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Analysis of Patient Flow Using Discrete Event Simulation for An Emergency Room: A Case Study of Bhim Hospital Rupandehi, Nepal

by

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A THESIS

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled "**Analysis of Patient Flow Using Discrete Event Simulation for An Emergency Room: A Case Study of Bhim Hospital Rupandehi, Nepal**" submitted by Sudin Khanal in partial fulfilment of the requirements for the degree of Master of Science in Technology, Innovation and Management.

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ABSTRACT

The Emergency Room experiences a daily influx of patients, putting significant strain on departmental resources. Concurrently, treatment duration for patients has risen, leading to dissatisfaction and prolonged wait times. Hospital management is exerting maximum effort within existing resources to mitigate these issues, with a primary focus on reducing wait times. To address these challenges, a Discrete Event Simulation is employed to simulate real-world scenarios and identify optimal solutions for reducing length of stay, wait times, and other contributing factors, thus bolstering the foundation for robust decision-making. Bhim Hospital's Emergency Room serves as the case study, assessing wait times, length of stay, and bed utilization. Experimental scenarios are applied to the model, aiding the hospital management team in decision-making processes. Selection and rejection of strategies are based on paired test analyses, comparing real-world hospital data with results generated by the simulation model. Given the feasibility of all scenarios in decreasing length of stay, and bed occupancy rates, the results are recommended to the hospital for implementation. The time to stay for Red zone, Green zone and Yellow zone patients is 6 hours according to hospital data and simulation suggest of 3,4 and 5 hours respectively, this also suggest on decreasing of length of stay in the hospital.

The percentage of RED BED occupy by Red zone patients in Base case is 16.64%, whereas for REST BED is 10.06%. Similarly for alternative 2, slight reduction in bed for both RED BED and REST BED of 10.21% and 6.724% respectively. Furthermore, by adding one more Physician decreases bed utilization to 10.62% less then base case and for REST BED to 7.39%. Finally, adding a path lab inside the Emergency room and only one Physician increases the RED BEDS utilization, but decreases in REST BED utilization by 17.097% and 9.467% respectively.

Keywords: Emergency Room, Physician, Health Assistant, Acuity level, Discrete Event Simulation

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LIST OF ABBREVIATION

ER: Emergency Room

ESI: Emergency Sensitivity Index

DES: Discrete Event Simulation

LOS: Length of Stay

HA: Health Assistant

CHAPTER ONE: INTRODUCTION

1.1 Background

The increasing concern for healthcare quality has made the healthcare industry essential for people. With this rising concern, the time taken for check-ups has also increased, highlighting the strain on healthcare resources such as human resources and testing equipment (Fadhil, Jusop et al., 2012). Public healthcare institutions are facing challenges due to long waiting times for services (Ghazali et al., 2011). Tehrani, Feldman, Camacho, and Balkrishnan (2011) conducted a survey revealing that waiting time significantly affects patient satisfaction. In Nepal, the government has released the National Health Policy, emphasizing the optimal use of healthcare sector resources within financial constraints to deliver high-quality healthcare services and enhance the efficiency and effectiveness of the healthcare system. Research conducted by Kharel, Ramu et.al., (2023) founds that emergency room of government have not follow the proper protocol of emergency room, that cause pressure on the system, thereby increase in waiting time for patient.

In Nepal, both public and private hospitals are popular, especially public hospitals that accept health insurance at lower costs. Public hospitals include Federal/provincial-level, local-level hospitals, community hospitals, sub-district health promoting hospitals, university-affiliated hospitals, and other related healthcare centers. According to the Ministry of Public Health and National Statistical Office in Nepal, 215 public hospitals and 366 private hospitals were actively operating in 2022. In Nepal; in 2018, the doctor to population ratio was 0.17:1000, the professional nurse to population ratio was 0.5:1000. The World Health Organization (WHO) recommends a doctor to population ratio of 1:1000. Comparing this ratio to Nepal’s, it shows a higher doctor's workload leading to overcrowded hospitals and long waiting times at public hospitals.

Bhim Hospital, located in Siddarthanagar, Rupandehi, Nepal, is a public hospital positioned at the city's heart. The hospital serves over 90,000 outpatients and more than 12,000 emergency room patients in a fiscal year. It has a total bed capacity of 70 beds, with 15 beds are dedicated to the emergency room and additional space for up to 20 more beds in Emergency Room. The queue starts from triage following registration, Health Assistant and their assistant, Doctor checkup, test room and

finally to last visit with doctor after the results are obtained from each department.

The Emergency Room at Bhim Hospital operates 24 hours a day, with three shifts for each doctor and paramedic. Each shift includes two health personnel, one from each team. To manage the busiest hours from 10 AM to 5 PM, the hospital has enlisted the help of intern students in the paramedic field to support the medical team. Despite this, as a public hospital, its official opening hours remain from 10 AM to 5 PM. The hospital experiences its busiest days starting from Sunday, with a decreasing order of business up to Saturday. Additionally, the busiest day is often the day after public holidays. Patient influx varies according to the season, with more patients seeking services in the summer and fewer in the winter.

Patients enter into the hospital through generally two media; walk-in and an ambulance. As the percentage coming through ambulance seems 3.1%, whereas walk-in patients are 96.6%. Data of patients interarrival time were obtained from hospital electronic data sheet. Total data for three months (from Mangsir 2080 to Baishak 2081) were used to analysis purpose of total 4626 number of cases and total number of cases for last 6 month is 7207. Analysis was further carried on excel sheet in order to get desired data. The sample include arrival rate for each hour and average arrival rate for a month was obtained from 3 months average. Following figure represents the patient's inter-arrival time., and the 4month average arrival data is in Appendix below.

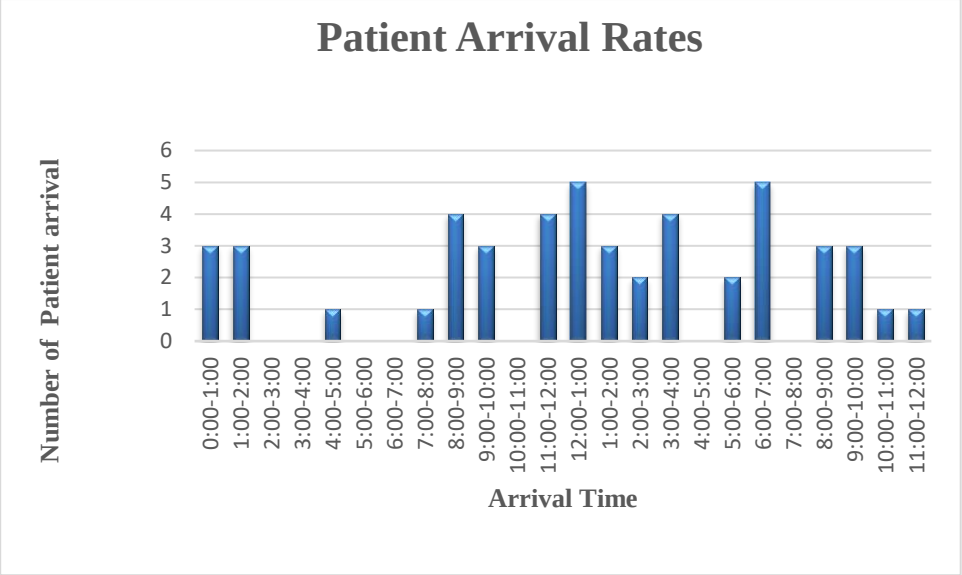


Figure 1.1: Average Patient inter arrival rate for a month

The process that a patient follow during entry of the system involves entry to triage room, first doctor visit, then paramedic visit, second doctor visit, examination room, second doctor visit and finally decision for the patients. After report of patient is seen by the doctor from the reports, he will decide whether the patients will be inpatients, follow up patients and referral patients, the level of severity will be used and priority will be given to red zone patients and then to yellow zone patients and finally to green zone patients. Then the system use by patients will be completed and the flow pattern of the patient using the emergency room is by block diagram below:

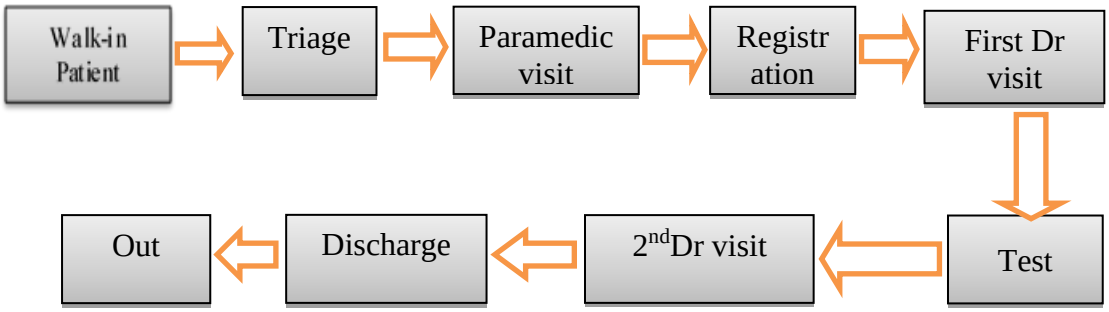


Figure 1.2: Flow chart of patient entry to exit during system engagement

The data collected was from the hospital's database that include information of patient's record like entry time, ticket time, doctor visit, lab time, and finally discharge, refer or inward admission time. There were 13794 usable patient data. Last one year of continuous data were collected for our observation. Then data thus collected were analyzed before we could utilize them for designing our model.

Appropriately distributing emergency room resources can significantly impact costs, the quality of care, and patient satisfaction, especially in terms of throughput. Key resources such as staffing (including physicians, nurse practitioners, nurses, and support staff), examination rooms, and available appointment times require careful allocation decisions. Emergency room challenges can be broken down into four interconnected components: predicting demand, analyzing practice patterns, determining facility size, and staffing appropriately. Improving quality by reducing waiting times at public hospitals seems challenging, as patient flow patterns and service nature cannot be determined instantly. Many recommend utilizing discrete-event simulation (DES) for modeling healthcare systems (Jacobson, Hall & Swisher, 2006). Since the health system fits the simulation characteristics like creating an independent entity, no change in the system in between events, and modeling a sequence of events in time, DES is a promising tool.

Discrete Event Simulation (DES) is being employed to analyze patient flow within Bhim Hospital's emergency room, encompassing not only the waiting line but also ancillary facilities such as the Path lab, X-Ray, and CT scan lab. The simulation method adopts an experimental approach to assess different scenarios, aiming to optimize the patient journey and ultimately enhance system performance. Through the utilization of probability distributions and random sampling, DES constructs models that closely mirror real-world dynamics, offering valuable insights for decision-making processes.

1.2 Statement of Problem

The prolonged duration of resource consumption in the healthcare sector poses significant challenges in providing quality and timely services, raising concerns about the sector's overall effectiveness. Healthcare providers are striving to reduce waiting times and optimize resource utilization to enhance patient throughput. To address these challenges and optimize resource allocation, researchers are increasingly turning to simulation models as a promising methodology. Simulation, a tool in operations research, uses numerical and mathematical models to represent real-world problems. Widely applied in fields such as military strategy, business, and healthcare, simulation involves logical and mathematical modeling, using computers to simulate system behavior under controlled conditions through iterations and trials.

The influx of patients in the Emergency Room(ER) creates pressure throughout the healthcare system, leading to longer wait times for patients to receive care. Limited human resources, such as physicians and paramedic teams, mean that patients may need to consider alternative options, which can be risky as it involves human life. Patients cannot proceed without proper diagnosis, and waiting in queues further adds to their frustration. This is evident at each stage of the healthcare process, from entry and triage to registration, paramedic checkups, and examinations in departments like Pathology and Radiology.

This study focuses on an in-depth analysis of an Emergency Room (ER) within a hospital, selected as a case study. It aims to examine how the system is utilized by patients, healthcare professionals (doctors/nurses), and various departments such as the lab and pathology department. The study seeks to provide insights that can inform decision-making, enabling prompt responses and the delivery of high-quality services, ultimately saving lives.

1.2 Objective

1.3.1 Main Objective

The primary objective of this study is to discern the patterns governing the utilization of patient flow time within the healthcare system, with a specific emphasis on creating a comprehensive simulation model for the system.

The specific objectives guiding this research are as follows:

1. To develop a robust Discrete Event simulation model that serves as a predictive tool for analyzing real-world problems within the Emergency room.
2. To analyze experimental scenarios in the Discrete Event simulation for minimizing length of stay, waiting time and bed utilization.

CHAPTER TWO: LITERATURE REVIEW

The examination of time and motion, dating back to the early industrial era, initially centered around the production of diverse products. Through the analysis of time in service delivery and the optimization of ideal time, resources can be efficiently utilized by leveraging statistical data and employing computer simulation models. Research efforts, as indicated by a S.H. Jacobson et al. (2006), underscore the increasing application of operations research techniques and simulation methodologies within the realm of healthcare.

Survey research conducted by J.B. Jun et al. (1999) emphasizes the suitability of simulation in addressing healthcare system challenges, establishing itself as an effective tool for modeling processes and facilitating improvements. M.M. Gunal et al. **(**2006**)** in their analysis of performance targets within healthcare systems, highlight the pivotal role of simulation models in optimizing resources, planning capacities, and enhancing staff and resource utilization. Their findings indicate the efficacy of applying such models beyond healthcare, presenting a versatile approach.

W. Abo-Hamad's (2013), exploration of an interactive simulation-based decision support framework delves into the improvement of healthcare processes. The study specifically notes the applicability of simulation models in Emergency Rooms (EDs), particularly in scenarios where resources are scarce, and patient arrivals follow irregular patterns. Notably, there appears to be a gap in research pertaining to the simulation of irregular patterns and time consumption within the health sector of Nepal. The work by Ahmed et al. (2009) introduces a discrete event simulation-based optimization model for determining optimal staffing levels in an emergency department. Their approach, aiming to maximize throughput while adhering to budget constraints and patient waiting time criteria, demonstrates the feasibility of simulation-based decision support frameworks.

Maureen C. Leckie et al. (2016) successfully employed a simulation-based decision support framework in an ER redesign project. The outcome was the achievement of a performance goal—ensuring that over 80% of patients experience a Length of Stay (LOS) under three hours. Andersen et al., in their work involving simulation modeling based on Markov Chain models, derived near-optimal solutions with a relative gap of just 1% from the optimum. This approach showcased its effectiveness in enhancing

day-to-day processes within healthcare. Beaulieu et al. (2000) and Basler et al. (2003) explored mathematical programming and simulation models, respectively, for optimizing healthcare resource allocation and estimating maximum capacity in an emergency room. Huguethee et al. (2000) focuses on the scheduling Physician by using mathematical programming. Result shows of reduction of schedule within one day and this increase the productivity of Physician and helps in Emergency Room for reducing waiting time.

Kazi et al. (2019) analyzed on various analytical models for optimization of Emergency Room resources for improving patient flow by studying on various optimization technique that focus on reducing waiting time, length of stay. Ibtissem et al. work on optimization of medical and paramedical human resources in order to improve the quality of the service provide to the patient and reduces the waiting the waiting time of patient and average inpatient stay.

Abdeljeli et al. (2018) studied on improving length of stay by simulation and experimental design. Reducing of waiting time for registration and improvement of the treatment time for patients under observation. They conclude on increasing in number of beds and established separate unit for a short -stay patients under observation.

Amh et al. (2019) uses optimization of health care facility resources such as manpower and medical equipment. They conclude on reducing health care, overcoming the problem of lack of limited nursing staff resources with maximum uses of resources.

Lenardo Bedoya et al. (2016) analyzes on resource allocation for reducing patient length of stay and time to be seen by Physician or Physician Assistant while leveling resources utilization resource utilization. The experiment analysis on DES simulation show result of on average reduction of 14% in the average patients' length of stay, 16% in average patients' time to be seen by Physician or Physician Assistant when allowing restructure of the Emergency Room resources.

These studies collectively emphasize the widespread focus on resource optimization within healthcare systems. Drawing inspiration from this body of work, the proposal to conduct an analysis within the Nepalese context emerges as both feasible and

solution-oriented for decision-makers in the health sector. The utilization of simulation models offers a promising avenue for addressing challenges and optimizing resource allocation in the unique healthcare landscape of Nepal.

Nagershwaraniyer et al. have created the simulation driven frame work to effectively strategize the usage of the material handling system in a prominent coal mine. Their approach employes a discrete event simulation model to optimize the coal mining process followed by utilizing Op Quest to determine the best train loading solution and material handling system scheduling, aiming to maximize the coal mines revenue.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Problem Identification

The patient arrival pattern at hospitals is inherently variable, with arrival times for medical checkups differing based on the time of day, day of the week, and even the month. Data collection for this study was conducted through observation, with the total number of patients using the facility gathered from the data recording and collection department at Bhim Hospital. Data collection was performed twice, once in winter and once in summer, as the number of cases was found to vary with different weather conditions. Additionally, it was noted that Sundays were slightly busier, with a decreasing trend in patient numbers as the week progressed, reaching a low point on Saturdays. Waiting times for patients were observed to exist on any day of the week. For this study, the flow chart depicted in a figure was followed. After problem identifying the process to go through the study process, work done by various scholars on the selected topic was carried out.

3.2 Literature Review

Literature regarding the topic was studied in a thorough manner, including all areas studied by different authors that mainly focus on the optimization of the Emergency Room (ER) and related work in the periphery of the topic. Studying different authors' work gave a precise idea for the process ahead to carry out. Study was mainly focus on the papers works that were studying about the patient waiting time. From manufacturing industry to service industries, line is ubiquitous that make burden for decision making. For this study it was focused on Emergency Room length of Stay, waiting time and their bottleneck, along with the process adopted for solution.

3.3 Data Collection

The data were collected on first hand observation basis and the interview with Emergency room nursing head, data form emergency record book and expert of the hospital in case of verification of the data. First of all, observation-based data for interarrival patient flow was recorded, manually. As an electronic recording was available for recording of arrival times of patients, data of three months were taken from emergency patients record book. Saff scheduling was made after an interview with head of emergency room and is shown in table 2 below. Generally, 1 Physician is available for 24 hours in three shifts from 8Am to 2PM, 2PM to 8PM and 8Pm to 8AM in the morning. Similarly, Health staff with one in number in similar shift are

available. Since 10 AM to 5 PM is officially opening hours and flow of patients seems very high during this time, additional internship students in 2 number are allocated in this time, by combining 3 Health Assistant in total for busy period.

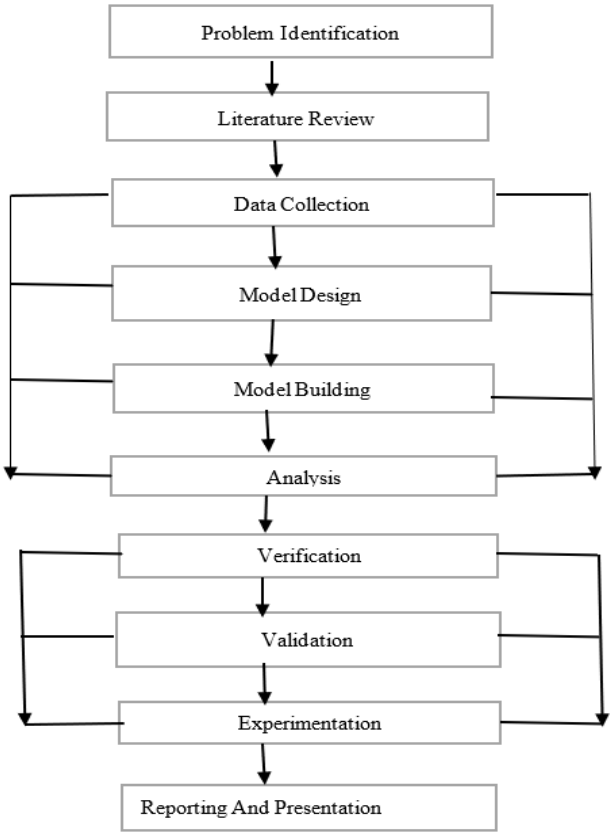


Figure 3.1: Flow chart of Work Methodology

3.3.1. Interarrival times

Inter-arrival times refer to the time difference between the arrival of the patients, and it depend upon the ways of arrival, Walk-ins, Ambulance and police to the emergency. It was found that the majority of the patients were either Walks-ins patients (96.9%), and Ambulance (3.1%).

