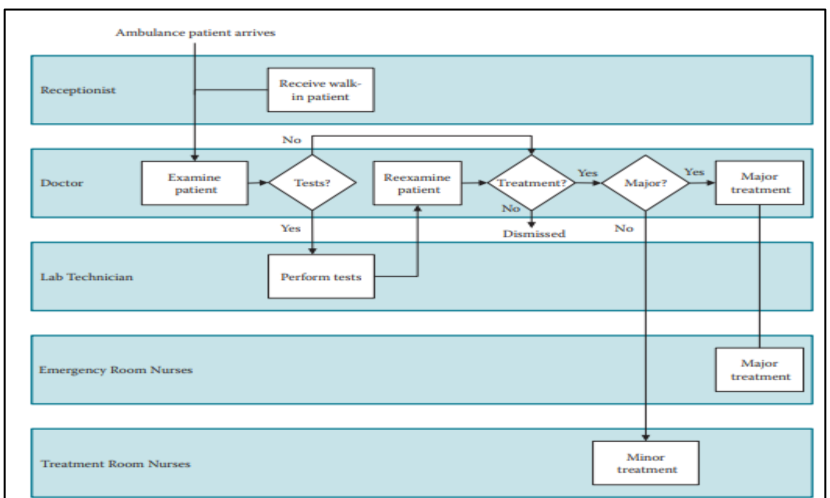

FIGURE 10.14
Service system map of emergency department.

Figure 1: Service System Map of the process

The hospital is concerned about the average waiting time of a patient and hence is looking to optimize the resource allocation and utilization such that the average waiting is within the specified limit of 3.5 hours and under a budget of 10 business units. By presenting two cases for this problem, one being the trial-and-error method on allocating the resources, and the second using the optimizer option in the simulation model, we were able to recommend the hospital the best solution.

Models and Methods:

As per the service system map, we built a simulation model with maximum resources available, for 30 days. The below figure shows the basic simulation model.

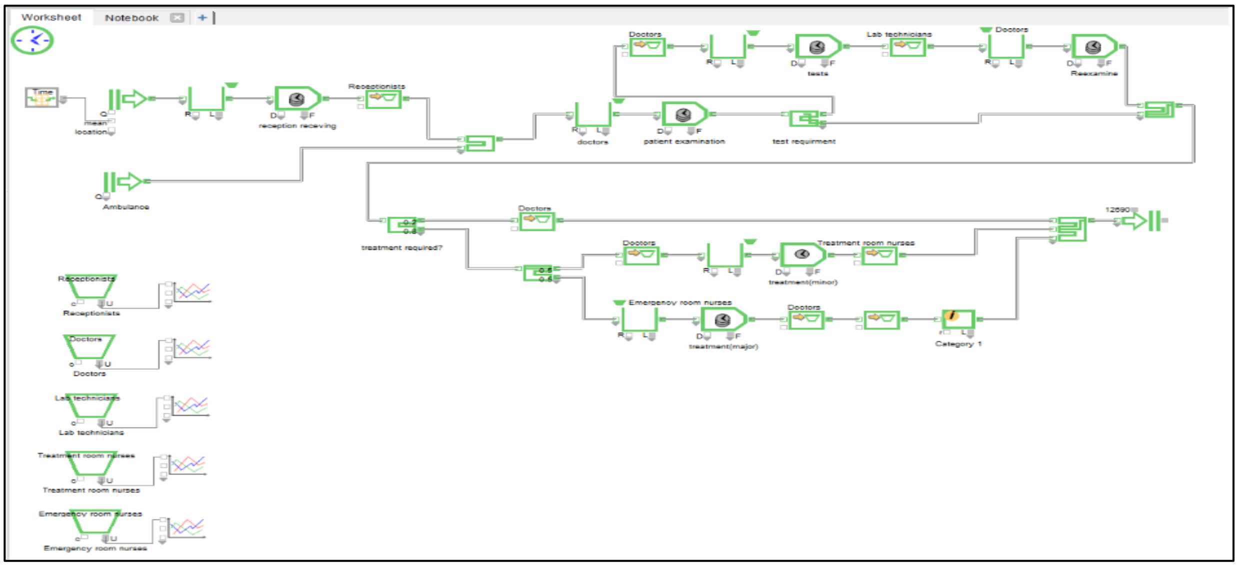

Figure 2: Basic simulation model for 30 days

The mean interarrival times of the patients are known. With the help of the lookup table, we could input the interarrival times of the patients. Having the information on the distribution of processing times for each resource, these were inculcated in the model.

