Study to Assess the Utility of Discrete Event Simulation Software in Projection & Optimization of Resources in Out-Patient Department at an Apex Cancer Institute in India: A Simulation Based Study

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Research Article

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Abstract

Background

Healthcare is growing more complex with mandate expanding from the primary function of providing care to include economic, legislative and social conditions that has led to the rise of numerous ancillary services. These have necessitated multiple new processes and systems which are closely intertwined. A study was done to create and run a discrete event simulation in OPD of a tertiary care cancer hospital of North India to project and optimize resource deployment.

Methods

The OPD process & workflow as per the expected load at tertiary care cancer hospital were finalized with various stakeholders in a focused group discussion. The finalized OPD process & workflow along with the OPD Building plans were utilized to develop a discrete event simulation model for the OPD at tertiary care cancer hospital using a DES. The simulation model thus developed was tested with incremental patient loads in 5 different scenarios/ “What if” situations (Scenario 1-5). The data regarding initial patient load and resources deployed was taken from on ground observations at tertiary care cancer hospital.

Results

It was found that rooms and doctors were over-utilized and support staff utilization remained low. This was implemented with lesser waiting time for patients. No additional support staff was provided thus improving utilization of existing staff and saving on resources. The simulations enabled us to deploy resources just when it was required, which ensured optimal utilization and better efficiency. The peak census helped us to determine the capacity of the waiting area in different scenarios with incremental patient load and resource deployment.

Conclusion

The Simulation software was very helpful, as “what if scenarios” could be created and the system tested, without disturbing the normal functioning of OPD. This enabled decision making before making on ground changes which saved lot of time and money.

Introduction

Healthcare is growing more complex with mandate expanding from the primary function of providing care to include economic, legislative and social conditions that has led to the rise of numerous ancillary services. These have necessitated multiple new processes and systems which are closely intertwined. According to the World Health Organization [1], a good health system requires *“a robust financing mechanism; a well-trained and adequately paid workforce; reliable information on which to base decisions and policies; well-maintained facilities and logistics to deliver quality medicines and technologies*.”

Today, healthcare organizations are challenged by pressures to reduce costs, improve coordination and outcomes, and be more user friendly. Yet, at the same time, the healthcare delivery is increasingly challenged by entrenched inefficiencies and suboptimal outcomes. These have, over the period of time, brought in new concepts/ approaches that can better manage and optimize healthcare systems which are generally referred to as “Healthcare Engineering” [2].

Data is a key driver for any healthcare engineering project. Globally, healthcare organizations are tryingto harness “big data”to create actionable insights.Healthcare Analytics as a way of transforming data into actions is gaining ground. In essence, Data analytics should help in connecting the dots and making sense out of the data which in turn can assist in decision making [3][4].

There are many operations research [OR] tools that are helpful in this regard. Among them Discrete Event Simulation [Simulation] has the capacity to model complex situations with inherent advantages of interactive visualization. Even users who are not operation researchers or industry engineers can understand, develop, and validate the system better. It can describe a complex real-world system while accurately representing stochastic elements. Users can ask 'what if?' questions and design new systems [5].

Simulation can act as a forecasting tool where the performance of an existing system with changes in operating conditions can be evaluated. This enables hospital administrators to experiment with different management policies in multitude possibilities without interfering with the normal functioning of the healthcare facility [5]. Thus, simulation gives an edge to the administrators.

The parent institution has OPD footfall of around 12000 patients per day [5]. The huge patient load has put tremendous pressure on existing systems and infrastructure. Long waiting times are a common occurrence, affecting overall patient experience, which has also been reflected through the in-house feedback system [6].

The lessons learnt from the parent institution have prompted the use of new tools and techniques for resource optimization in the tertiary care cancer institute. The cancer institute is an apex centre for translational research in prevention &care for India centric cancers and is the flagship project of MoHFW. The institute was recently inaugurated and is being operationalized in phases. Patient load is expected to increase rapidly and this makes it pertinent to scientifically design processes and optimize resource allocation for more efficiency and better outcomes.

DES over the years has found numerous applications including modeling Lean process for reducing patient delays [7], reduce the turnaround time for patients [8], predict and plan for staffing needs [9] and develop high-fidelity simulation models for Quality Improvement [QI] [10]. Therefore, it was decided to leverage Discrete Event Simulator [DES] to model processes and functioning of the cancer institute to help timely, efficient deployment of resources. Hence a study was done to run discrete event simulation in outpatient department of cancer institute to project and optimize the resources.