Table 3.1: Mode of Arrivals in percentage (from Mangsir 2080 to Baishak of 2081)

Modes of Arrival	**No of Patients**	**Percentage**
Ambulance	223	3.1
Walk-in	6984	96.9
Grand Total	7207	100

In our model, we differentiated between ambulance arrivals and walk-in patients to

determine the inter-arrival time distribution for patients. Upon analyzing the data, we noticed that the arrival patterns for walk-in patients didn't conform to any known distribution. Therefore, we opted to use real-world arrival rates, basing our calculations on a four-month average to derive a monthly average.

3.3.2. Staff Scheduling Data

As for the simulation of the base case scenario in model, the current staff allocation and scheduling data was obtained from Emergency Room. The schedule is divided into 3 shifts where the duration varies among Doctor and Health Assistant.

Table 3.2: Staff Scheduling Data

Shift	Schedule	Number of Doctor	Number of Health Assistant
1	8AM-2PM	1	1
2	2 PM-8PM	1	1
3	8PM- 8AM	1	1

3.3.3 Resource Utilization by Acuity

The patient passes through triage after the arrival to the ED, where their acuity or severity of ailment is categorized into 3 ESI levels ranging from green, yellow and red zones. Patients with Red zone is in the most severe condition and demand the greatest number of resources, and treatments start as soon as possible, Whereas Yellow zone with medium and treatment start within 15 minutes. For Green zone treatment start once all process of entry is completed. Below is the percentage of patients for each ESI (Emergency Severity Index) level -it separates red zone, green zone yellow zone patient, obtained from hospital's record.

Table 3.3**:** ESI percentage

ESI Level	Percentage of Patients
Green Zone	70
Yellow Zone	22
Red Zone	8

Information related to the allocation of resources for patients with each ESI Level was also obtained. The test like Blood test, CT-Scan, X-Ray depend upon the ESI of the patient. Similarly, the requirement of human resources (health assistant, Doctor, Emergency medical Technician (EMT) also depend upon the ESI level of the Patient. Following table defines physical and human resources for patients with each ESI level.

Table 3.4: Human and medical equipment resources.

ESI Level	**Human Resources**			**Physical Resources (Tests)**			
	Doctor	**Health Assistant**	**EMT**	**Pathology**	**X-Ray**	**Ct-Scan**	**Risk**
Green	1	1	1	✓	✓	✓	Low
Yellow				✓	✓	✓	Medium
Red				✓	✓	✓	High

3.4 Model design

Before implementing in the software, the process time in each and every step was identified. As the t patient will do second visit once all the lab results are in his hand, the Pathology lab processing time was found to be time taking point adding more waiting time, as the Pathology lab operate more than any other lab of the Bhim Hospital. The model was design and flow chart as shown in figure 4 was implemented. Model design was carried out in order to continue the research work. In order to carry out the analysis, it's important to discuss with the Medical Superintendent of Bhim Hospital about the nature of the thesis study and the scope of the study. For simulation modeling, it's crucial to know the pattern of patient flow in advance. Typically, for simulation modeling, one of the following distributions should be known: Poisson, Exponential, and Weibull distribution. Also, if no any pattern is observed then average arrival rate of patient in particular time is used. In this study as no distribution was seen, we have used an average arrival rate of 4 weeks of a month. it's important to note that the busiest time for patient arrival was between 10 AM to 3 PM. After the model design was done than model was developed. Recording of data starts once the patient enters the system to receive service. The following data points are recorded: time of arrival, waiting time before the first meeting with the paramedic team, registration time, first meeting with the doctor, tests to be carried out, and the second visit with the doctor. The study focuses on walk-in patients, as ambulance arrivals account for less than 3% of cases. Patients entering the system need to wait in

the triage room, except for those arriving by ambulance, who are sent directly to the Red zone for immediate life-saving processes. Then patients are sent to Triage area where severity of patient is checked and once patient are identified by severity level then they will assign abed. List of severity is listed in table 9 of Appendix after discussion with Physicians of Bhim Hospital. After counseling by the paramedic team, patients are sent for the registration process. There will be waiting time during the registration process. After registration, patients are sent to the doctor's room for screening if the physician is busy then patient has to wait for their turn. Following counseling by the doctor, patients are sent for further testing, which may include visits to the Pathology lab and Radiology lab, depending on the patient's requirements as identified by the doctor.

The Pathology department at Bhim Hospital uses equipment with result times ranging from 30 minutes to 60 minutes. Patients need to wait in line before taking out their blood for the testing process. The Radiology department includes X-ray and CT-Scan, each with their respective time ranges for obtaining results, depending on the nature of the case. For X-ray, the process follows a Triangular distribution with a minimum of 5 minutes, a maximum of 20 minutes, and an expected time of 20 minutes.

For CT-scan, the process follows a range of minimum 15 minutes to expected 30 minutes and maximum 60 minutes, with the total time for the patient varying as they might be waiting after entering the department for treatment. All data were recorded during the observation process, and each department was interviewed for the likelihood of the time frame.

3.5 Model Building

After collecting the data, the model design process was initiated. The design thus model assembles the real-world scenario of emergency room that will accuracy reflect the simulation. All design were considered by in each and every path patient will take during his visit to emergency room. All waiting time were considered and patient are allowed to take final visit to Physician once all reports are obtained from each laboratory. After model was design it was implemented in the simulation software that is programmed and worked on Discrete Event method and SIMIO version 17. Patients were given name as entities, each station like triage section was named as source, similarly for registration, Physician, Health Assistant (HA) and their assistant, each lab; Pathology lab, Xray lab and CT scan lab were called as source-there is

entry, processing and output system available in the software and discharge as sink. As all patient need to do blood test so they are first sent to Pathology lab and according to condition and as prescribe by Physician any of the department is used. The data for emergency room was only considered.

3.6 Analysis

Following the model formulation in SIMIO software version 17, an analysis was conducted by running the software in its current state to observe whether any faults occurred. After verifying that the input, processing, and output were functioning correctly, the animation feature of SIMIO was utilized. Any bugs encountered during this process were then identified and addressed.

3.7 Model verification

After successfully running model without any error generated, then verification of the system model was carried, in this the animation system as provided by the SIMIO was displayed in the model so that number of patients entering the system was notice and recorded. Bed, Physician and HA utilization were also recorded so that everything were working. And thus, obtained data were compared with the result obtained from Bhim hospital ER, and finally verification was done.

3.8 Experimental

After verification and validation process, experimental setup was carried out in the platform that was designed in the software. During this process real world case was taken as base case as, comparing is to be done on the basis of this. Three more scenario was created namely; 1 more Physician with same blood processing time, placing Path lab machine in the ER, and 1 more Physician and a Pathology lab machine. After successfully running the model, data thus obtained, namely- average LOS of each entity, maximum average LOS of each entities, minimum average LOS of each entities and RED bed utilization (in percentage) and REST bed(means bed for green and yellow) were recorded and paired test was carried out. Once the comparison in paired test was done and result were recorded.

3.9 Validation

After the experimentation process, the result needs to be verified, and it was done with consulting with hospital Physician. Also, validation process involves the cross

checking of the model data and the number of patients that are already in the system. For example, model showing total 34 number of patients in the model for 14 hours, and on fetching information from Emergency Room their data was 38, hence it provides the validity of the model. Next step is of Reporting and Presentation, which involves the documentation process.

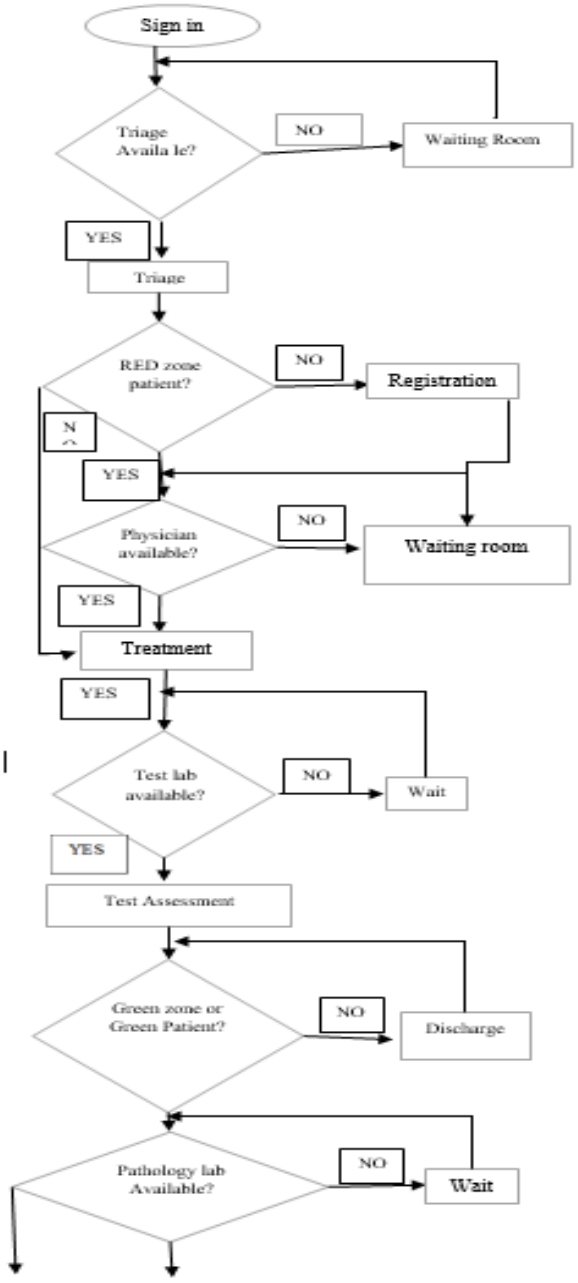
3.10 Reporting and Presentation

After the data collection, model design and building, experimentation analysis, the result thus obtained was recorded and get ready for the presentation. Finally, the model that mimic the real-world data was created along with the alternative were developed, reporting and documentation was done.

CHAPTER FOUR: RESULT AND DISCUSSION

4.1 DISCRETE EVENT SIMULATIONMODEL

SIMIO software version 17 uses Discrete Event Simulation method for analysis in simulation. This simulation software helps to analysis in different prospect for ER. For finding data of patient's throughput (length of stay), health resources use, decision for addition of doctor or paramedic. The flow chart displays all the information of model simulation.



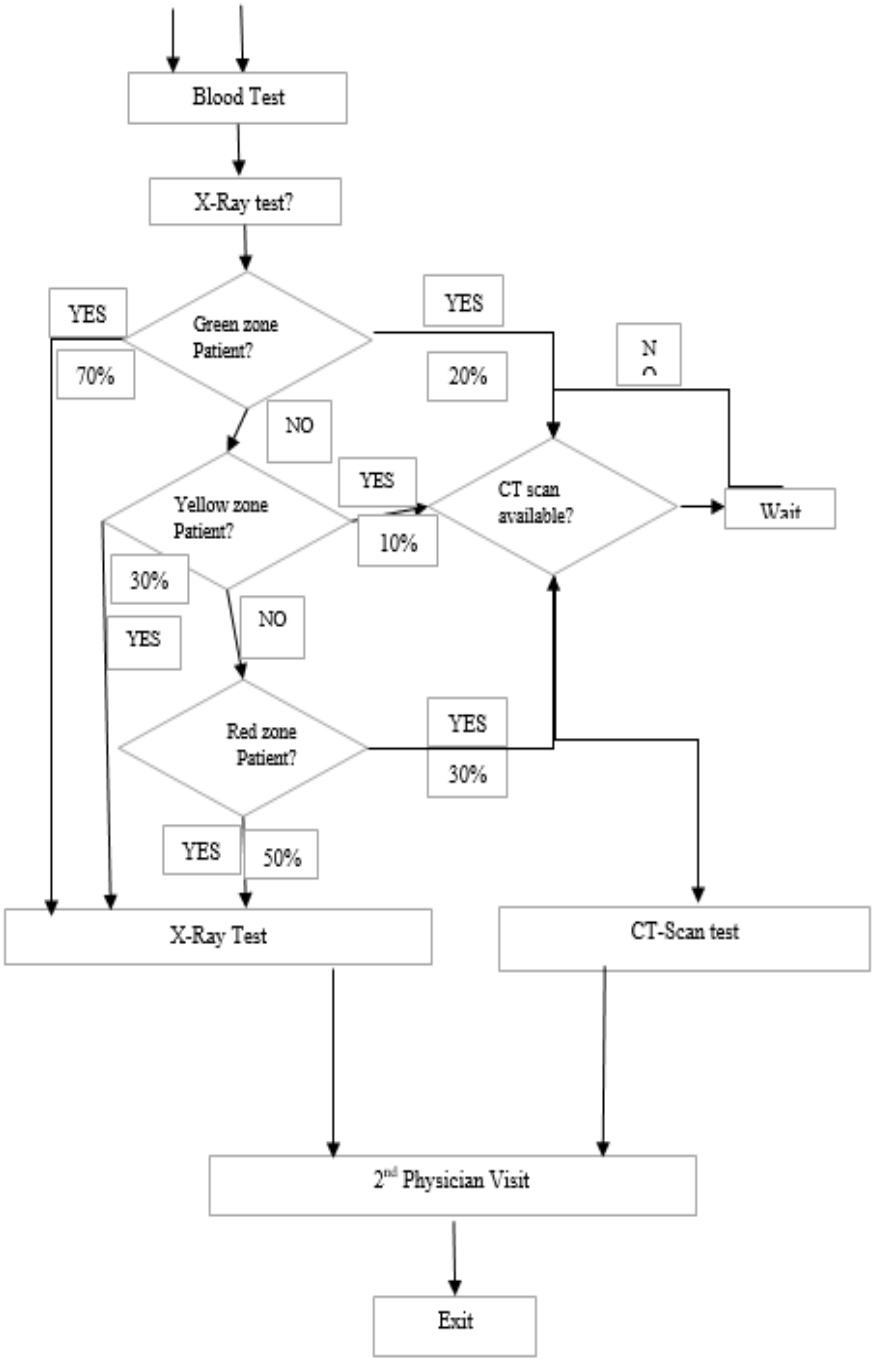


Figure 4.1: Flow chart for model development.

Flow chart of figure 4, above gives information about the logic for model formulation. At first patients arrive into sign in process where they are directed to triage section, in this section patients are classified according to severity level. Red patients-who need immediate care are directly sent to bed and initial treatments start. For Green and Yellow zone patients they are sent to registration, after registration if beds are available, they are assigned to bed else are kept in waiting room. Before sending to

beds, they have first visit with HA and their assistant for Vital and recording of their demography. Once the Physician room is available, they are sent to Physician room else have to wait. As the treatment begin, Physician starts checking and take history, and 100% of Red zone patients are send for Pathology lab, 70% for X-Ray, and 30% for CT scan. Whereas for yellow zone patients 80%,50%and 30% are sent for Pathology lab, X-Ray and CT scan. Also, 60%, 30% and 10% Yellow zone patients are asked to take test of Pathology lab, X-Ray and CT scan respectively. After all the reports are available, then they have second visit with Physician for either follow up, or inpatients admission or referral.

The following information of processing time is used for the modeling process.

1. **Processing time for various steps**: The processing time required in each and every step (Sign-in, Triage, Registration, first (Doctor visit), Health Assistant visit, Second (Doctor visit), X-Ray, Blood Tests, Ct- Scan) in ED. The data was collected on observation basis for 1 week in winter (Poush) time and 1 week in summer time (Chaitra), also interview survey was also conducted where Doctor, Health Assistant, Pathology, X-Ray and Ct-Scan were asked about the optimistic (best case), most likely (Expected), and pessimistic (worst case) amount of the time required to complete the steps. The following table provides the time distribution for every step/ process categorized into the ESI levels.

Table 4.1: Processing time for various stages.

Process	Green	Yellow	Red
Triage	Triangular (2,5,7)	Triangular (2,5,7)	-
Registration	Triangular (2,5,10)	Triangular (2,5,10)	Triangular (2,5,10)
First Doctor visit	Triangular (2,5,10)	Triangular (2,5,10)	Uniform (5,10)
Health Assistant visit	Triangular (0.75, 2, 5)	Triangular (.75,2,5)	Triangular (.75,2,5)
Second Doctor Visit	Triangular (2,5,10)	Triangular (2,5,10)	Triangular (2,5,10)
X-Ray	Triangular (5,10,20)	Triangular (5,10,20)	Triangular (5,10,20)
Ct-Scan	Triangular	Triangular	Triangular

	(15,30,45)	(15,30,45)	(15,30,45)
Pathology	Uniform (30,60)	Uniform (30,60)	Uniform (30,60)

4.1.1 SIMIO Modeling

The formation of model was created according to the flow chart that patient will enroute. All the human resources available within the Emergency room was considered as an element of model. In case, staff coming from Pathology lab to Emergency room for blood withdraw of Red zone Patient are not counted, since their timing assemble with Health Assistant time and also very little time that can be excluded. As in real world the analysis is done on the basis of inter-arrival time of patients and the process they take during their treatments. Patients are taken as entity and they are classified according to entity level; Red zone patients, Yellow Zone patients and green zone patients with respective of their probability of taking the facility. The detail information is shown in Table 3.

4.1.2 Model development in software

For the simulation SIMIO software is used, and modeling was done with the software. Once model was created, the patient inflow inter-arrival time was set up. The interarrival rate was obtained from the average arrival rate of one month that was obtained from the electronically available data from hospital.

For each replication of the simulation represents on working day, so the replication will end only when the last entity (patient) leaves the system and the length of iteration is 1400 minutes (24 hours). Kelton et al. (2006) provides equation for calculating the number of replications to ensure the error and is calculated by using following equation:

$$n* = n \times \left(\frac{h}{h*}\right)^2 \quad \ldots\ldots\ldots (1)$$

Where, n*= number of simulations that satisfied the error construction

n= number of simulations that was assumed for the running of simulation

h= half width of the initial run

h*= required half width to satisfied error constraints

For our case, n=30,

h= 0.215 hour

h*= 0.167 hour

∴n*=52

We have used 52 number of simulations in order to get the solution.