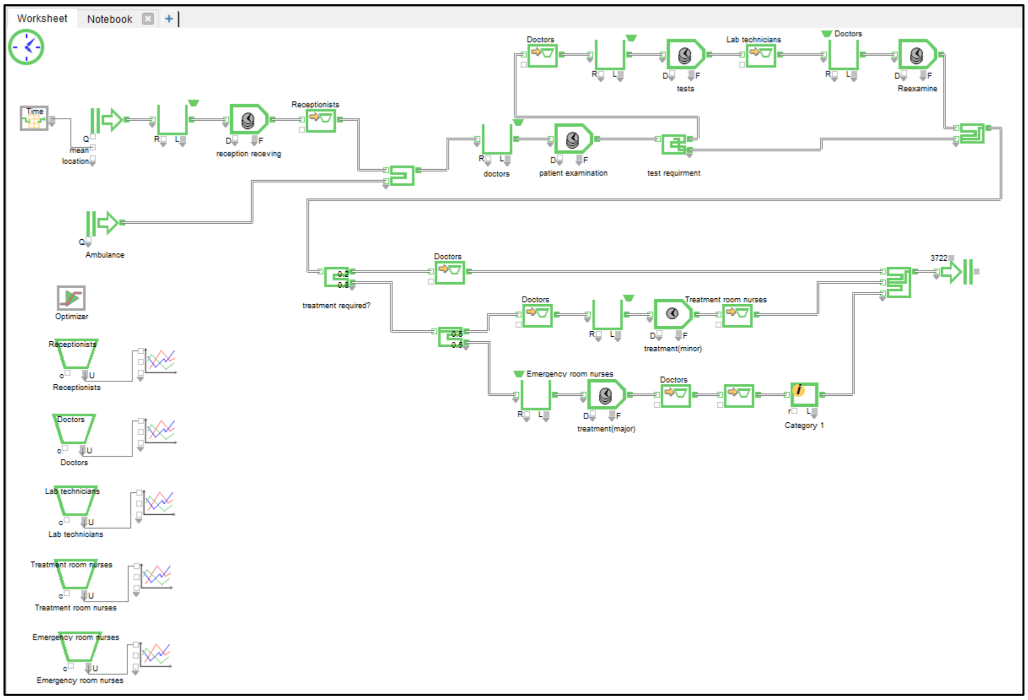

Figure 3: Optimized Model

To further solve this business problem, we used an optimizer block to optimize the model, inculcating the resource limits and budget constraints not greater than 10 BU.