Methodology

The study design is a stimulation model based on focused group discussions. The study setting was a tertiary care hospital which was recently inaugurated. The hospital has around 700 beds dedicated to cancer treatment making it one of the largest cancer hospital of the country and a total of 250 bed were to be started in Phase I.

1. *To build a simulation model of out-patient department at the institute using Discrete Event Simulation Software.*

Methodology: As part of the research project, the OPD process & workflow as per the expected load at the institutehave been finalized with various stakeholders in a focused group discussion. The various stakeholders were Head, and key faculty from the department of Medical Oncology, Surgical Oncology, Radiotherapy, Onco-anesthesia& Palliative Medicine, Laboratory Medicine, Radiology, Nuclear Medicine and Hospital Administration.

The finalized OPD process & workflow alongwith the OPD Building plans were utilized to develop a discrete event simulation model for the OPD at the institute by using healthcare specific discrete event simulation software,Flexsim Healthcare.

1. *To simulate different scenarios with incremental patient load in OPD at the institute on the simulation model and identify bottlenecks, if any.*
2. *To suggest possible solutions/ give recommendations for improvements based on findings from simulation of sequence of scenarios.*

The simulation model thus developed was tested with incremental patient loads in 5 different scenarios. The data regarding initial patient load and resources deployed was taken from on ground observations at the institutes OPD. Each scenario tested incremental patient load, identified the bottlenecks and thus recommend additional resources to ease the bottlenecks.

These were then simulated in the subsequent scenarios thus giving us a longitudinal picture of how the system has evolved with incremental work load.

Results

Different scenarios/ “What if?” conditions were simulated during the operationalization of NCI OPD to facilitate decision making. In all the scenarios the focus was on improving the overall patient experience by optimally deploying and utilizing resources. The parameters include average patient waiting times, census, throughput, staff utilization parameters, utilization of screening rooms, utilization of DMG [Disease Management Group] rooms and time at which OPD finishes. The dashboards function in the software provides a real time update on these parameters and thus it is easy to obtain a longitudinal trend over period of time.

The decision points were for deployment of staff [different cadres], size of the waiting area andopening up of additional floors for patient care with focus on better patient experience. The simulation model has helped to strike a fine balance to minimize the waiting times by optimally deploying resources. The general tendency towards blanket increase in manpower could be circumvented as the models provided a real time picture of staff utilizations and staff state times. They also helped to identify the main bottlenecks in the overall process.

The process flow of patients at cancer institute is that the patient first goes to the screening room where the doctor first screens and decides if the patient has to be registered under the institute. Subsequently the patient goes to the registration counter, gets the card made and proceeds to the DMG [Disease Management Group] room where detailed evaluation is done. Subsequently the patient goes to the SWEC [Single Window Exit Counter] where fees for tests are paid, and then samples are drawn in the sample collection area by a lab technician, following which the patient leaves the OPD. [Figure 1]

The different scenarios that were modeled are as under:

Scenario 1

The initial patient load was about 40 patients per day. The resources deployed were 2 screening rooms [with 2 doctors], 2 DMG rooms [with 2 doctors], 1 receptionist, 2 PCCs [patient Care Coordinators] and 1 lab technician. With these resources the OPD finished at 3 pm which was also what we could see on ground. [Figure 2]

The peak census at any given point of time was 25, based on which the capacity of waiting area was kept at 30 initially. This helped to provide seating for patients while they wait for consultation. We could see that utilization of DMG rooms [83.58%] and utilization of doctors in DMG rooms [83.5%] was high and was likely to become a bottleneck with any increase in workload. The staff state times also reflected the same. The utilization of receptionists however was barely around 11% which clearly indicated that there was no need to augment in near future. The average waiting time for patients was around 100 minutes towards the end of the OPD.

Scenario 2

In the second scenario patient load was increased to 60 patients per day in the simulation model. With the same resources as in scenario 1, the OPD did not finish at 3pm. Instead 20 patients were yet to be seen with average waiting time of 115 minutes. Utilization of DMG rooms and doctors in DMG rooms was around 89%. The utilization of screening rooms and doctors there was about 83%. The average state times of the doctors and patients reflected the same. The peak census crossed 40 patients. The capacity of the waiting hall was increased to 50 which provided seating arrangements for patients waiting. The OPD got over around 5pm which was corroborated on ground. [Figure 3]

Scenario 3

In the third scenario patient load the patient load was increased to 100 patients per day with the same resources in scenario 1 and simulation was run. The OPD did not finish at 3pm and 58 patients were still waiting to be seen at 3pm. The peak census had crossed 80 which called for more waiting area. The average wait time increased to 138 minutes. Utilization of screening rooms and doctors there had crossed 93% and utilization of DMG rooms and their doctors had crossed 91%. The staff state times reflected the same. Utilization of reception area, lab area, lab technicians, receptionists and PCCs all remained barely around 20%. [Figure 4]