4.1.3 Arrival

Once the patients arrive in arrival module their time starts and the symbolic representation is shown as in the figure below:

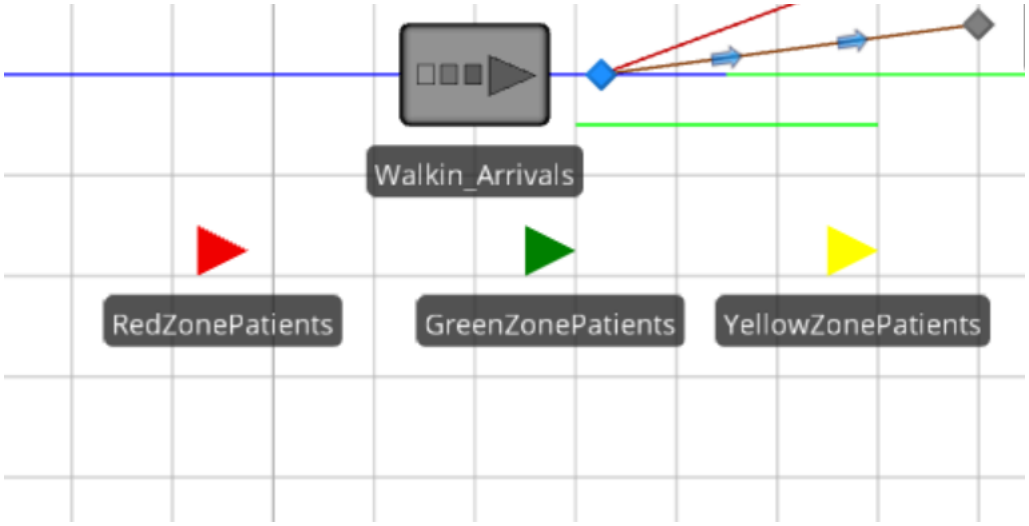


Figure 4.2: Model representation of simulation for patient entry

As in above figure patient enters into the system and the purposes is to take checkup. In an emergency Room patient may be of any acuity level, so acuity level is entity (mean for each category of patients Red zone, Green zone and Yellow zone) is made. For our purpose there are three types of patients so 3 entities are made, and patient will be created on the basis of this. After entities level acuity level, along with the priority order (for service) are assigned, for acuity level 1 that is Red zone patients they are directly send to Bed, HA or their assistant will move to the patients for initial process and information gathering. But for other acuity level they are send to triage room. During this process patient's family member will do registration process and time before and after registration process is also recorded.

4.1.4 Triage

Generally, triage means the area after entry door in an Emergency room where patients are separated according to the level. As Red zone patients are direct send to beds, the rest patients after entering triage are hold to take their history and records of

their health conditions. Like in figure below, patients entering after sign in, they are hold.

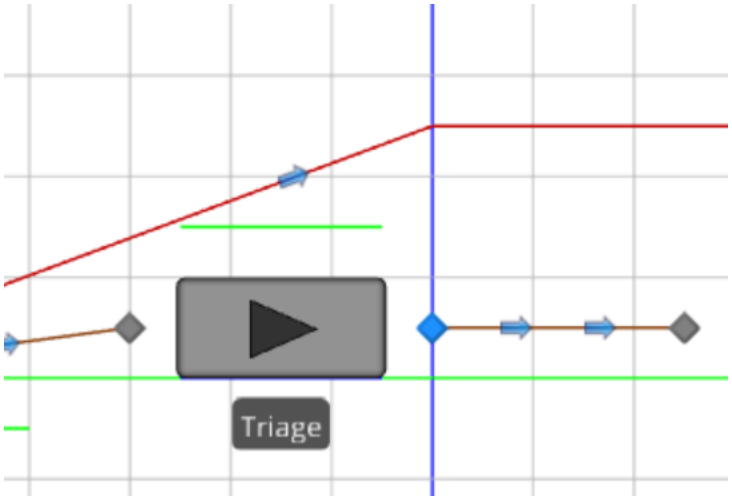


Figure 4.3: Triage section

This symbol is source where input, processing and output activities are carried out and for our study are the patients entering, through the system. As server (Triage) might be occupied by the patients who already had enter, rest patient should wait in queue in waiting room. Once the processing time is complete, then the system under this is directed toward another process.

4.1.5 Registration

Once the triage section is completed, then patients of Green Zone and Yellow Zone are sent for registration. This process involves recording time for ticketing process and initial payments for using resources. After completing this then they are sent to Physician room.

4.1.6 Bed waiting

Before Health Assistant or internship student, patients are kept in bed, and priority is given for Red Zone patient, also there are 2 beds available for this type of patients, and incase if number of patients increases then they are assigned to remaining rest beds of Green and Yello zone. Then next step is of Health assistant.

4.1.7 Health Assistant/ Internship student

Health assistant or internship students are that manpower that kept record of patients in the system and carry-on vital check; Blood pressure measurement, temperature and saline water for needy people. Following figure shows the modeling scenario for

health assistant, and capacity is of 1 and can increase up to 3 for 10AM to 5PM in busy time.

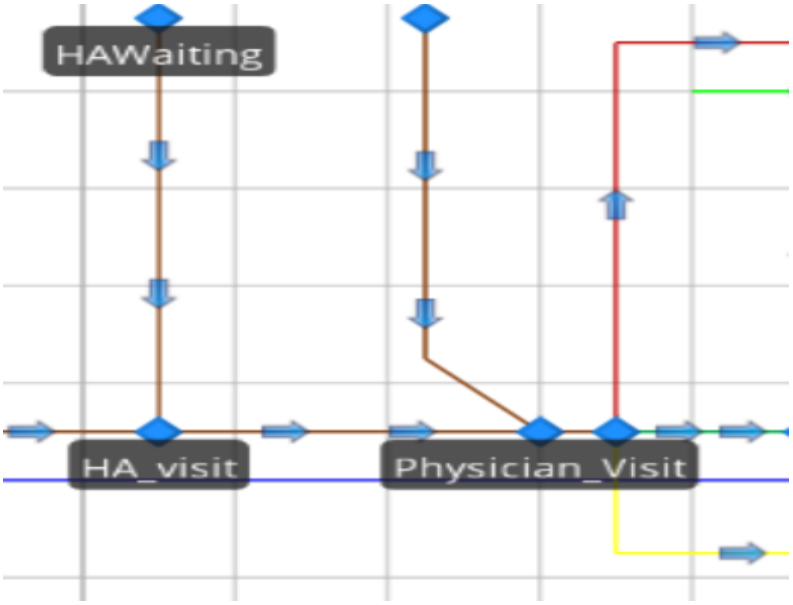


Figure 4.3: Model symbolling HA visit and Physician visit.

Once the checkup is completed and then the entities are out of the system and wait for first Physician visit. If there is a physician room is already occupied by the patients, then they are sent in waiting room, Red Zone patients are given priority in the whole system. If one entity leaves in this system then another enters and process goes on.

4.1.8 First Physician visit

After entities are released from ahead process and if Physicians is idle then new entities enter the system. As priorities are given and treatment starts. As shown in fig1.4, there are three system; patient coming from HA visit, patients in waiting room, and patients out for taking Pathology lab, Xray and CT scan department within hospital premises. Physician take history of the patients, here patients are asked to test the result according to the condition of their body. It was found that all Red zone patients uses 100% Pathology lab,70% of X-Ray and 30% of CT scan. After discussion with Physician uses of each facility are obtained. Similarly, Yellow zone people uses 80% of Pathology lab, 50% of Xray and 20% of CT scan. And finally Green Zone patients uses 60% Pathology lab, 30% Xray and 10%. It so because for example if patients come to emergency room for snake bites case it might not needed him to go to Xray and CT scan, only Pathology lab fits for him.

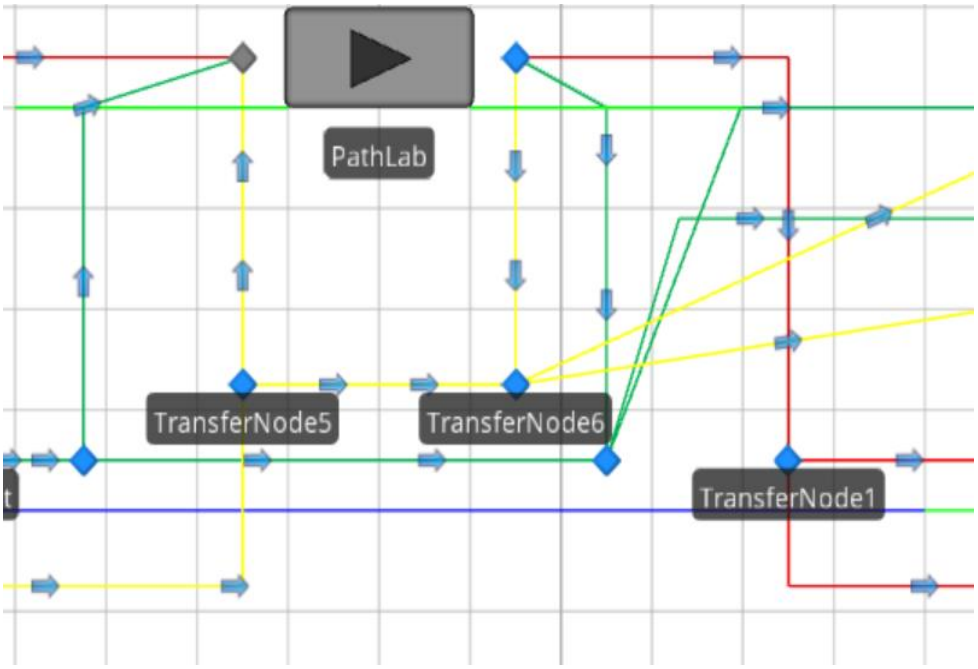


Figure 4.5: Routes for Patients for taking Path Lab Test

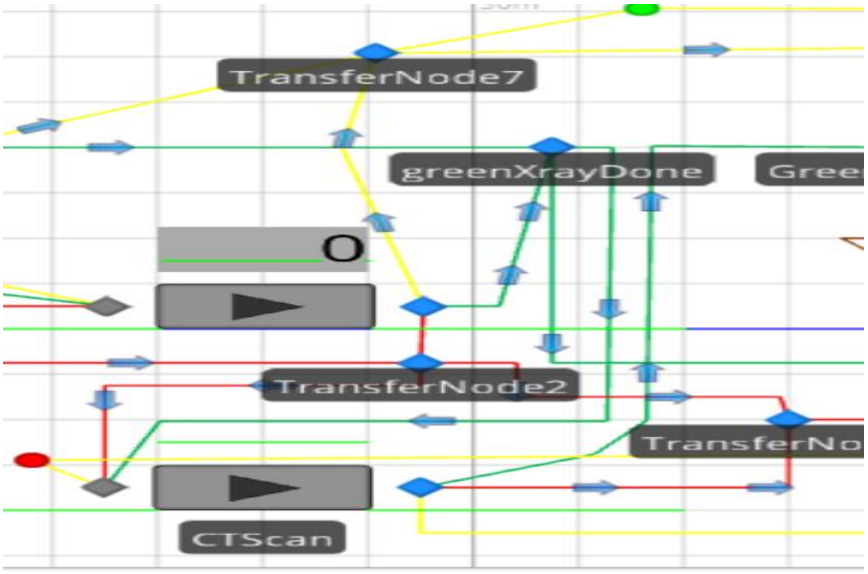


Figure 4.6: Routes to Take CT scan and X-Ray lab

4.1.9 Second Time Physician Visit

Once the reports are gathered on the basis of Physician observation, patients then arrive to the same physician rooms for conclusion. If a patient is asked to take all test then he will be seen by doctor once all report are in his hand, means the Pathology lab may take time for providing the report but patient might have rest report, in this case he must wait for the Pathology lab report and will be seen by the Physician once all

three reports are in his hand. During this period, a patients will be declared as inpatients or follow up patients or referral patients. And finally, patient is discharge from Emergency room system.

Different logical inputs are given on different points, like Bed waiting time, Health Assistant Assignment, Bed Release, Physician Assignment and finally 2nd Physician visit. Each of them is describe below:

1) **Bed Waiting**

As patient enters through arrival nodes, first separation is made on the basis of acuity level, Red Zone patients are assigned to their beds respectively.

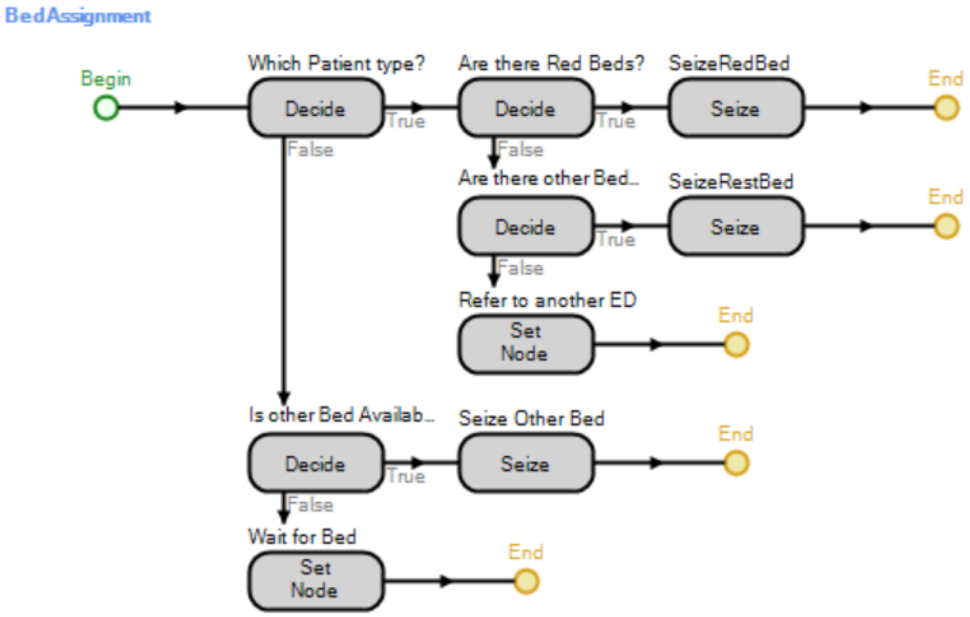


Figure 4.7: Bed Assignment

If Red zone patients arrive then the decision on RED bed availability is checked, then if empty Red Zone is assigned to the patients. Otherwise, decision other bed then Red zone patients are sized. There are 2 dedicate bed for this type of patients and other 11 bed for Green and Yellow type patients. If in the entry, the patients found to be of other category that is Green and Yellow then they are assign to their respective beds.

2) **Health Assistant**

As the time involvement for health assistant involves, so there is also waiting time. Acuity level with first priority is send to waiting and rest for other.

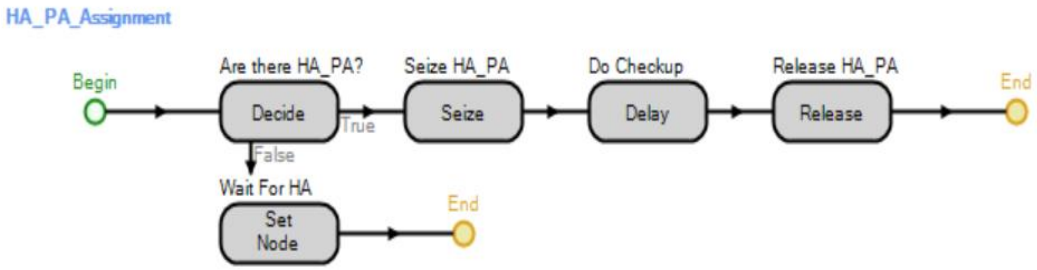


Figure 4.8: Health Assistant Assignment

As entry on this system begins, the decision on available of HA _PA is done. HA is then seized by the patient, once the checkup process is completed, the HA is release. But if, HA is busy than the patients are sent to waiting room.

3) Physician Assignment

After the release of patient from HA_PA Assignment and they are directed toward Physician room. Like other sources, Red Zone Patients are given priority and logic works according to following:

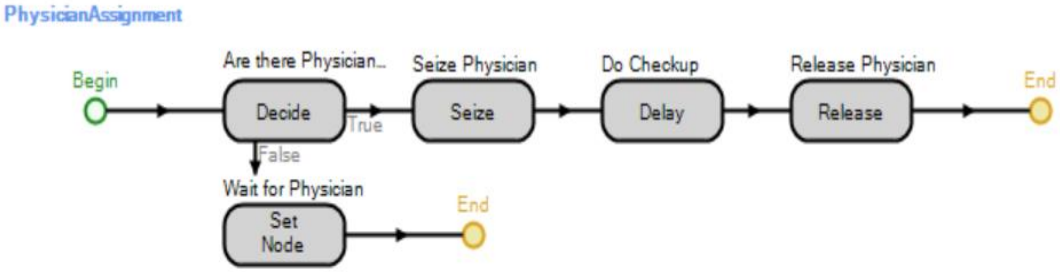


Figure 4.9: Physician Assignment

First of all, Physician idle time is observed and decision based on this is carried out. Furthermore, if no patients are found inside then the patient just enter seize Physician. The treatment processes begin, and once all the history observation is seen and current condition is recorded then they are sent to respective lab for test, finally Physician is released for another patient. If at the beginning Physician is busy then the patient is sent to waiting room.

4) Second visit to Physician

After test(s) result are gather then the for final treatment comes. The logical step behind this system can be seen from figure below:

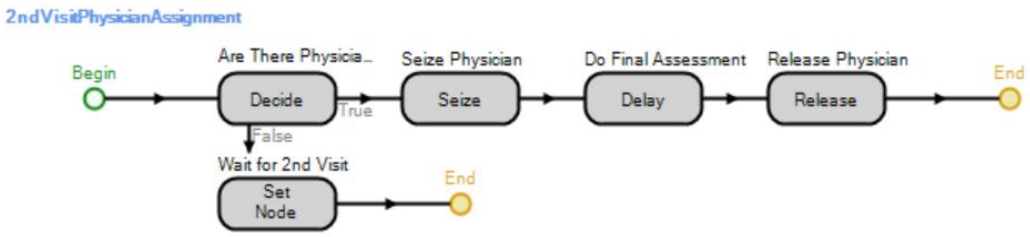


Figure 4.10: Second visit Physician Assignment.

It begins with searching Physician available that means there are no other patients and no patient is seen then the same Physician will be occupied or system will be busy. Here final decision like staying in hospital for further investigation, or leave as a follow up patient and refer to other hospital if hospital is out of scope. Finally, the patients are out of the system.

4.1.10 Model Verification

Before the verification of the model and during model construction following assumption were considered:

1) The patient will always use any of the resource when it enters the system.
2) All medical equipment is under working condition and does not affect in change of any schedule.
3) Movement of staff from Pathology lab, Physician, HA and their assistant movement time is negligible.
4) Patients will remain in the same bed as sent from triage in the bed zone area.
5) Patients arriving from the ambulance will exclude triage and are consider as red zone patients and placed in red zone patient. Physician will move to this type of patients for treatment.