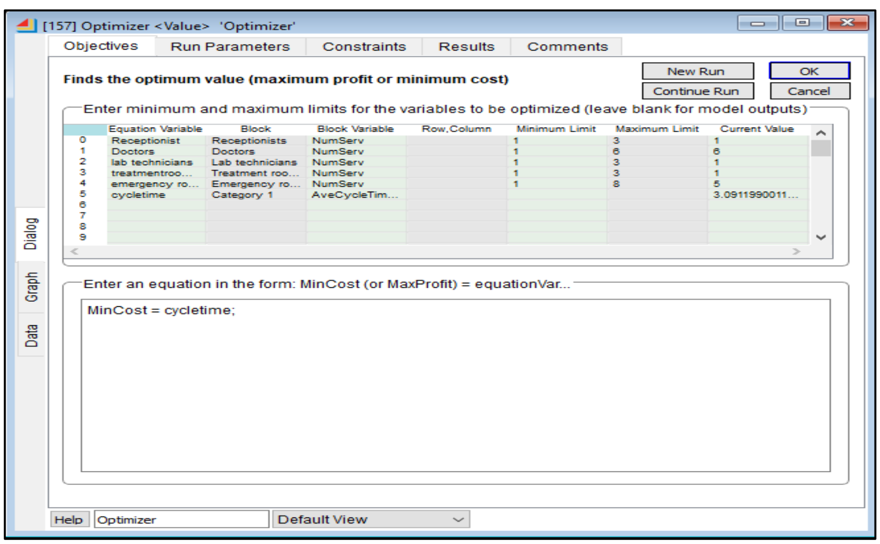

Figure 4: Resource Constraint and Objective Function

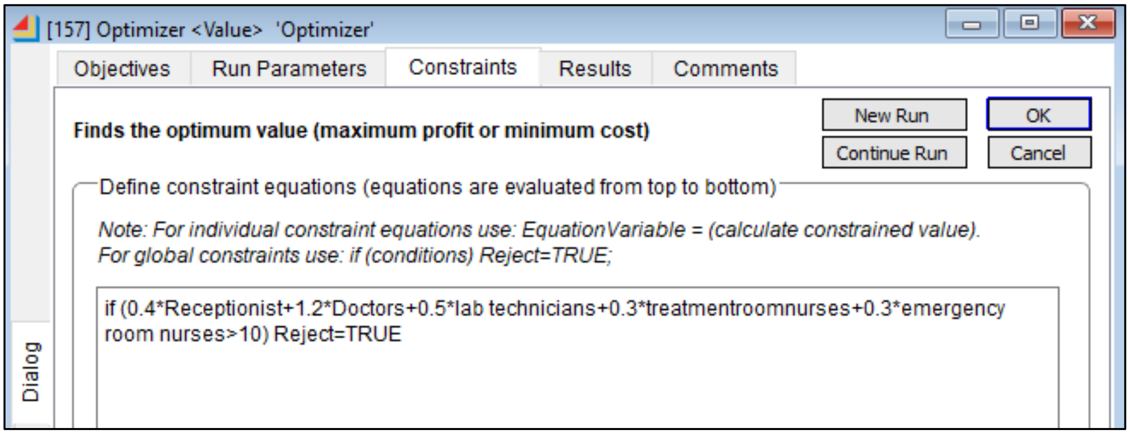

Figure 5: Budget Constraint

Overall, we have updated the model by including an optimizer block, specifying staffing limits, and defining the objective equation for cost minimization based on cycle time.

Analysis and Results:

- **Part 1:**

Initially, we conducted a 100-day simulation of our model using the prescribed staffing levels: three receptionists, six doctors, three lab technicians, three treatment room nurses, and eight emergency room nurses. The average cycle time is 2.47 hours. Through a trial-and-error approach, we refined the staffing configuration to one receptionist, six doctors, two lab technicians, one treatment room nurse, and seven emergency room nurses. As a result, we achieved an average cycle time of 2.38 hours.