Scenario 4

In the fourth scenario the manpowerwas increased for a patient load of 100 patients per day in the simulation. Based on the staff utilization seen in scenario 3, additional 1 doctor was deployed in screening area and 2 additional doctors deployed in DMG rooms. That makes a total of 3 doctors in screening area and 4 doctors in DMG rooms. There were some improvements with average waiting time coming down to 128 minutes, with about 24 patients remaining to be seen at 3pm in the OPD waiting area.

The utilization of DMG rooms and its doctors cooled down to 81% but utilization of screening room and its doctors continued to be more than 90%. The peak census came down to little above 60 which decreased the waiting area required. The utilization of other staff increased but continued to be around 40%. [Figure 5]

Scenario 5

In the fifth scenario an additional floor was opened to cater to the load of 100 patients per day. Based on utilization figures from scenario 4, the screening room was found to be the bottleneck. Therefore all the DMG rooms were now shifted to the first floor and capacity of screening rooms increased in ground floor. With the increased manpower and additional floor opened, the OPD finished at 2:10 pm itself with average waiting time dropping dramatically to 81 minutes. The utilization of screening room and its doctors cooled down to around 81% and that of DMG rooms and its doctors hovered around 82%.The peak census came down to a little below 60 which decreased the need for any further expansion of waiting areas. The utilization of other staff slightly increased but still didn't mandate any further augmentation. [Figure 6]

The results are summarized in Table 1 for different scenarios.

Discussion

The simulation models built on the discrete event simulation software, Flexim healthcare, has been helpful in decision making during operationalization of OPD services at the NCI, AIIMS. The model built in scenario 1 with 40 patients per day and the said resources, very closely resembled the on ground situation when the OPD was operationalized.

Subsequently planning was done for periodic deployment of resources to ensure their optimal utilization. Early deployment, especially of manpower would have led to idling and wastage. In scenario 2 the patient load was increased to 60 per day. In this case it was noted that the OPD would go on until 5 pm. The bottleneck was noted to be the DMG room and doctors. The utilization of support staff like the receptionists, lab technicians and PCCs was barely around 11%. The peak census crossed 40. Therefore, these mandated increase in waiting hall capacity and augmentation of DMG rooms.

Subsequently, the simulation was run with higher patient load of 100 patients per day. In scenario 3 this load was tested with existing resources of scenario 1. It clearly reflected the system was at the verge of failing as less than half the patients were seen by 3 pm with long waiting times and utilization of doctors in screening and DMG rooms clearly crossing 90%. The peak census crossed 80. These indicated requirement for augmentation at levels of waiting areas, screening rooms and DMG rooms. Utilization of support staff however remained around 40%.

Therefore it was suggested to augment with two more DMG rooms [with 2 additional doctors] and one more screening room [with 1 additional doctor]. This was simulated and tested on the software in scenario 4. The augmentation of resources slightly eased the system by bringing down waiting times but still 24 patients remained to be seen at 3 pm in the OPD.

Table 1: Summary of simulation of different scenarios

Scenario no.	Patient load	Resources Deployed	OPD Finish time	Utilization of DMG	Utilization of Doctors	Average wait times
1	40	2 screening rooms [with 2 doctors], 2 DMG rooms [with 2 doctors], 1 receptionist, 2 PCCs [patient Care Coordinators] and 1 lab technician	15:00 hours	83.58%	83.5%	100 minutes
2	60	2 screening rooms [with 2 doctors], 2 DMG rooms [with 2 doctors], 1 receptionist, 2 PCCs [patient Care Coordinators] and 1 lab technician	Did not finish at 15:00 hours still 20 patients remain	89.0%	89.0%	115 minutes
3	100	2 screening rooms [with 2 doctors], 2 DMG rooms [with 2 doctors], 1 receptionist, 2 PCCs [patient Care Coordinators] and 1 lab technician	Did not finish at 15:00 hours still 58 patients remain	93%	90.0%	138 minutes
4	100	2 screening rooms [with 3 doctors], 2 DMG rooms [with 4 doctors], 1 receptionist, 2 PCCs [patient Care Coordinators] and 1 lab technician	Did not finish at 15:00 hours still 20 patients remain	81%	90%	138 minutes
5	100	2 screening rooms [with 4 doctors], 2 DMG rooms [with 4 doctors], 1 receptionist, 2 PCCs [patient Care Coordinators] and 1 lab technician	14:10 hours	81%	82%	81 minutes

Besides, utilization of screening rooms and its doctors continued to be more than 90% which turned out to be the bottleneck. Also since the peak census was high, there was also need for a larger waiting area which put pressure on space as only the ground floor of the OPD block was initially operational.