Next step is of model verification of the models, as model was developed under different conditions and it must resemble the real-world situations. For verification process model is set to run after input data and all the logical inputs and the data provide by the hospital. The run time starts from 00:00AM in the morning and is kept for warm up period so that fluctuation in first 24 hours can be removed and average data after that is used to determine the results. Another method for model verification is done by the facility provide by SIMIO and can be carried out by using animation section were entering number of each patient. Logics on each system like; Walk in patient arrivals, triage, registration, number of beds occupy, the HA, Physician, path lab, Xray, Ct scan, 2ndvisit to Physician, and finally discharge number. If model runs successfully and does not show any error then verification of model is completed. The

model thus created is as follows:

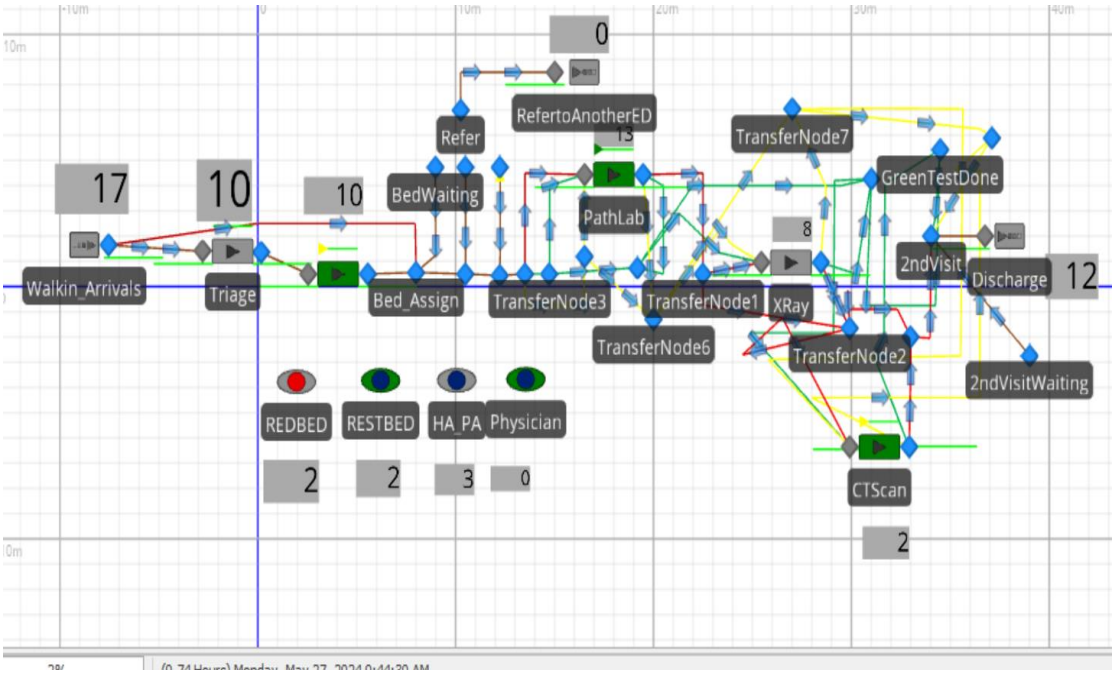


Figure 4.11: Model Verification

4.2 Analysis of Experimental Scenarios in the Discrete Event Simulation

To enhance the fidelity of the simulation, an additional step involved juxtaposing historical data with the data derived from the simulation. By leveraging patient arrival times sourced from hospital records, the simulation aimed to closely emulate real-world arrival patterns. This process ensured that the simulated arrival times closely approximated those observed in actual hospital settings, thereby bolstering the accuracy of representing the real world. Naylor et al. (1967) outlined a validation procedure consisting of three steps:

Step 1: Model construction

Step 2: Validation of model assumptions

Step 3: Comparison of model data with real-world data

Subsequently, a paired test was employed to compare the results with real-world data and the model outputs, identifying the most suitable alternative. On discussion with Physician and management team of Bhim hospital and during observation period, Pathology lab was consuming time for a patient and it directly affect the Length of Stay of patient in hospital. It was also found that more than 90% of patients need to do lab test. Also, other equipment like CT scan and X-ray equipment are use frequently only in the treatment process so, their time addition to patient stay time is negligible.

Further validation involved discussions with Emergency Room (ER) experts regarding the data, juxtaposing it with hospital-provided data and data obtained from the model output. A visual representation displaying the influx into the system is depicted in the following figure. Moreover, as patient arrival times were drawn from real-world data, the aim was to replicate real-world scenarios within the model, thereby designing the system to closely mirror reality. Given the study's focus on the length of stay in the ER for each entity level, Red bed and rest bed utilization were evaluated and compared with hospital data. The following table provides detailed information and is according to treatment time according to ESI level:

Table 4.2: Base Case

Base Case				
ESI	Share	Average Total Time	Minimum Average	Maximum Average
Red	0.08	1.23	0.26	3.81
Yellow	0.7	1.23	0.24	5.94
Green	0.22	1.1	0.23	2.15
Average		1.2	0.24	4.93
		Mean	1.2	
		Standard Deviation	0.78	

Table 6 above is the average data for base case, that uses real ER arrival pattern for the time spent by each of the zone patients.

Table 4.3: Alternative 1 purposed against Base data

Alternative 1: 1 Physician with a pathology lab machine				
ESI	Share	Average Total Time	Minimum Average	Maximum Average
Red	0.08	1.18	0.28	5.9
Yellow	0.7	1.17	0.25	4.46
Green	0.22	1.06	0.23	5.02
Average		1.15	0.25	4.7
		Mean Standard Deviation	1.15 0.74	

It reflects the alternative with a Physician and additional Pathology lab machine with respective mean of 1.15 and SD 0.74 for each zone patient.

Table 4.4: Alternative 2 purposed against Base data

Alternative2: 2Physician				
ESI	Share	Average Total Time	Minimum Average	Maximum Average
Red	0.08	0.86	0.23	1.68
Yellow	0.7	0.83	0.29	2.29
Green	0.22	0.7	0.22	1.92
Average		0.81	0.27	2.16
		Mean	0.81	
		Standard Deviation	0.32	

Table 4.4 is an alternative table that is purposed against adding one Physician then to base case data, that shows decrease in mean and also in standard deviation.

Table 4.5: Alternative 3 purposed against Base data

Alternative 3: 2 Physician with a Separate Pathology Lab				
ESI	Share	Average Total Time	Minimum Average	Maximum Average
Red	0.08	0.8	0.28	1.82
Yellow	0.7	0.79	0.23	2.43
Green	0.22	0.68	0.22	1.95
Average		0.77	0.23	2.28
		Mean Standard Deviation	0.77 0.34	

Table 4.5 is about adding 2 Physician along with additional Pathology machine inside the ER.

Result from all of the table shows different analysis against the base case, with additional in human resources and medical technology decrease in mean time and standard deviation can be seen. It implies that for reduction of current time for length of stay, either adding Physician or adding Pathology lab machine or both will

decrease time to travel for patient.

4.2.1 Pair test analysis

Though decrease in time was seen against the base, one need to provide solid mathematical evidence that alternative can be applied for change in system. This can be done paired test analysis. In this analysis base average mean is used as the point of subtracting, since other feasible and best alternative can be selected. This is done by Confident Interval base case. Following table provide the detail information about the changes and best and optimum solution for decreasing the length of stay and Bed utilization percentage.

Table 4.6: Best solution analysis

i	**X_i - X_1**	**Half-length**	**Interval**		
			LL	**UL**	
1	-0.05	0.32	-0.37	0.27	Reject
2	-0.39	0.25	-0.64	-0.14	Accept
3	-0.43	0.25	-0.68	-0.18	Accept
Confidence Level	95%				
Alpha'	5%				
Alpha	1.67%				
Normal	2.12805				

Table 4.6 show subtraction of base case mean with alternative case1, alternative case 2 and alternative case3 against the base case. Half width can be found by using

Half Width=Normal*(SQRT ((Base mean) ^2/52) + (Alternative mean) ^2/52))

For each 3 different alternative average sums of their square number divided by sample number is subtracted from base case. Since there are 3 alternative, so normal can be found by

Normal – NORMS. (INV(1-Alpha))

Alpha'= 100%- C.I

Alpha=Alpha'/3

Now for selecting the best alternative, referencing from table 9, significant difference

in lower limit is used, if the value is either greater than zero or less than zero and does not contain 0 in the number counting system, then alternative is accepted. Means if the value is zero after difference or adding base mean and alternative then, it is rejected. From above table it can be seen that alternative case two: 2 Physician and alternative case third: 2 Physician with a Separate Pathology Lab is accepted since, both of them does not have zero in between them. Hence, either of them can be used by management team for decreasing waiting time of patient who enter in their ER. It can be said that either Physician can be added with machine or two Physician for reducing waiting time and bed utilization percentage. This will relief ER team from pressure and patient satisfaction level will be increased there by less utilizing the hospital time. Also, the bed utilization is shown in table above:

Table 4.7: Bed utilization

S.N	Alternatives	RED BED(%)	REST BED (%)
1	Base case	16.64	10.06
2	2 Physician with Separate Pathology Lab	10.22	6.72
3	2 Physician	10.62	7.39
4	1 Physician with a Pathology lab machine	17.09	9.46

Table 4.7 above shows the bed utilization in terms of percentage. RED BEDs are used only for the Red zone patients with total of 4 beds in Bhim hospital. Whereas REST BEDS means the beds that are separated for Green zone and Yellow zone patients. If the number of the Red zone patients arrives at same time then they are given priority and kept in rest bed, else if other category patients arrives then they are assigned bed once the bed is empty.

The percentage of RED BED occupy by Red zone patients in Base case is 16.64%, whereas for REST BED is 10.06%. Similarly for alternative 2, slight reduction in bed for both RED BED and REST BED of 10.21% and 6.724% respectively. Furthermore, by adding one more Physician decreases bed utilization to 10.62% less then base case and for REST BED to 7.39%. Finally, adding a path lab inside the Emergency room and only one Physician increases the RED BEDS utilization, but decreases in REST

BED utilization by 17.097% and 9.467% respectively.

From above data from, the simulation it was found bed utilization percentage decreases as alternatives are made, then compared to real world scenarios. This matches the motto of emergency room bed utilization so that many emergency patients can be accepted by the Emergency Room and their life saving treatments can be carried out. The bed utilization also can be decreased, as there is a space for adding more beds with in Emergency Room of Bhim Hospital.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

The waiting time of Emergency Room of Bhim hospital was consuming unnecessary time of patient and unnecessary burden in Emergency Room staff. This analysis was done on the basis of interarrival time of patient from Emergency Room medical record room and electronic log sheet. This was done so that it will behaves as real world and running successfully simulation further add bricks in proofing process. Significant number of changes was seen if alternatives are used. On average the patient visiting time for red people was 1.2 hours, where that of hospital was 2 hours, generally patients are refer of red zone categories and other ended up as visiting passenger or admitted to Impatient ward of the ER. The maximum average of each patient in hospital is 6 hrs. whereas simulation model suggests of 3 hours maximum staying in hospital for Red zone patients, 4 and 5 hours each for green and yellow zone patient. The simulation model provide robust design on real world situation and the conformation regarding the accuracy of model was done by sampling cross check and result seem interesting.

The percentage of RED BED occupy by Red zone patients in Base case is 16.64%, whereas for REST BED is 10.06%. Similarly for alternative 2, slight reduction in bed for both RED BED and REST BED of 10.21% and 6.724% respectively. Furthermore, by adding one more Physician decreases bed utilization to 10.62% less then base case and for REST BED to 7.39%. Finally, adding a path lab inside the Emergency room and only one Physician increases the RED BEDS utilization, but decreases in REST BED utilization by 17.097% and 9.467% respectively.

For decision to hospital, different scenarios that were made and the result seems impressive. Three different scenarios were created where each of them was compared using paired test method. It was found that on addition of either 1 or 2 Physician can decrease waiting time of a patient. In order to decrease Bhim Hospital, either of the accepted alternative can be used for the Emergency Room, so that waiting time can be reduced, and all the time patient can used emergency without any pressure.

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ANNEX ONE: SIMIO MODELING

Arrival Rate Time of Patient for average of 4 month

	AVERAGE of 4 months																												
Time-range	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0:00-1:00	1	1	0	1	1	2	1	1	1	2	1	1	1	2	1	1	1	0	1	2	2	2	1	1	1	1	1	1	1	2
1:00-2:00	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	0
2:00-3:00	2	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	0	1	0	0
3:00-4:00	0	1	2	0	1	1	1	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	0	0
4:00-5:00	1	1	1	1	1	1	1	1	1	1	0	2	1	1	1	0	1	1	1	1	1	1	0	1	1	1	0	0	0	0
5:00-6:00	1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	2	0	1	0	1	0
6:00-7:00	1	1	1	1	1	2	0	1	1	1	1	1	2	1	1	1	2	2	0	1	1	1	1	1	1	1	0	1	1	1
7:00-8:00	1	1	2	1	1	1	1	2	1	2	1	1	1	1	1	1	1	2	1	2	1	1	2	1	1	1	1	1	1	1
8:00-9:00	1	2	1	1	1	2	1	0	1	1	1	1	1	1	1	2	2	1	2	1	2	2	2	2	2	2	1	1	2	2
9:00-10:00	3	4	2	2	2	1	1	1	3	2	1	2	2	2	2	1	1	2	1	2	2	2	2	3	3	3	2	2	3	1
10:00-11:00	3	5	5	4	4	2	2	2	3	2	2	2	2	3	2	4	2	2	2	3	4	3	3	3	2	3	4	2	3	1
11:00-12:00	1	4	4	3	2	3	0	2	4	6	4	3	2	2	3	3	0	2	3	1	4	2	2	3	4	2	3	5	3	2
12:00-13:00	2	4	3	2	3	2	3	2	3	2	1	3	3	3	3	4	2	4	3	2	5	2	2	4	3	3	3	4	2	3
13:00-14:00	4	3	3	3	2	2	2	3	3	2	3	2	4	3	3	2	2	2	2	4	5	4	3	2	3	3	3	2	3	2
14:00-15:00	4	4	5	5	5	4	2	5	4	4	5	3	5	3	3	2	4	4	2	4	3	4	6	4	6	3	4	4	3	3
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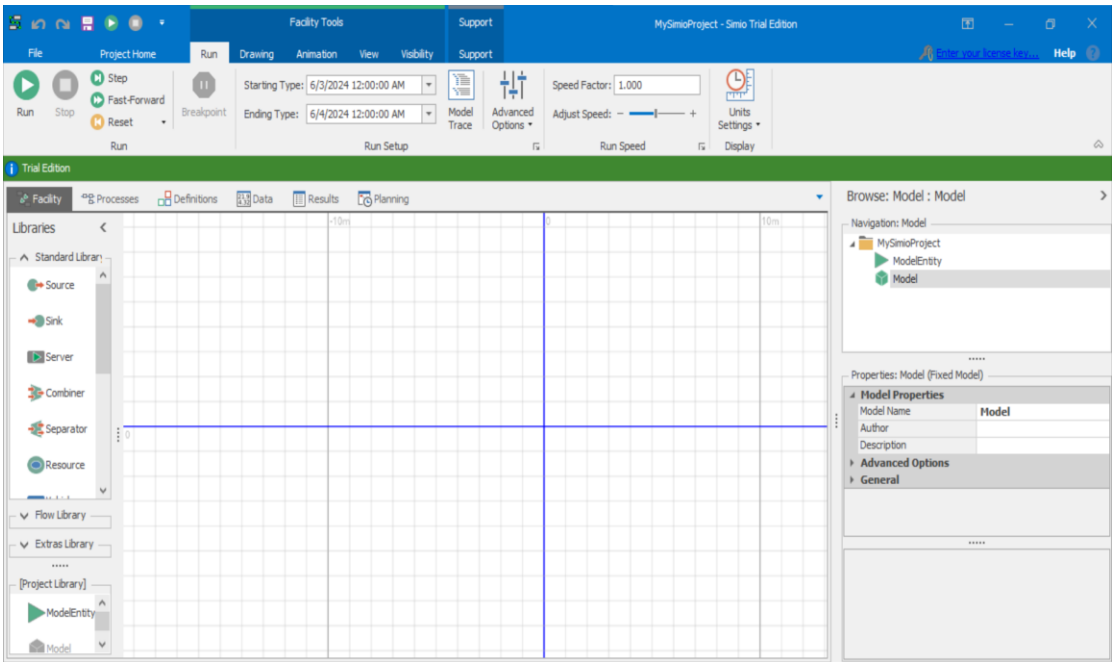
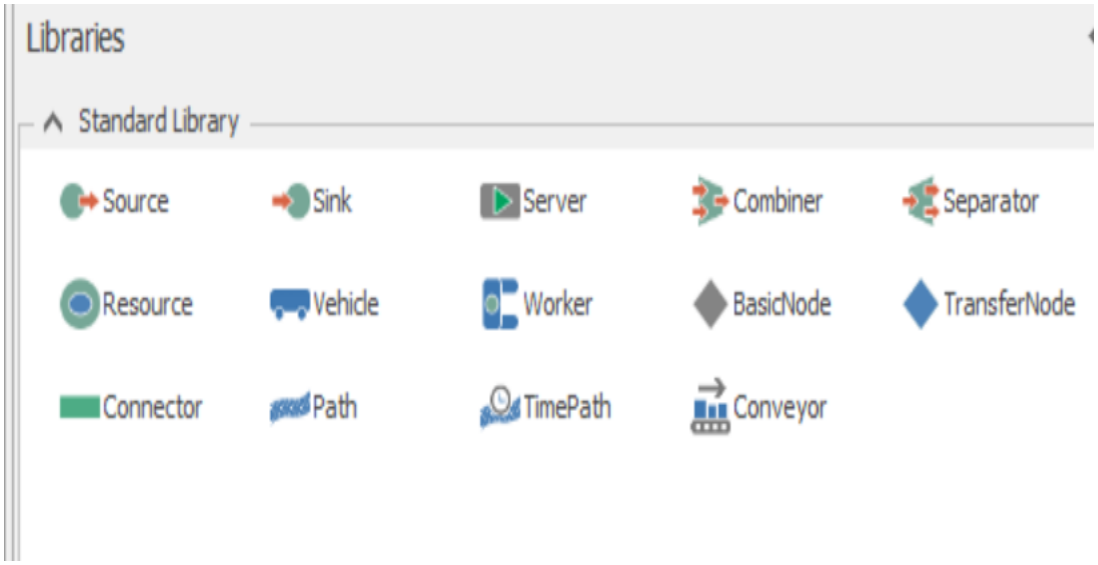
21:00-22:00	1	2	2	1	3	3	3	2	4	1	2	3	2	2	2	4	3	2	2	1	2	2	4	2	3	3	2	2	2	5
22:00-23:00	1	2	1	1	2	1	4	2	2	5	1	2	2	0	1	1	1	1	1	2	2	3	3	3	3	3	3	1	3	2
23:00-0:00	4	2	1	1	1	1	2	1	1	2	2	2	1	1	2	2	1	2	0	2	2	1	1	1	1	2	1	2	1	1