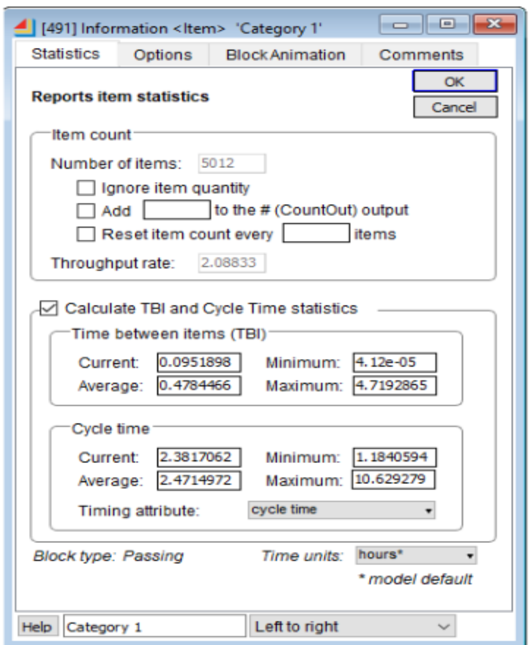

Figure 6: Average Cycle time for basic model

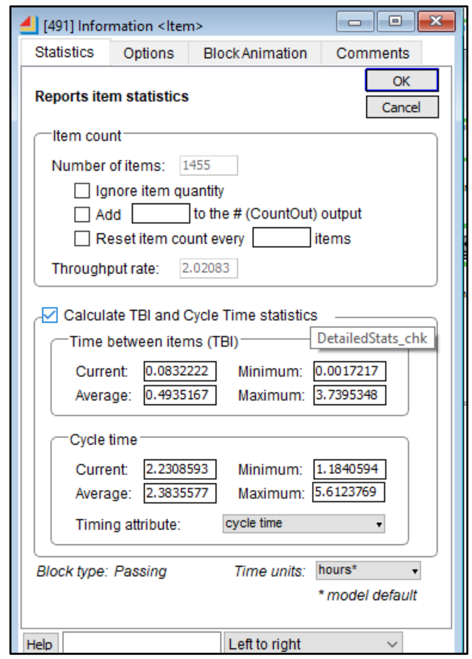

Figure 7: Average Cycle time for trial-and-error model

- **Part 2:**

We imposed a labor budget constraint of 10BU in our analysis. By running the model, we determined the optimal staffing configuration for a 30-day period to be <u>one receptionist, six doctors, one lab technician, one treatment nurse, and five emergency room nurses</u>. This staffing arrangement resulted in an average cycle time of *3.35 hours*.