It was therefore now suggested to increase the screening rooms and its doctors. Considering the need for space, it was decided to operationalize the first floor of the OPD and shift all 4 DMG rooms there. This was simulated in scenario 5 on the software. It was found that by operationalizing the new floor and adding just one extra screening room [with 1 extra doctor], the average wait time dramatically dropped to around 80 minutes with the OPD finishing by 2:10 pm. The utilization of screening rooms, DMG rooms and its doctors also hovered around a little above 80%, which indicates optimal utilization.

Utilization of support staff has slowly increased with patient load. Utilization of lab technicians [32%] & PCCs [18%] remained low and would not need augmentation till patient load increases to more than 200 per day. Utilization of receptionists however reached 72% with 100 patients per day. There is no need for immediate augmentation and would be required when patient load crosses 120 per day.

Conclusion

1. The Simulation software was very helpful, as “what if scenarios” could be created and the system tested, without disturbing the normal functioning of OPD.This enabled decision making before making on ground changes which saved lot of time and money.
2. The peak census helped us to determine the capacity of the waiting area in different scenarios with incremental patient load and resource deployment.
3. Cumulative utilization of staff [doctors, DEOs, PCCs & lab technicians] and areas [screening rooms, DMG rooms, registration counters and SWEC] helped us to identify the bottlenecks in the process.

4. The bottleneck in the whole process was the screening room and patient load of more than 100 could also be managed with just 2 DEOs [Data Entry Operators].
5. The average staff state times and average patient waiting time also served as indicators to see the impact of increasing deployment/ resources across different scenarios.
6. The simulations enabled us to deploy resources just when it was required, which ensured optimal utilization and better efficiency.
7. Especially the decision for operationalizing an additional floor was crucial, as adding more floors would entail more resources. This necessitated that the additional floor had to be operationalized not too early to avoid wastage of resources and not too late pushing the system's limits. The simulation models helped us to strike the right balance and precisely time the operationalization of an additional floor.

Therefore, discrete event simulation has served as an important tool for decision making. There are many more applications of this tool like integration with Kaizen activities, alignment with Quality Improvement programs among others which needs to be explored.

Declarations

Ethics approval and consent to participate and Consent for publication – Not applicable

But still Ethical approval was obtained from the Institute's ethics committee.

Availability of data and materials –All data generated or analysed during this study are included in this published article

Competing interests - None
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Authors' contributions - ARS and SS conceptualized the study. ARS and AG collected the data. NRG and AG analyzed the data and wrote the result, and manuscript. ARS prepared figures. All authors reviewed the manuscript.
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Figures