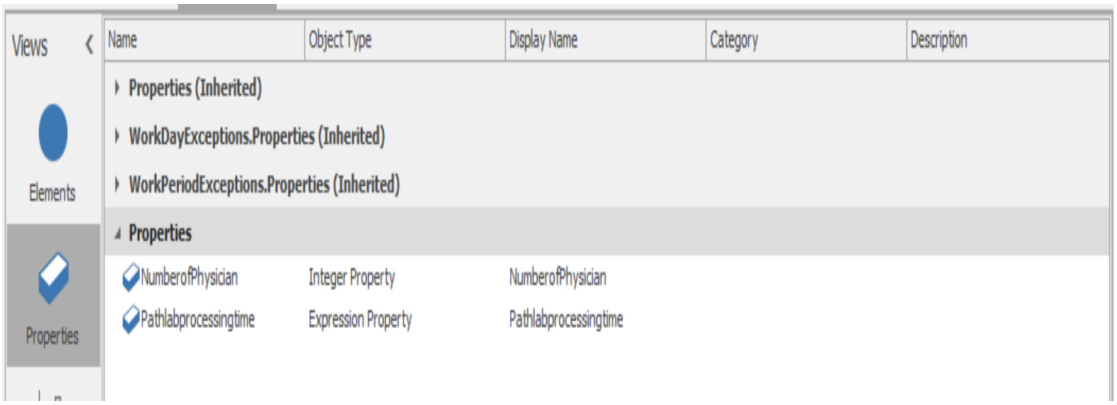
SIMIO working display



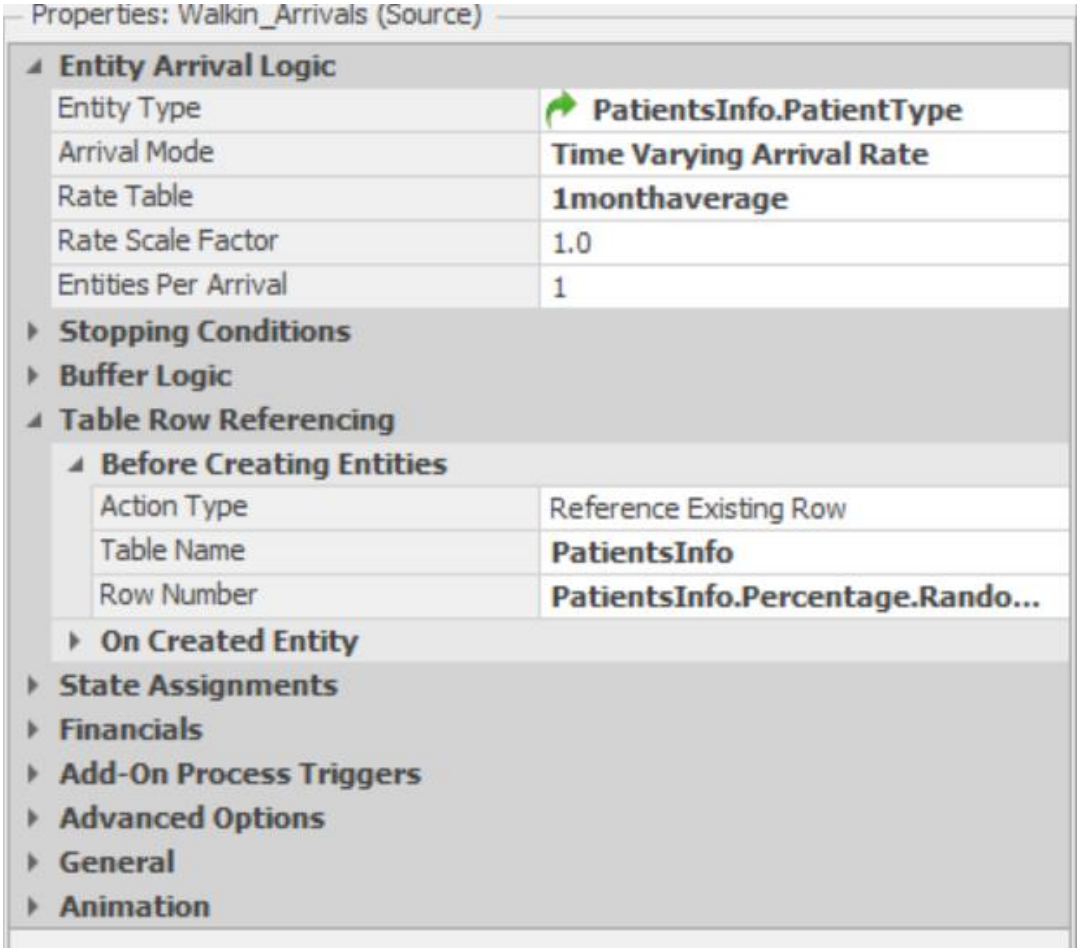
Standard Library



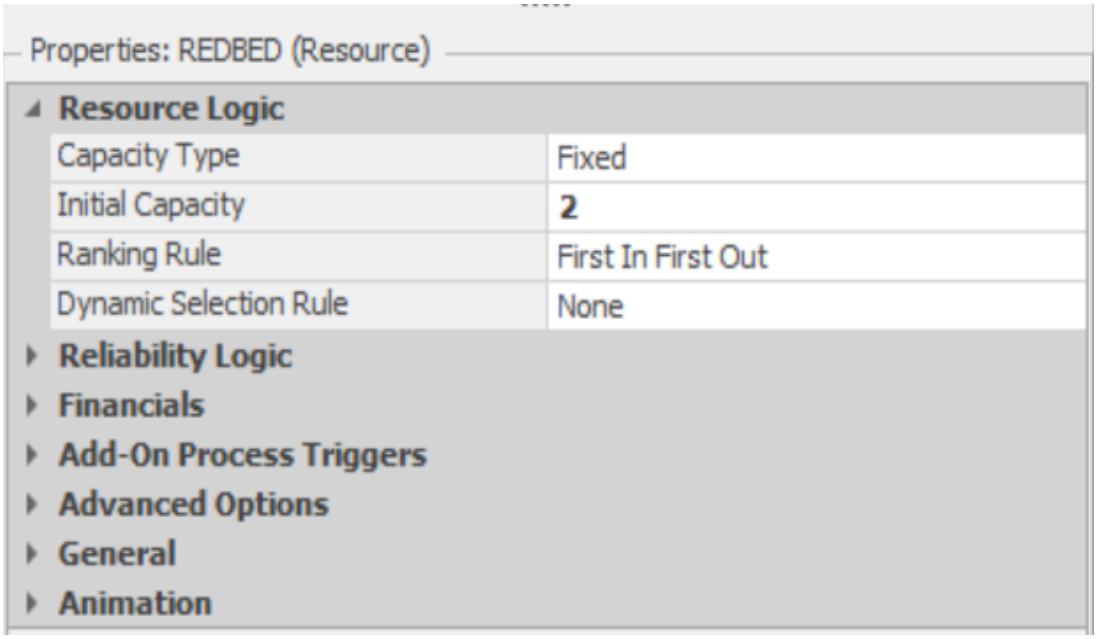
Input Variable decision tab



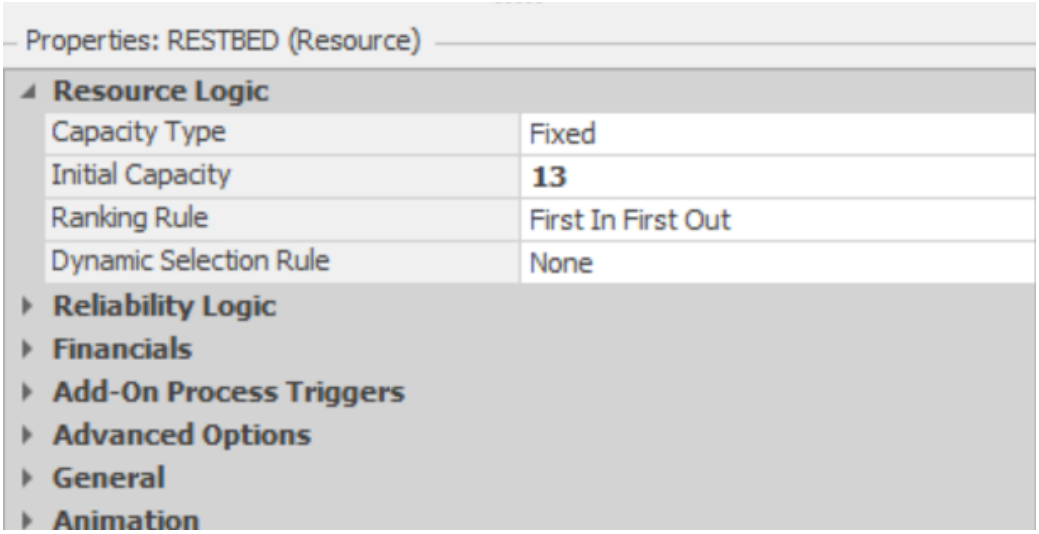
Walk in Patient Arrival source coding



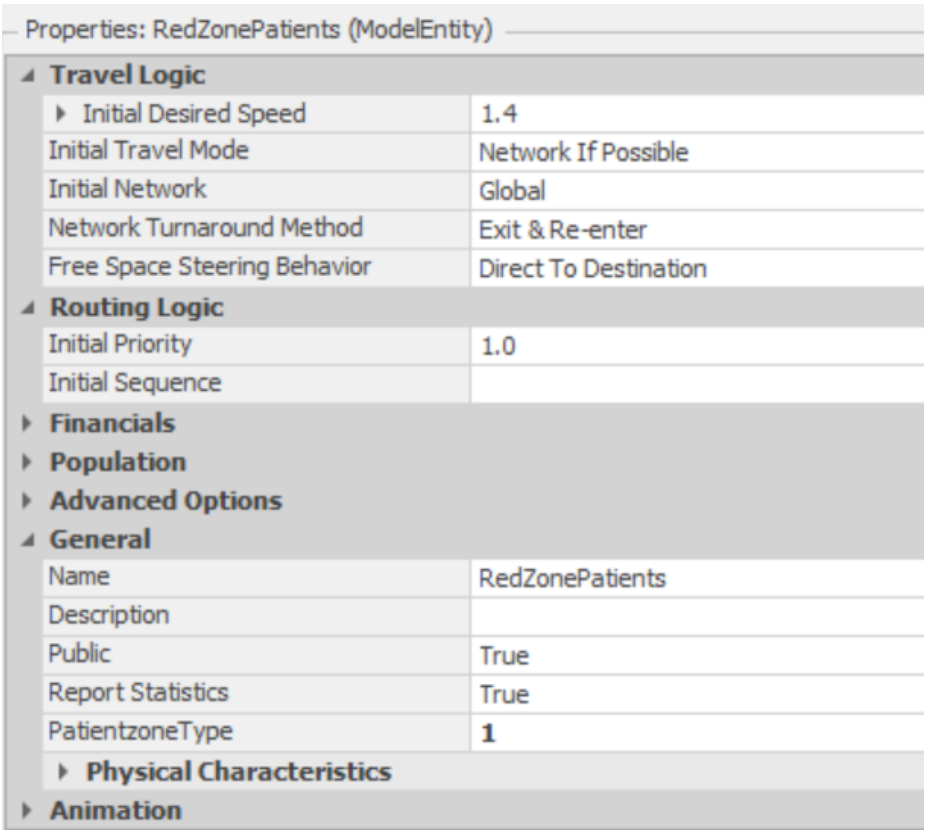
RED BED Resource



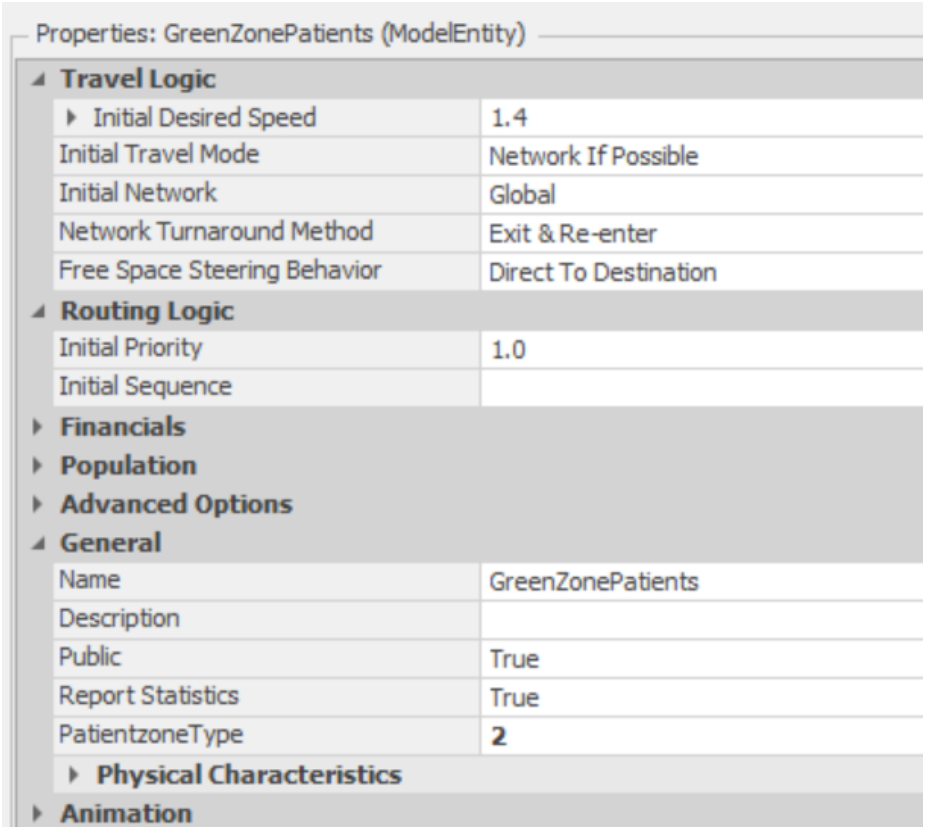
REST BED Resource



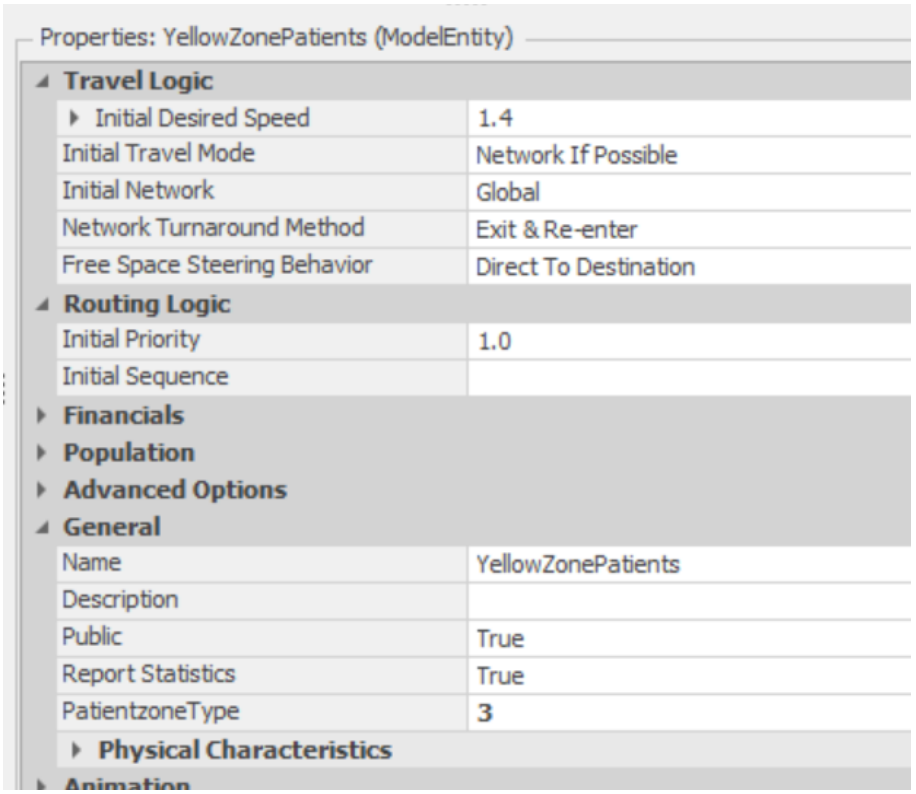
RedZone Patient (Model Entity)



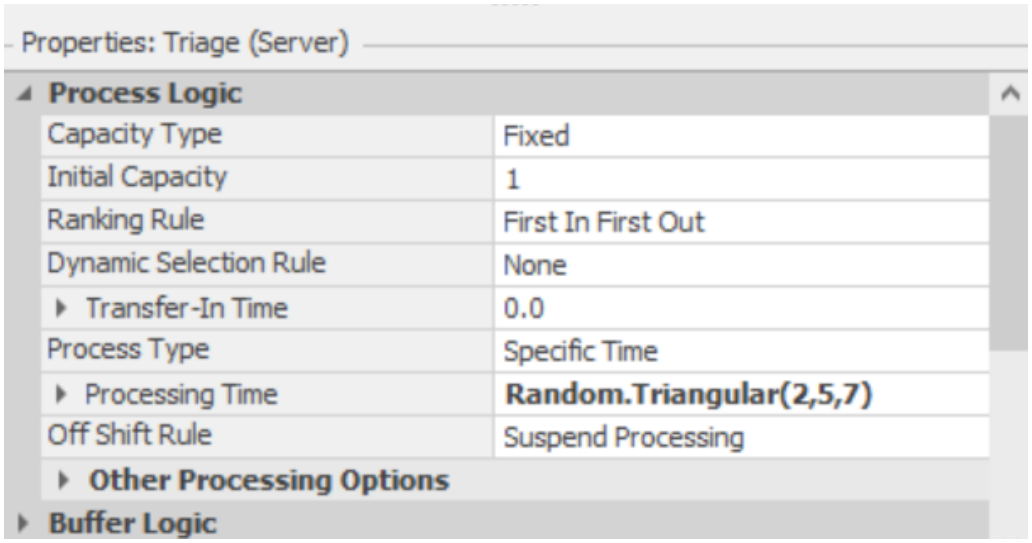
Green Zone Patient (Model Entity)



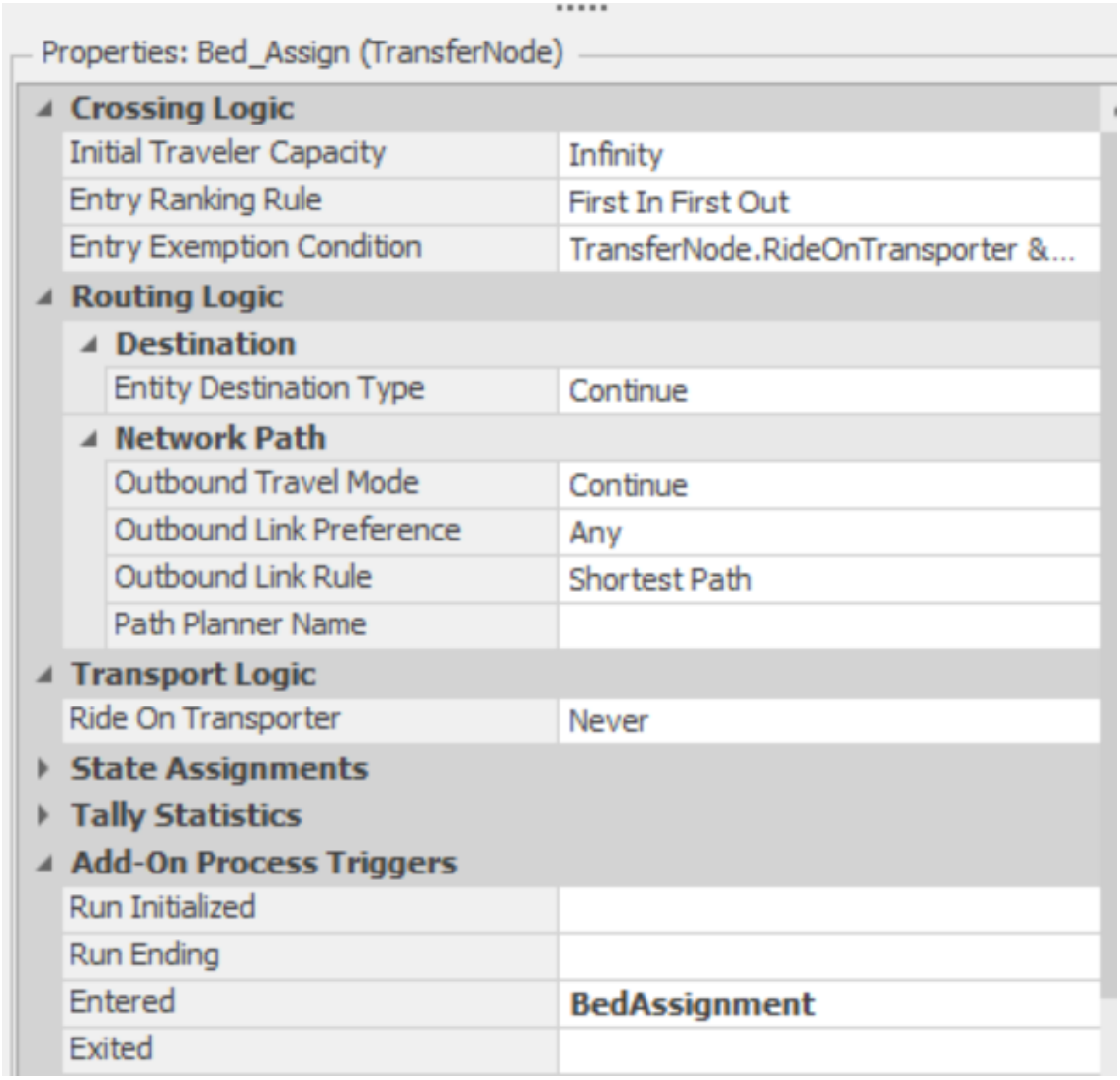
Yellow Zone Patient (Model Entity)