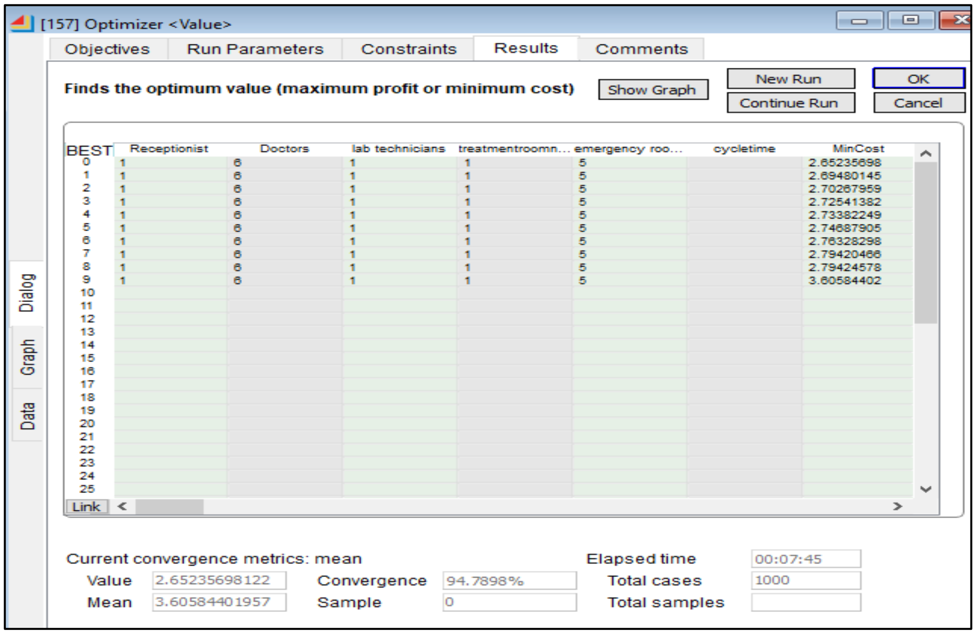

Figure 8: Optimal number of resources

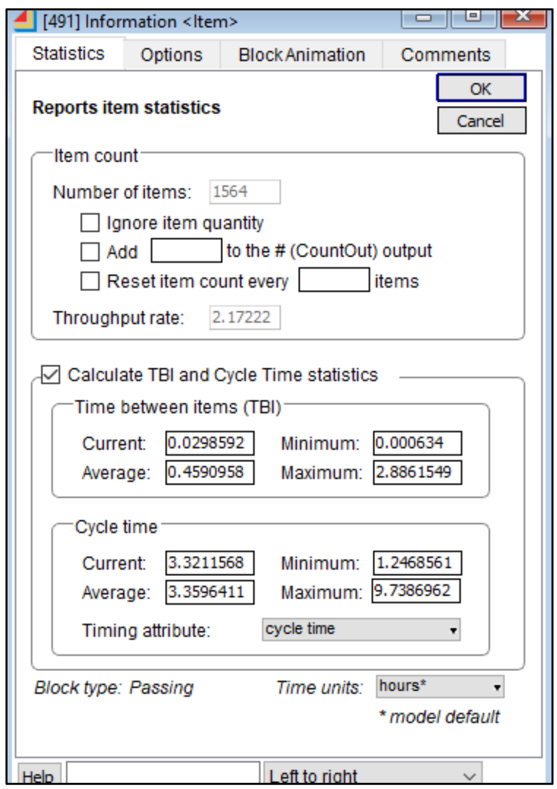

Figure 9: Average Cycle time of Optimized Model

- **Part 3:**

Once the optimized model is run for 30 days and the results are obtained, we then proceeded to run the same model for 100 days. We observed an average cycle time of 3.15 hours, maintaining the same staffing numbers throughout the simulation.

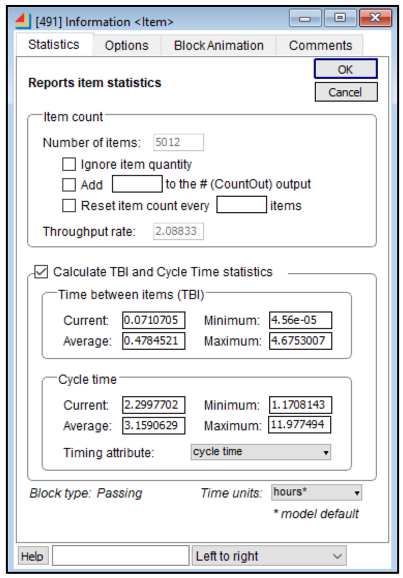

Figure 10: Average Cycle time of Optimized model run for 100 days

Comparisons of Performance Analysis based on Utilization -

The table below summarizes the utilization of each resource in both these models run for 100 days.

	Trial and error	**Optimizer**
Resource	*Utilizations*	*Utilizations*
RECEPTIONIST	40.40%	40.37%
Doctor	79.04%	80.1%
Lab Technician	43.5%	86.06%
Treatment Room Nurse	88.93%	87.86%
Emergency Room Nurse	43.11%	61.39%

It is observed that the utilization of doctors, receptionists, and treatment room nurses is almost the same in both these processes. However, the utilization is higher in the optimized model than in the trial-and-error model. We see that there is a drastic increase in utilization for Lab Technician and Emergency Room Nurse.

Comparisons of Performance Analysis based on Cycle Time & Cost –

The table below summarizes the cycle time and cost for both these models run for 100 days.

	Average Cycle Time	Max Cycle Time	Cost
Trial And Error	2.38 hours	5.61 hours	11 BU
Optimizer	2.99 hours	10.29 hours	9.9 BU

For the trial-and-error model, the average cycle time and maximum cycle time are lesser than the optimized model. However, the cost is exceeding by 1 business unit in the case of the trial-and-error model, whereas the budget constraint is met for the optimizer model.

Recommendations:

It is observed that there is a trade-off between the average cycle time and the cost proposed by these two models. We recommend that the hospital should consider the optimized model i.e., with one receptionist, six doctors, two lab technicians, one treatment room nurse, and seven emergency room nurses because the budget constraint is met with 9.9 BU, and the average cycle time is 2.99 hours.

However, if the hospital can decide on expanding the budget by 1 BU, the entire process from the patient entering the emergency unit to getting released by the doctor will be reduced from 2.99 hours to 2.38 hours.