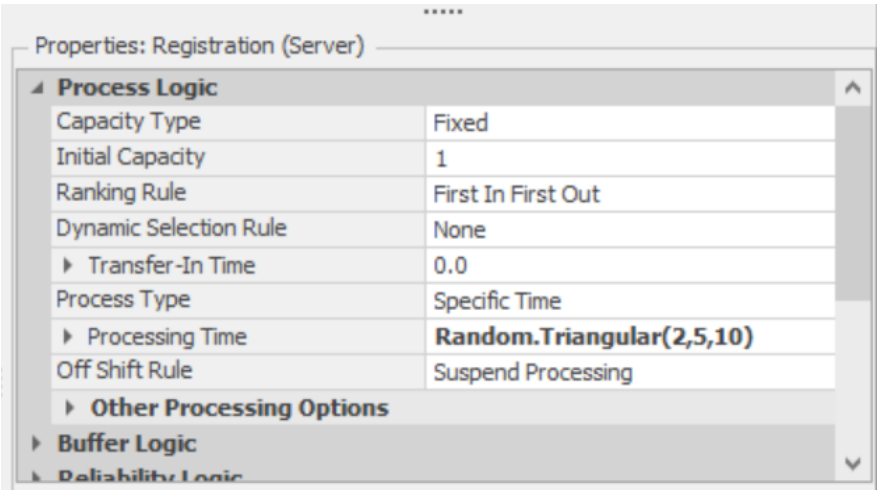
Triage (Server)



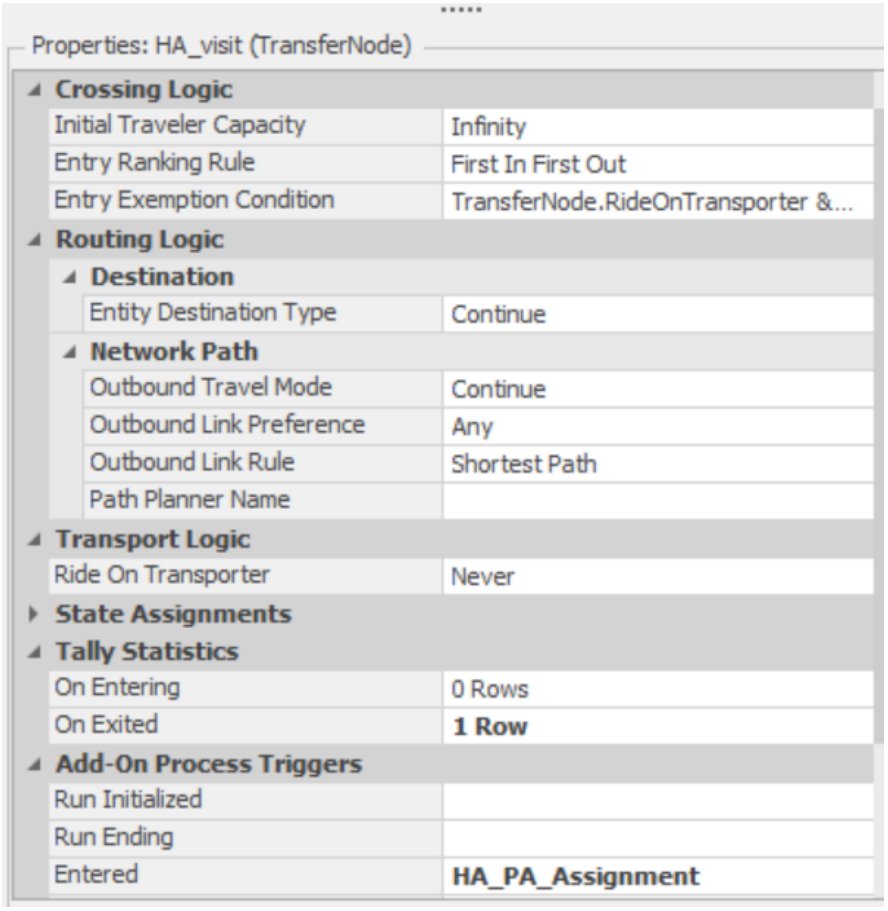
Bed Assign (Transfer Node)



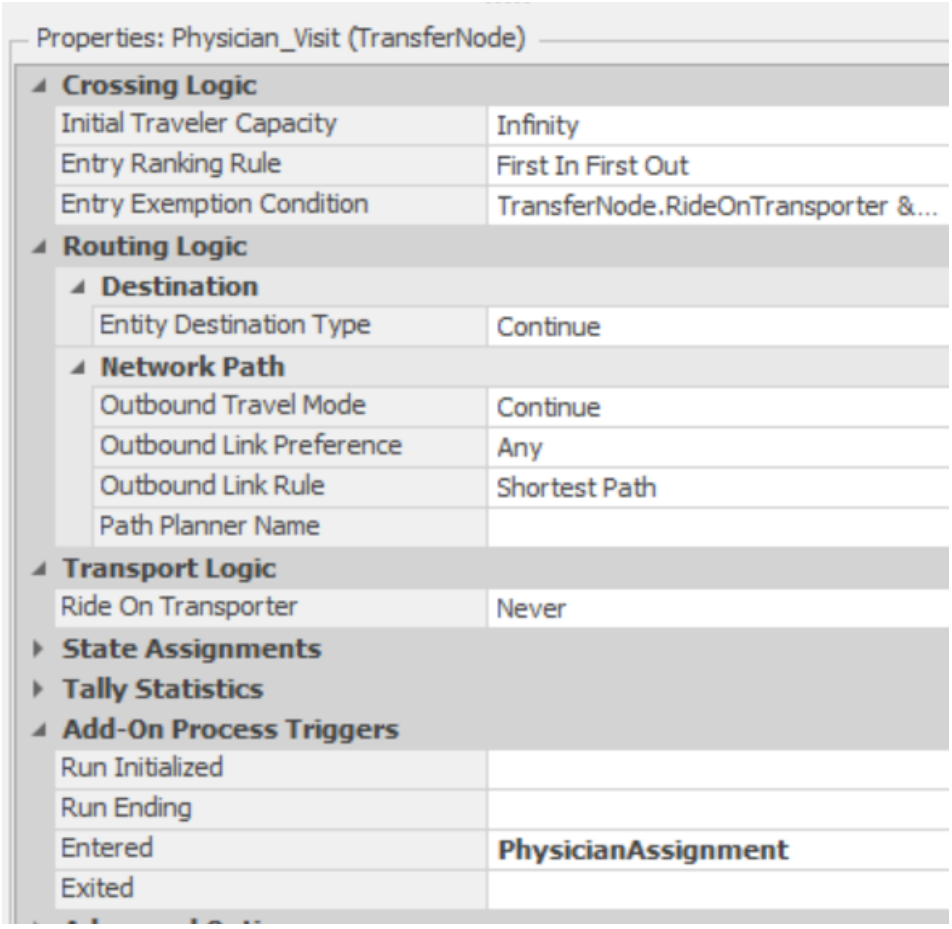
Registration (Server)



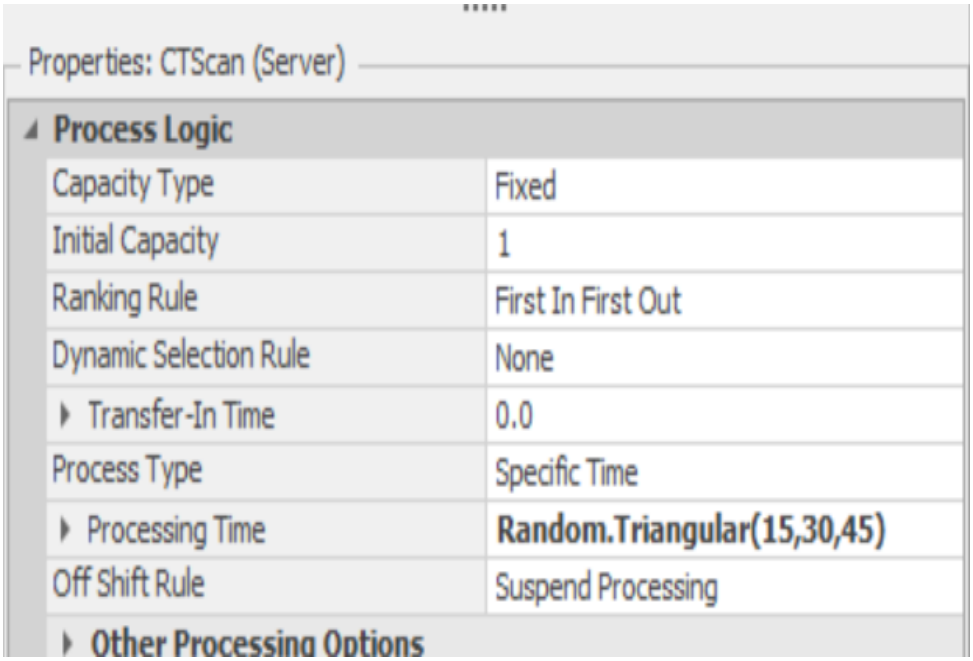
HA (Transfer Node)



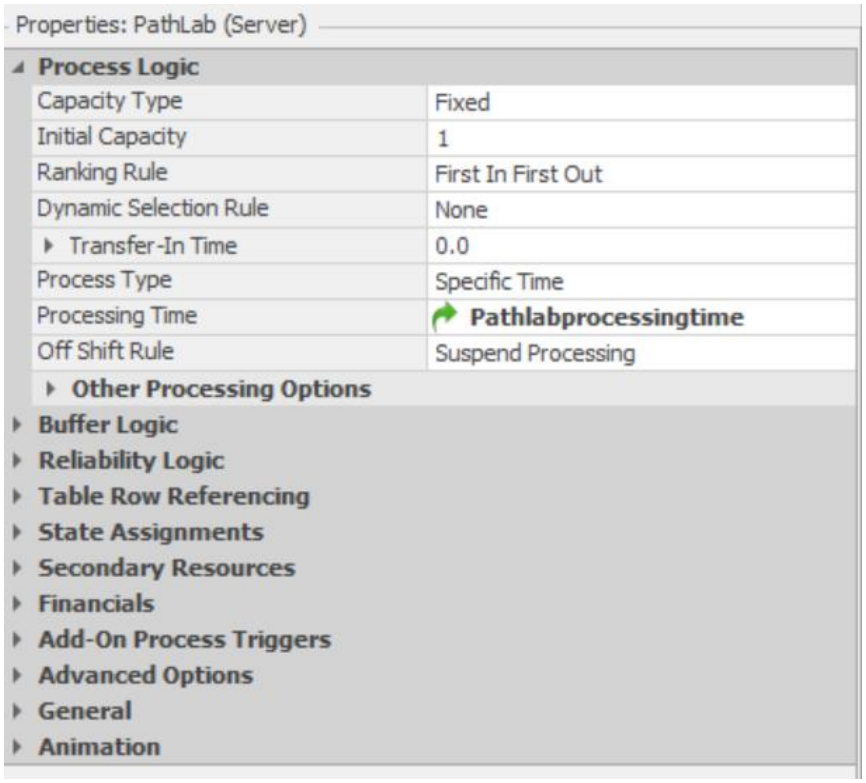
Physician Visit (Transfer Node)



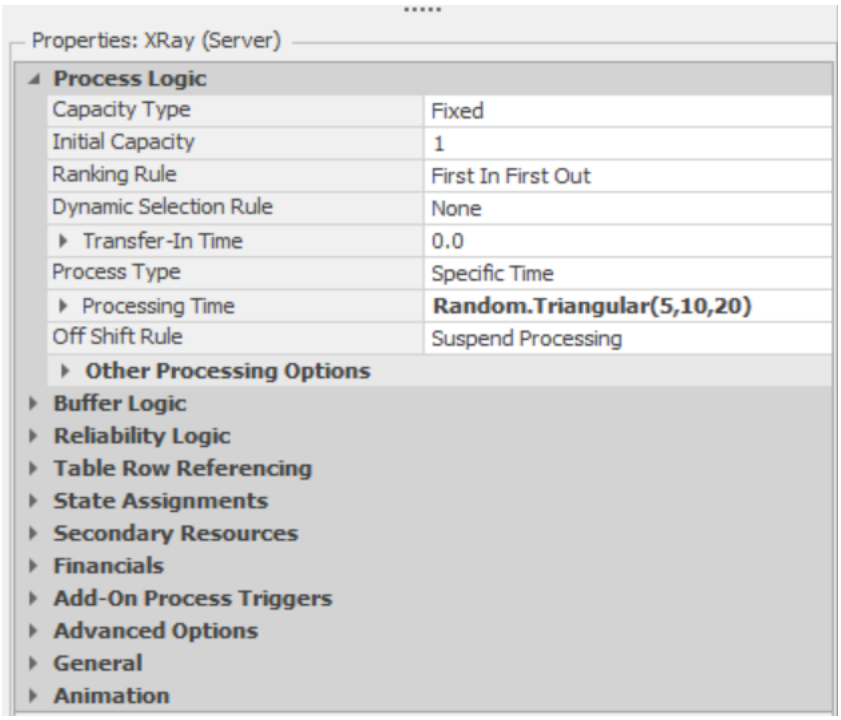
CT scan (server)



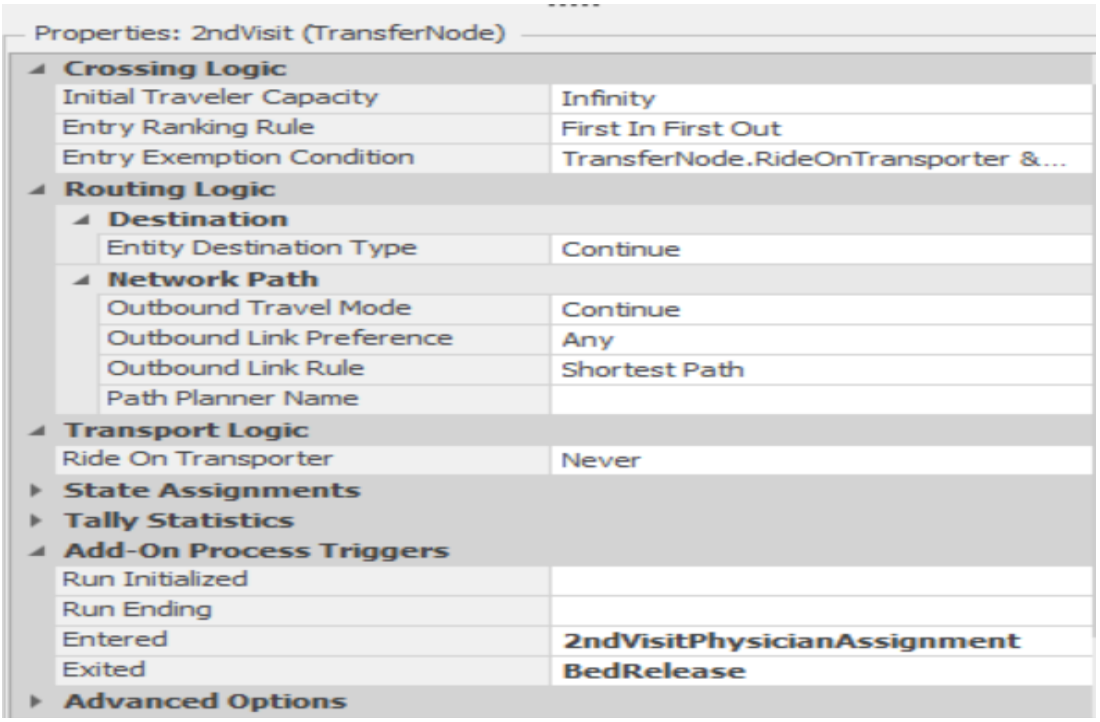
Pathology lab (Server)



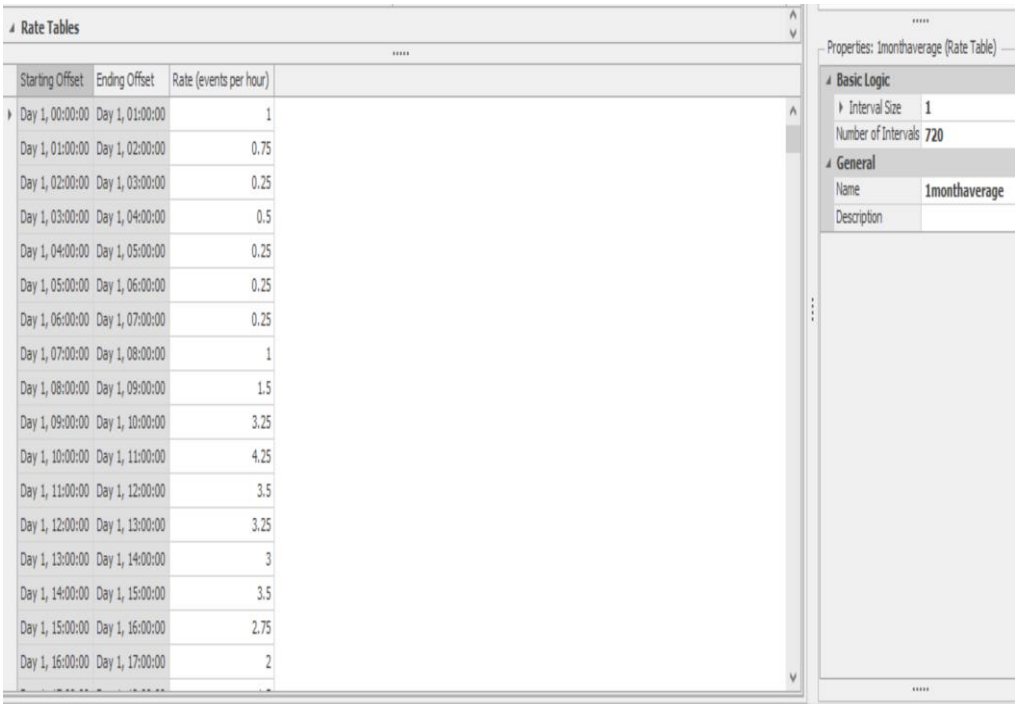
X-Ray (Server)



2nd Visit to Physician (Transfer node)



Data of 4-month average



ANNEX TWO: BHIM HOSPITAL DOCUMENT

Cases, their test Criteria and Severity Level

S.N	Particulars	Which test need to carried on?	Severity level
1	Abdominal pain	Pathology lab	Low
2	Allergy	Pathology lab	Low
3	Loose Motion	Pathology lab	Both medium and high
4	Cut Injury	Situational basis	Both medium and high
5	Hypertension	Pathology lab	Both medium and high
6	Trauma	Path and other as per needed	Medium
7	Dizzness/Weakness	Pathology lab	Both medium and high
8	Vomiting	Pathology lab	Both medium and high
9	Retention Urine	Pathology lab	Both medium and high
10	Headache	CTscan	High
11	Snake Bite	Pathology lab	High
12	Other Bite	Pathology lab	High
13	Ear Pain	Situational basis	Low
14	Alcohol Intake	Pathology lab	Low
15	Anxiety	Situational basis	Both medium and high
16	Physical Assault	XRay and CTscan	High
17	Road Traffic Accident	Pathology +XRay	High
18	Burn	Situational basis	High
19	Poison	Pathology lab	High
20	ENT	Situational basis	All
21	Fever	Pathology lab	High
22	Sudden faint	Pathology lab	High
23	Fall down	Pathology lab+CT scan+XRay	High
24	Chest pain	Pathology+XRay	High
25	Electric shock	Pathology lab	Both medium and high
26	Cough	Xray	Medium
27	UTI	Pathology lab	Medium
28	Nasal bleeding	Pathology lab	Medium

29	PV bleeding	Pathology lab	Both medium and high
30	Shortness Of Breath	Xray	Both medium and high
31	Anemia	Pathology lab	Both medium and high
32	Whole body ache	Xray	High
33	Bee Bite	Pathology lab	All
34	Chicken pox	Situational basis	Medium
35	Lizard bite	Pathology lab	High
36	Dog Bite	Pathology lab	Both medium and high
37	Throat pain	Pathology lab	Both medium and high
38	PR bleeding	Pathology lab	Both medium and high
39	Blood in Urine	Pathology lab	Medium
40	Hepatitis	Pathology lab	Medium
41	Thripid	Pathology lab	High
42	Suicide attempt	Pathology lab and other as needed	High

ANNEX THREE: SIMULATION DATA

Average length of stay and Bed utilization for base case of simulation

Replication	LOS_RED	LOS_Yellow	LOS_Green	LOS Red max	LOS Green max	LOS Yellow max	Res tBed Utilization	RedBedUtilization	LOS Green min	LOS Red min	LOS Yellow min
1	1.352076	1.336358822	1.3505096	2.4759589	5.527123313	6.143983764	19.20885238	7.699070645	0.254255457	0.49585442	0.275877972
2	1.7093	1.440643236	1.11795406	3.8972186	3.877050643	5.618900477	18.73855356	13.69646668	0.297721298	0.435404501	0.296910567
3	1.280609	1.06432294	0.96041974	2.6499503	3.060070841	3.135222476	13.79928542	8.537390218	0.227430048	0.371133722	0.240548309
4	1.167729	1.11053649	0.99314703	2.2977254	2.440918559	2.902706481	15.28708824	11.61005518	0.278126116	0.404239908	0.300554213
5	1.667729	1.289333399	1.13904982	4.6425665	4.862008243	4.826324859	16.93078455	17.09085911	0.279780438	0.422833036	0.261827674
6	1.27552	1.222803493	1.11124405	4.4514228	5.453127477	4.958911681	17.68760374	12.09278233	0.246212452	0.280279863	0.243114191
7	1.3557	1.151143421	0.92689095	3.4222933	3.578164698	4.067346536	15.43959588	9.703569592	0.226554541	0.407144369	0.269914493
8	1.140488	1.020627915	1.03420306	2.1897623	2.469131868	2.314990928	12.88636021	7.294854529	0.308006774	0.285702879	0.30280858
9	1.546225	1.278943226	1.09190245	3.9728698	4.754492681	4.472238049	17.85418129	10.36475696	0.227923626	0.380597039	0.27486733
10	1.068729	1.215250878	1.32337535	3.4217478	4.734635888	5.698176023	16.4946107	8.905508836	0.278151758	0.001353518	0.280229555
11	1.058621	1.051981517	0.89947551	2.0004365	2.074168615	2.696524079	12.97235728	10.72204608	0.279111558	0.343885677	0.287312357
12	1.396595	1.360558719	1.19994088	5.4913981	5.416383055	5.654119129	19.50615986	13.96594789	0.32009496	0.385555741	0.251929118
13	1.265888	1.250108738	0.99855941	3.0919531	2.102034599	4.486505302	16.15214556	10.02815291	0.314516749	0.355088928	0.214361796
14	0.982248	1.238139036	1.02239395	1.3829343	2.274416004	4.634888469	15.99881852	7.94441783	0.353827576	0.256095172	0.306911383
15	1.555804	1.251559944	1.23991542	3.641944	3.219677766	5.271234213	19.07028732	8.479742629	0.333541256	0.913205917	0.269758536
16	1.431112	1.298590266	1.13874363	4.0623046	2.827712631	4.003643763	18.09300531	8.576940352	0.268821753	0.320480747	0.27195534
17	1.1941	1.320868811	1.21549319	2.1977303	4.942172788	6.670819711	19.84776274	9.950836392	0.31999589	0.398324801	0.238878397
18	1.452079	1.560205183	1.4848105	4.6524296	6.694632844	5.690486064	21.70492202	14.40106408	0.313945245	0.363813853	0.251863926
19	1.120256	1.076900429	0.94573062	1.9192081	2.335459353	2.484240278	14.43551298	8.902979147	0.292226897	0.531184274	0.258181591
20	1.039874	1.175273051	0.98741507	2.2455616	2.574217694	2.971778757	15.54812139	8.232333385	0.340264793	0.293664664	0.308786074
21	1.349879	1.222655558	1.1575076	3.6226126	2.314382365	3.777727435	16.41041139	10.12408876	0.284789996	0.216416057	0.231312161
22	1.25191	1.247026135	1.06904443	2.4314404	3.120617537	3.501567135	17.55911743	11.36526649	0.272116051	0.35795749	0.312563779
23	0.827358	0.978313589	0.96579746	1.5083944	2.702183561	3.029541455	12.36725414	4.481520529	0.352557535	0.364833325	0.285025635
24	1.141068	1.337349014	1.37192585	2.2977783	6.068743922	5.027976588	19.17049628	8.558013412	0.316443156	0.298667917	0.291862266
25	1.617655	1.160374695	1.05574459	2.8105657	3.458271259	3.301485706	16.07040685	9.255717135	0.218364669	0.843113688	0.237598366
26	1.282361	1.22207687	1.04799615	2.506491	3.492833955	5.050179289	16.91498064	15.27055329	0.246136741	0.352800162	0.320078008
27	1.290192	1.340369646	1.0232539	4.8235979	2.586104113	4.280993155	17.84963898	13.07555927	0.309226632	0.272843375	0.27800886
28	1.134422	1.379244945	1.16178357	1.8586125	3.512031021	6.177233885	18.38610384	11.85003892	0.268385014	0.327509495	0.281831902
29	1.398016	1.242470606	1.12733237	4.0877111	4.392240367	4.813945332	17.00111053	9.97784658	0.363435783	0.388665382	0.257509021
30	0.960514	1.152228527	0.88597789	1.4156337	1.878875859	2.933358076	13.97343001	5.202784882	0.322136005	0.282893687	0.333860198
31	1.125072	1.129238611	1.03460522	1.9296914	2.461518116	3.485969127	15.27723828	9.99780843	0.278393619	0.388538517	0.271654567
32	1.177873	1.027401292	0.83508601	1.9552927	1.940444162	2.308555517	13.38410038	4.378995228	0.239808589	0.364743253	0.317519115
33	1.059357	1.07534064	0.97867135	1.5816706	1.91118596	2.529174491	15.12663556	8.865609061	0.213662258	0.333217529	0.268144439
34	0.956864	1.02227664	0.88891095	1.6669088	2.100336653	2.621645119	12.35759727	6.083239316	0.277573756	0.328637487	0.271116993
35	1.314897	1.211356824	0.96526101	2.5560128	2.240526066	3.156279433	14.39587969	13.6837603	0.261371038	0.35308614	0.303525028
36	1.309601	1.166813316	1.22211994	1.9270929	3.561979878	3.289769218	17.99966522	11.77674898	0.29353885	0.313134956	0.231874167
37	1.047007	1.169306147	1.03301202	1.7330597	2.364567294	3.248803198	15.24059363	6.543795728	0.191696032	0.307604604	0.230101162
38	1.237822	1.087897147	1.02249759	3.5166143	4.072470322	3.234992928	14.87544412	8.252147071	0.303102679	0.366827611	0.282199468
39	1.422902	1.385206899	1.13740461	3.4466238	3.322459992	5.80169398	19.44240274	13.69785669	0.210575642	0.001353518	0.311774056
40	1.242116	1.336213518	1.23055805	3.9800297	4.935531006	5.082972739	18.81014328	8.509868155	0.268055853	0.346269465	0.283888856
41	1.208082	1.3475297	1.10283421	2.0217238	3.749770483	4.707853278	20.50380824	8.557244081	0.245642271	0.530754632	0.295529533
42	1.106412	1.223143729	1.14338961	2.3157226	3.915113988	4.479142795	16.13861645	10.14210623	0.271496337	0.383312558	0.306711051
43	1.250153	1.26475427	1.09714796	2.8228012	3.34189334	4.207420437	16.6707247	11.98062936	0.269571555	0.364304107	0.247194637
44	1.120587	1.072240378	0.94088256	1.7751804	2.618090032	2.642289129	14.53437403	6.069843714	0.237075074	0.462486413	0.209955896
45	1.219859	1.151067743	0.90823728	1.7214516	2.559486942	3.199005026	15.05437834	10.16549084	0.287542638	0.610264135	0.293684109
46	1.319939	1.12365089	1.02548359	3.5292364	2.36839645	2.703593197	16.21047375	10.88726833	0.320176814	0.326844198	0.270468375
47	1.463276	1.708095199	1.45185873	4.3598178	6.062230647	7.797951134	24.89356688	11.5842663	0.292511679	0.634702051	0.318571442
48	1.310263	1.11898201	0.92748603	2.3919786	2.363070701	2.799535331	13.08339565	12.56303003	0.24709861	0.865937541	0.227523046
49	1.350622	1.213711663	1.23574004	3.1979935	3.194302396	3.023583887	18.20547767	7.878629868	0.262806367	0.970316115	0.210189304
50	0.94936	1.087399581	0.96170905	1.976672	2.602683153	2.143348343	12.80843639	8.247578677	0.330347967	0.320413219	0.25010363
51	1.417115	1.425840374	1.27432901	2.8185549	4.630124469	7.14852422	21.98244924	15.61704333	0.274149551	0.269070096	0.274927099
52	1.038238	1.158741026	0.9809335	1.8839774	2.092224553	2.872271507	14.79442559	10.38238364	0.215879414	0.374826998	0.269069078

Average length of stay and Bed utilization for 2 Physician and 1 separate Pathology lab

Replication	LOS_RED	LOS_Yellow	LOS_Green	LOS Red max	LOS Green max	LOS Yellow max	Res tBed Utilization	RedBedUtilization	LOS Green min	LOS Red min	LOS Yellow min
1	0.88529	0.8482	0.72759	2.46634	2.79557	2.27724	11.7558	7.00852	0.2808	0.39985	0.25943
2	0.86703	0.82585	0.73627	1.25132	2.06079	1.90236	10.3859	6.864	0.25386	0.44683	0.25096
3	0.75753	0.79581	0.66791	1.5216	1.3965	1.83808	10.1109	8.52221	0.23068	0.3369	0.23315
4	0.87234	0.80705	0.68754	1.80172	1.52944	1.77553	9.86033	5.08865	0.23887	0.36072	0.24999
5	0.778	0.79333	0.63825	1.09844	1.66292	1.77066	10.1954	6.80752	0.22537	0.35415	0.26885
6	0.88611	0.77887	0.63628	1.68886	1.69995	1.63101	9.62849	10.852	0.21063	0.33674	0.23399
7	0.78846	0.82007	0.68308	1.4514	1.41076	2.05392	10.6599	5.83456	0.29602	0.35998	0.22679
8	0.77902	0.77839	0.65619	1.1683	1.74415	1.86036	9.23152	5.84261	0.2407	0.37378	0.22213
9	0.78603	0.71064	0.60306	1.47282	1.57363	1.3599	8.46102	7.20524	0.25795	0.27356	0.25179
10	0.7262	0.80191	0.64796	0.92044	1.25739	1.90834	10.9329	3.9336	0.28346	0.41345	0.27749
11	0.86748	0.80746	0.75171	1.25314	1.7211	2.77046	9.77299	7.22904	0.307	0.32976	0.28423
12	0.80014	0.77835	0.64569	1.19074	2.1776	1.64661	10.1995	5.80415	0.25359	0.2596	0.20803
13	0.66816	0.84339	0.66708	0.91718	1.49305	2.23743	11.6088	5.53371	0.22599	0.30763	0.20934
14	0.88051	0.77108	0.67827	1.27449	1.30026	1.63851	8.70757	7.05508	0.22319	0.37278	0.27748
15	0.80406	0.77177	0.66503	1.46043	1.51044	2.01903	9.29318	5.69542	0.20865	0.30247	0.27223
16	0.78932	0.82133	0.65431	2.04956	1.08689	2.23008	9.64424	8.55101	0.23563	0.27156	0.20404
17	0.69999	0.75907	0.71473	0.9284	1.83806	1.75845	9.88859	5.83322	0.28957	0.23737	0.23174
18	0.67541	0.77425	0.647	1.21994	1.91023	1.57708	9.05039	5.90987	0.25008	0.3808	0.24543
19	0.83173	0.76763	0.69165	1.28065	1.96454	1.77535	9.72755	8.59967	0.25021	0.34772	0.21106
20	0.70913	0.77437	0.6507	1.36917	1.54329	1.66639	9.4232	5.74872	0.30286	0.30114	0.20712
21	0.81873	0.83438	0.62563	1.37246	1.28244	1.9402	11.779	8.18729	0.24047	0.3597	0.29324
22	0.74291	0.77101	0.59584	1.74962	1.69521	2.32825	10.2816	6.50045	0.25353	0.28881	0.26354
23	0.88635	0.85828	0.71206	3.05014	3.02857	3.09881	12.0243	5.53969	0.26393	0.39207	0.25778
24	0.70793	0.72602	0.63641	0.99011	1.14798	1.63292	8.33525	3.53963	0.31799	0.34475	0.27565
25	0.69617	0.76275	0.62623	0.95677	1.33033	1.65642	9.38249	5.80138	0.24393	0.33145	0.21709
26	0.88432	0.75455	0.70913	1.27399	1.3863	1.85787	10.106	8.69367	0.25075	0.33491	0.25281
27	0.80196	0.80364	0.67257	1.42806	1.45758	1.53172	9.56323	9.69037	0.27911	0.2646	0.20424
28	0.75546	0.76881	0.61473	1.16619	1.27668	1.48593	9.47226	5.0364	0.24061	0.42197	0.25382
29	0.87602	0.8546	0.70015	1.99201	1.48242	2.26267	12.3983	8.76021	0.23055	0.27033	0.21535
30	0.78677	0.75229	0.6714	1.65128	1.77766	1.65563	9.888	7.21205	0.27738	0.34695	0.24601
31	0.84434	0.75179	0.72619	1.55155	1.31971	1.43338	9.49266	10.5013	0.28198	0.35131	0.25912
32	0.79227	0.83565	0.61779	1.20967	1.52187	1.7595	11.2268	6.27217	0.26361	0.25279	0.26387
33	0.86719	0.80414	0.71794	1.23535	1.53192	2.05499	10.1597	3.97464	0.30306	0.39179	0.25076
34	0.85607	0.76113	0.6459	1.51179	1.28258	1.49295	9.2369	8.55905	0.25899	0.3491	0.2825
35	0.84118	0.82107	0.65395	1.84376	1.30573	2.14607	10.5001	6.30885	0.25729	0.29638	0.24856
36	0.81533	0.8669	0.71891	1.33157	2.0845	2.82435	12.769	7.90122	0.25165	0.35978	0.24724
37	0.78212	0.80214	0.6128	1.0028	1.51035	1.58216	9.92512	2.93296	0.27	0.36944	0.27183
38	0.75114	0.75746	0.64595	1.14222	1.11381	1.77416	9.99386	6.57024	0.23563	0.34373	0.25779
39	0.67925	0.81314	0.58564	1.35741	1.29607	1.82832	10.2095	3.39625	0.26191	0.34885	0.26317
40	0.83029	0.78238	0.7295	1.36958	1.73763	1.88499	10.6491	5.18934	0.27311	0.36354	0.26234
41	0.85471	0.77938	0.6555	1.70288	1.54726	1.80612	10.5348	8.19099	0.25535	0.29169	0.25256
42	0.79528	0.74595	0.62795	1.62593	2.17953	2.38325	9.32735	8.61554	0.2479	0.33658	0.2486
43	0.72697	0.81235	0.6624	1.47168	1.31978	2.19627	10.2105	6.96684	0.26728	0.31255	0.27351
44	0.74137	0.80904	0.68844	1.15396	1.80295	1.95309	11.1657	7.10475	0.24182	0.33681	0.27447
45	0.79364	0.79419	0.70862	1.12059	1.53637	2.24431	11.583	4.62957	0.27819	0.38285	0.28108
46	0.76698	0.75713	0.65568	1.21997	1.36318	1.62864	9.49391	5.75234	0.28445	0.30312	0.26556
47	0.79578	0.80712	0.64526	1.66278	1.19687	2.15844	10.1148	7.19676	0.20441	0.23497	0.29858
48	0.73389	0.78365	0.63507	1.11931	1.4855	1.71049	9.45891	4.58679	0.25218	0.35599	0.2689
49	0.89093	0.77112	0.66735	2.15723	2.26388	2.17123	11.0239	7.41156	0.20532	0.37583	0.24998
50	0.79384	0.82849	0.71881	2.04747	1.57255	2.04224	10.3211	8.58064	0.25028	0.30158	0.2372
51	0.76167	0.76173	0.67541	1.46295	1.18075	1.59958	10.1037	8.88616	0.26945	0.34442	0.27359
52	0.70694	0.8507	0.73419	1.13707	1.40351	2.21746	12.0043	7.268	0.27101	0.26809	0.25769

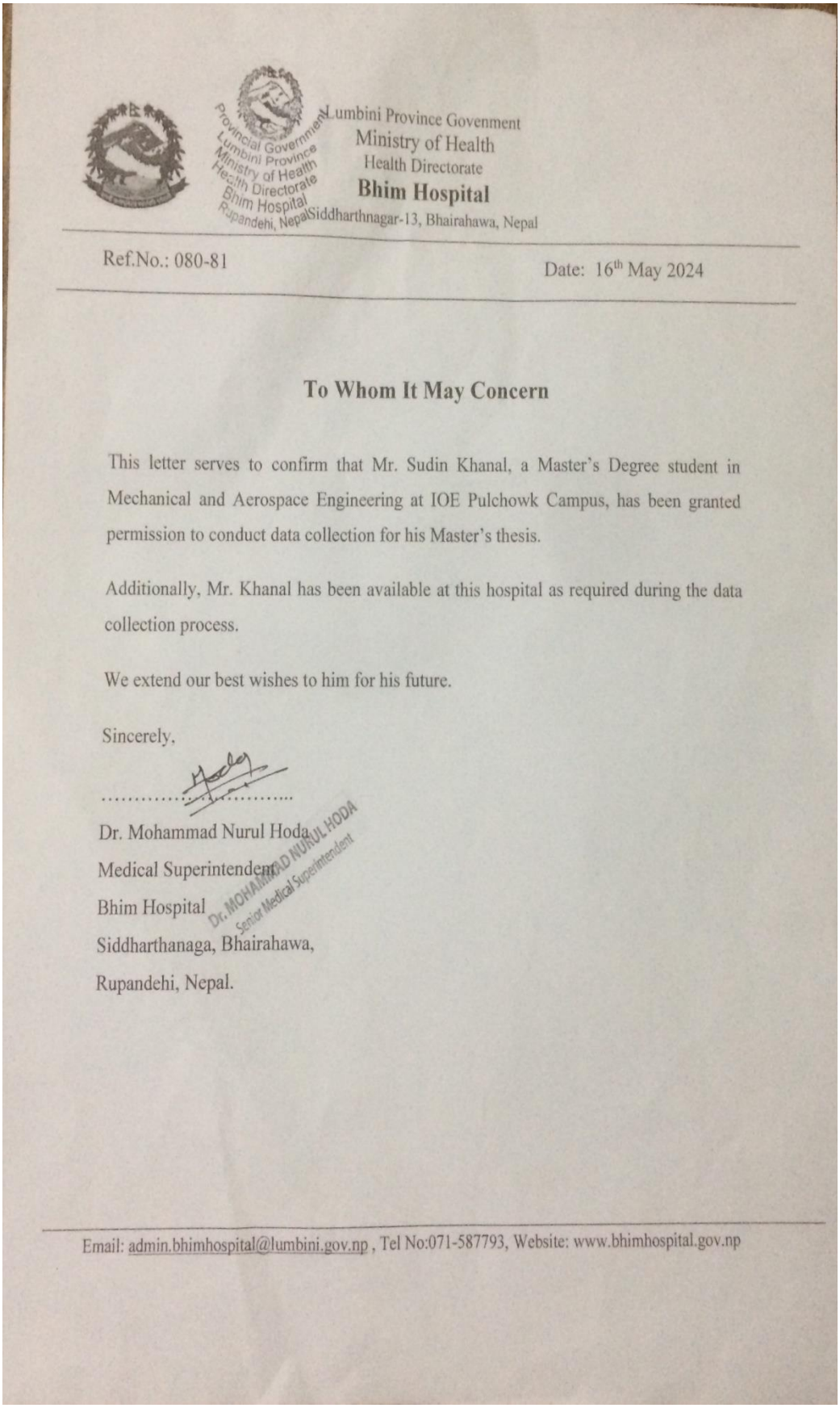
Average length of stay and Bed utilization for 2 Physician

Replication	LOS_RED	LOS_Yellow	LOS_Green	LOS Red max	LOS Green max	LOS Yellow max	Res tBed Utilization	Red Bed Utilization	LOS Green min	LOS Red min	LOS Yellow min
1	0.903704	0.846592	0.630869	1.818409	1.334269	2.257196	9.734804	7.128508	0.271053	0.480125	0.271207
2	0.780409	0.823555	0.693012	1.420824	1.960918	2.181224	10.56974	7.153749	0.263817	0.30951	0.270914
3	0.876688	0.828465	0.674112	1.300351	1.475841	1.848839	10.02211	4.742608	0.293595	0.297633	0.241183
4	0.799198	0.792052	0.600739	1.284876	1.243026	1.501983	8.80218	4.661989	0.246232	0.384581	0.251017
5	1.047727	0.832414	0.628967	2.593807	1.395825	2.379254	10.25426	9.167607	0.237879	0.417386	0.232181
6	1.120387	0.921864	0.737309	3.016136	2.143524	2.4862	12.46326	10.72711	0.287485	0.347184	0.249468
7	0.825838	0.812985	0.78304	1.471601	1.946818	2.100309	11.14649	5.236516	0.299279	0.299996	0.256939
8	0.725854	0.857044	0.745744	1.077385	1.859681	2.186724	9.485825	6.351224	0.244762	0.394235	0.276754
9	0.855139	0.81508	0.735561	1.184302	1.238028	1.724882	10.961	10.33293	0.259813	0.330709	0.272411
10	1.006998	0.773573	0.705165	1.726118	1.300598	1.670855	9.731048	10.44763	0.252539	0.325129	0.240171
11	0.861116	0.824979	0.658788	1.345979	1.229753	1.676484	10.5038	8.03409	0.223355	0.370683	0.250892
12	0.879818	0.856248	0.622829	1.979	2.363552	2.694325	11.29533	8.711732	0.251784	0.325732	0.258162
13	0.851929	0.811468	0.730779	1.213289	1.888208	1.799668	9.692788	8.519291	0.301785	0.339079	0.206025
14	0.825574	0.832671	0.745958	1.153994	1.653397	1.749419	9.730834	5.847814	0.307241	0.307703	0.213802
15	0.774649	0.826093	0.673383	1.32036	1.410404	1.925191	9.964533	6.778178	0.254444	0.285183	0.26305
16	0.824887	0.845437	0.74886	1.274248	2.355951	2.539484	12.43795	6.439072	0.276377	0.368999	0.234437
17	0.796294	0.900038	0.693769	1.090518	1.248647	2.333159	11.74997	8.292178	0.218556	0.301491	0.211984
18	0.82906	0.808837	0.748502	1.265834	1.302204	2.014771	10.78942	7.599721	0.280975	0.349733	0.264753
19	0.877845	0.842322	0.725547	1.20658	1.86979	3.536152	12.22699	6.218068	0.280921	0.338832	0.238773
20	0.829163	0.788068	0.715314	1.15118	1.621819	1.729077	9.806764	8.291625	0.219593	0.253183	0.214745
21	0.800029	0.833139	0.690194	1.136757	1.29771	1.761259	10.31893	7.000253	0.207521	0.324708	0.256532
22	0.814795	0.873514	0.672319	1.18567	1.702872	1.600751	10.38113	7.129458	0.245077	0.293708	0.26589
23	0.943518	0.815991	0.654327	1.464732	1.261926	1.503049	9.681814	6.290119	0.259936	0.457595	0.276505
24	0.788113	0.837654	0.751108	1.297954	2.281597	1.85694	10.37085	7.015684	0.255807	0.311693	0.246501
25	0.860838	0.775448	0.66958	1.393282	1.357207	1.625355	10.97682	7.173651	0.227908	0.283241	0.2315
26	0.883566	0.872789	0.668367	1.669665	1.398514	1.966184	10.65333	8.099357	0.227825	0.352436	0.219737
27	0.907578	0.837063	0.74935	2.054332	2.044486	1.63578	11.9164	7.463495	0.242567	0.199412	0.218862
28	0.776282	0.855102	0.683071	1.080738	1.239915	1.704477	10.73802	7.439371	0.173239	0.295268	0.244202
29	0.841675	0.857352	0.747912	1.120522	1.373807	2.376037	10.26446	4.909774	0.243046	0.329841	0.272877
30	0.811399	0.806936	0.636602	1.330055	1.330038	2.052632	10.56279	8.728956	0.296107	0.33875	0.276407
31	0.805701	0.807274	0.700161	1.379339	1.516868	1.944592	11.11493	4.699922	0.232474	0.401253	0.211968
32	0.808641	0.839356	0.67337	1.261062	1.218705	1.891608	10.52058	6.738677	0.230506	0.352391	0.179042
33	1.002259	0.853841	0.676849	2.160304	1.25529	2.081584	10.75149	9.477635	0.269038	0.286663	0.210039
34	0.903153	0.811117	0.632249	1.340153	1.361752	1.832626	9.623062	10.78131	0.26405	0.316283	0.222442
35	0.842034	0.862744	0.726151	1.103719	1.519155	1.772641	12.03674	7.367795	0.246513	0.336445	0.27861
36	0.868364	0.823853	0.688754	1.221961	1.343538	1.659201	9.535059	9.358278	0.302555	0.347364	0.278293
37	0.854059	0.775173	0.746318	1.118868	1.657456	2.359918	9.759849	6.405441	0.267618	0.344125	0.213565
38	0.849355	0.841378	0.768317	1.655813	1.726715	2.911865	10.36489	7.564335	0.276812	0.349947	0.30222
39	0.855548	0.830129	0.594128	1.132043	1.430161	1.567853	10.84875	6.972726	0.247686	0.376413	0.258904
40	0.845967	0.833815	0.684025	1.099285	1.303772	2.070333	11.17619	4.794844	0.260341	0.390786	0.241686
41	0.85559	0.850375	0.711629	1.330491	1.519022	2.216498	11.18022	10.4541	0.267796	0.27253	0.278627
42	0.883798	0.85615	0.600066	1.191898	1.174556	2.134553	9.990858	3.928357	0.290921	0.378689	0.273564
43	0.845969	0.817065	0.639768	1.268351	1.514835	1.521048	11.5392	6.579026	0.273431	0.311591	0.27101
44	0.763555	0.851765	0.632721	1.192713	1.388025	1.915187	9.509902	4.772217	0.274565	0.331316	0.271792
45	0.899169	0.817289	0.694868	1.355808	1.334895	2.178476	10.685	8.784795	0.271354	0.285315	0.2542
46	0.791936	0.835508	0.706358	1.476125	1.462976	1.990993	11.36497	8.909279	0.251045	0.258775	0.241649
47	0.813222	0.808146	0.694662	1.147579	1.200183	1.6842	10.73511	7.793373	0.258579	0.317378	0.260745
48	0.746459	0.818137	0.691571	1.246155	1.338277	2.216489	11.44888	7.366155	0.274616	0.254626	0.247135
49	0.765498	0.831012	0.636528	1.419052	2.210592	2.489145	9.823979	6.379147	0.278961	0.236869	0.268617
50	0.87692	0.847196	0.70813	1.33803	1.443737	2.105509	11.96446	7.673049	0.246047	0.309389	0.22093
51	0.889309	0.866475	0.746736	1.487704	2.274963	2.650132	10.56774	6.669815	0.255924	0.309888	0.282359
52	0.852581	0.851619	0.732845	1.169289	1.54024	2.455007	10.56229	8.88105	0.27177	0.361323	0.263417

Average length of stay and Bed utilization for 1 Physician and a Pathology lab

Replication	LOS_RED	LOS_Yellow	LOS_Green	LOS Red max	LOS Yellow max	Res tBed Utilization	Red Bed Utilization	LOS Green min	LOS Red min	LOS Yellow min
1	1.161758	1.114897	0.989745	2.0599216	3.4384418	14.63962963	5.324722887	0.267442	0.454632	0.240799
2	1.282226	1.101315	1.029522	3.4734776	3.3798766	15.18750622	9.082430821	0.25478	0.467972	0.250318
3	1.245797	1.342549	1.192893	4.1779564	7.9671913	17.50440825	14.07188923	0.271975	0.465172	0.246047
4	1.09418	1.150765	1.038341	2.8136145	3.7507956	16.13619621	8.662258755	0.277645	0.387943	0.293244
5	1.883993	1.811886	1.570186	9.6231533	9.8430582	25.94695667	12.14069657	0.356747	0.24826	0.314081
6	1.278808	1.263717	1.056276	5.7739455	4.3410398	16.06895829	12.24244125	0.2628	0.337483	0.284468
7	1.39474	1.150422	1.13671	3.9940209	4.8170266	16.30354185	7.554843694	0.355353	0.409845	0.290433
8	1.131446	1.115442	1.038826	2.6603129	3.2816947	14.65687021	8.485846564	0.212238	0.345163	0.244286
9	1.138266	1.216316	1.421966	2.1249614	5.8912356	18.61983312	9.485547921	0.245254	0.240269	0.240229
10	1.432019	1.464222	1.299906	3.339109	7.5981166	21.72716201	8.868219854	0.267098	0.5074	0.285676
11	1.709814	1.228576	1.31036	5.595466	6.4184885	18.88370428	13.81037369	0.356	0.657129	0.229859
12	1.061002	1.132039	1.145759	2.3734252	5.0441034	16.03318476	9.341438307	0.26614	0.482014	0.272919
13	1.174547	1.189744	1.102432	3.284016	4.4302239	16.79346074	8.496764077	0.26663	0.414924	0.26242
14	1.249916	1.374927	1.267759	2.4399408	5.9567223	22.34966649	9.865153604	0.282703	0.401015	0.293983
15	1.203701	1.177519	0.944732	2.3126284	3.4650033	15.47608584	9.529297941	0.263541	0.848736	0.257315
16	1.204478	1.269886	1.198637	3.7461926	5.195391	17.58220265	16.75817463	0.343319	0.308985	0.260642
17	1.06633	1.179695	1.015833	2.7161131	5.5585071	15.3175584	8.862789943	0.380489	0.455931	0.273557
18	1.2908	1.208746	1.082491	2.4979084	5.7691964	14.99711905	9.400338434	0.365081	0.538088	0.320375
19	1.271994	1.375592	1.250366	2.3229763	4.6268638	18.98546262	9.539954929	0.267179	0.32169	0.274774
20	1.01921	1.074218	0.92424	1.8282032	3.2384067	12.67313043	8.06874212	0.320061	0.38145	0.250407
21	1.113044	1.135579	1.067574	2.2876239	4.3124121	16.57954366	7.420294985	0.288042	0.363555	0.215678
22	1.066082	1.347436	1.071767	2.0330272	7.0936388	16.49762078	7.107216048	0.223315	0.457951	0.30334
23	1.076417	1.162755	0.997896	2.0331363	3.3371923	16.53056302	9.242750061	0.275586	0.513866	0.258676
24	1.000634	1.171591	1.080509	2.6758962	4.2892597	16.1269365	7.504755129	0.30233	0.347235	0.266302
25	1.097901	1.267653	1.014022	2.4358901	4.9184943	17.31876713	6.861880986	0.300354	0.391589	0.253338
26	0.961143	1.013596	0.918171	1.6409381	2.901375	13.6561803	8.802599857	0.25724	0.424703	0.225545
27	1.193093	1.260486	1.058387	3.102176	7.57994	16.18083154	10.9366874	0.296827	0.358886	0.241262
28	1.196637	1.140251	1.053997	1.6736167	5.6168904	17.73838711	9.473375826	0.30234	0.784051	0.282098
29	1.30691	1.288418	1.180174	3.224497	4.6915233	19.93256241	9.801824479	0.259373	0.42499	0.322806
30	1.135618	1.134468	1.055942	2.2688292	2.8944042	15.56340713	7.131292587	0.250886	0.363303	0.255727
31	1.214027	1.612746	1.19247	2.4285881	8.8450271	22.68529665	9.83876072	0.285024	0.401008	0.280936
32	1.317169	1.145633	1.031866	3.4303169	5.5095366	15.92915056	9.429069776	0.3193	0.419986	0.270566
33	1.240609	1.152289	0.985855	2.3538545	2.7657114	14.61386605	13.6815545	0.228687	0.410965	0.275866
34	1.289192	1.168968	1.020357	4.7294039	6.4614685	16.02107622	11.45850281	0.234386	0.456549	0.270258
35	1.101459	1.240048	1.166009	2.9928002	4.0917986	17.71669036	6.884121271	0.250959	0.326826	0.277601
36	1.161674	1.116244	0.918741	2.828732	2.6502582	15.79891152	8.645772974	0.250219	0.262686	0.292799
37	1.338492	1.284821	1.584007	3.9617311	4.3607157	20.10248259	14.13772611	0.386261	0.335696	0.230908
38	1.032113	1.197325	1.16674	2.1805958	5.2502759	17.12724895	6.020659269	0.315974	0.365354	0.264331
39	1.541069	1.253529	1.098462	3.5772182	4.4605351	18.29152509	13.0391175	0.239625	0.766043	0.303368
40	1.164264	1.086269	0.999231	1.7627948	5.0944284	15.7258865	7.276651943	0.238883	0.789504	0.291492
41	1.282019	1.092225	0.972467	1.9427212	3.5534379	15.06901537	10.14931671	0.299562	0.880696	0.238718
42	1.27527	1.347647	1.302997	3.1126484	5.6076048	21.2191991	10.0958845	0.274265	0.444199	0.264282
43	1.233778	1.121879	1.112487	2.6789727	5.6402947	14.64092611	12.30020532	0.267691	0.391766	0.291415
44	0.926387	1.138612	0.907474	1.3014138	4.6155631	15.30229494	6.921566586	0.28101	0.423874	0.243927
45	1.112957	1.325975	1.147494	1.6432897	6.2893398	21.01456934	7.419714835	0.266826	0.330025	0.30627
46	0.964566	0.991807	0.967079	1.5488712	2.4928115	13.33159423	7.234246882	0.264907	0.627091	0.283123
47	1.221164	1.168068	1.127214	2.7453574	3.3432156	16.08458872	9.158731374	0.251865	0.303515	0.293358
48	1.019885	1.068814	0.854085	2.2120362	3.9958335	13.41780121	9.70212446	0.255466	0.2939	0.2441
49	1.372307	1.278536	1.107823	4.0889541	4.9198164	17.77820599	10.29229938	0.254795	0.32008	0.198368
50	0.83207	1.080859	1.011038	1.4609577	3.5356895	13.8645014	5.547134706	0.261254	0.356786	0.245783
51	0.987067	1.381927	1.060349	2.1033765	5.6289854	18.19901249	8.663352024	0.213585	0.398141	0.233783
52	1.4905	1.566557	1.372479	5.2418588	8.8403244	23.15313904	10.55770924	0.266043	0.38397	0.28572

ANNEX FOUR: BHIM HOSPITAL LETTER OF CONSENT



Lumbini Province Govenment
Ministry of Health
Health Directorate
Bhim Hospital
Siddharthnagar-13, Bhairahawa, Nepal

Provincial Government Lumbini Province Ministry of Health Health Directorate Bhim Hospital Rupandehi, Nepal

Ref.No.: 080-81

Date: 16th May 2024

To Whom It May Concern

This letter serves to confirm that Mr. Sudin Khanal, a Master's Degree student in Mechanical and Aerospace Engineering at IOE Pulchowk Campus, has been granted permission to conduct data collection for his Master's thesis.

Additionally, Mr. Khanal has been available at this hospital as required during the data collection process.

We extend our best wishes to him for his future.

Sincerely,

.....

Dr. Mohammad Nurul Hoda
Medical Superintendent
Bhim Hospital
Siddharthanaga, Bhairahawa,
Rupandehi, Nepal.

Dr. MOHAMMAD NURUL HODA Senior Medical Superintendent

Email: admin.bhimhospital@lumbini.gov.np , Tel No:071-587793, Website: www.bhimhospital.gov.np

ANNEX FIVE: PLAGIARISM REPORT

Analysis of Patient Flow Using Discrete Event Simulation for An Emergency Room: A Case Study of Bhim Hospital Rupandehi, Nepal

ORIGINALITY REPORT

2%
SIMILARITY INDEX

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