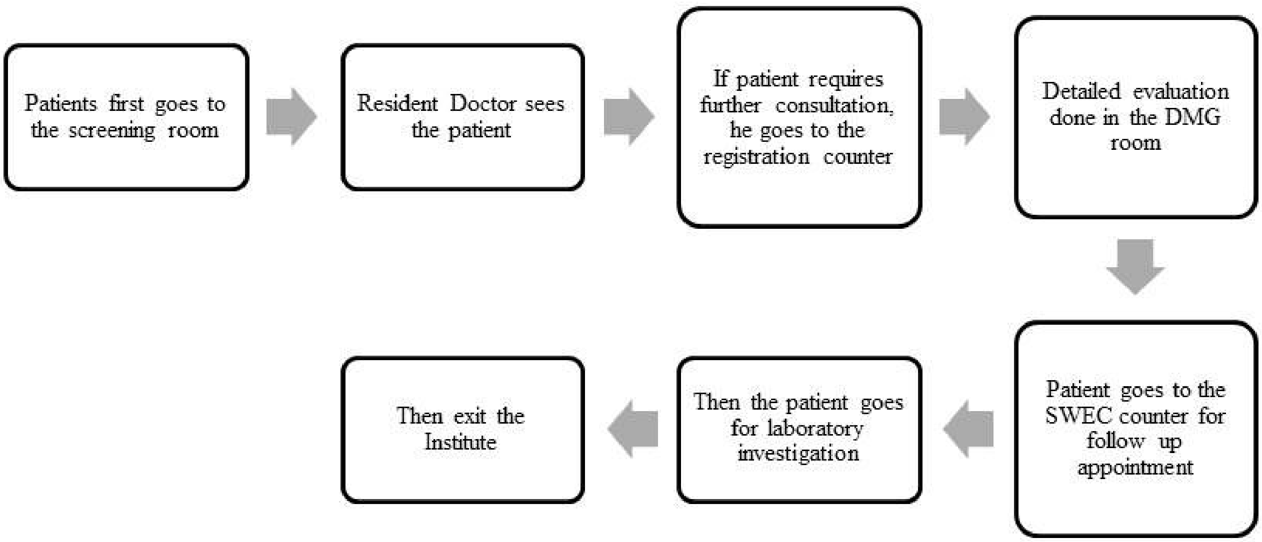

Figure 1

Schematic representation of process flow of patient

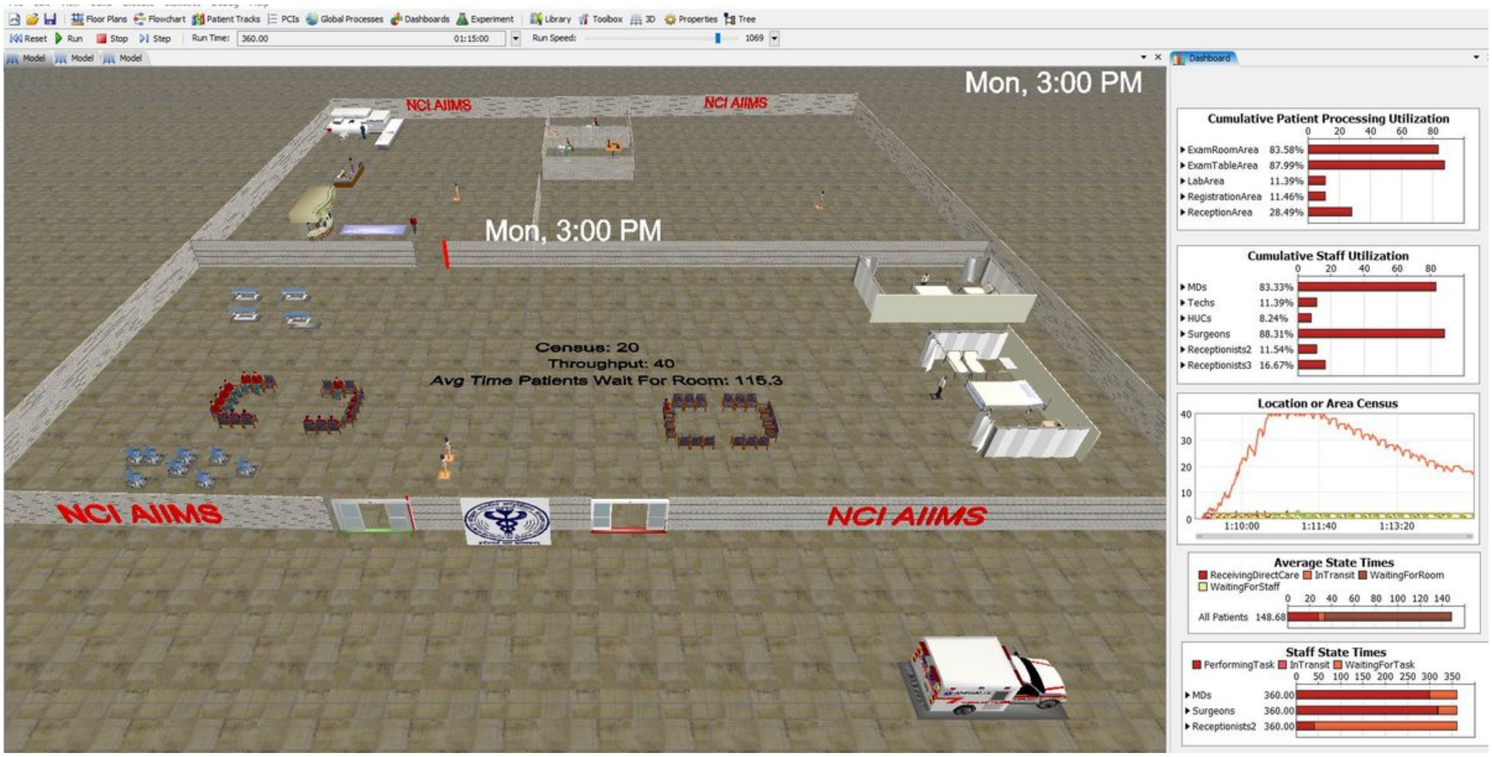

Figure 2

Simulation of Scenario 1

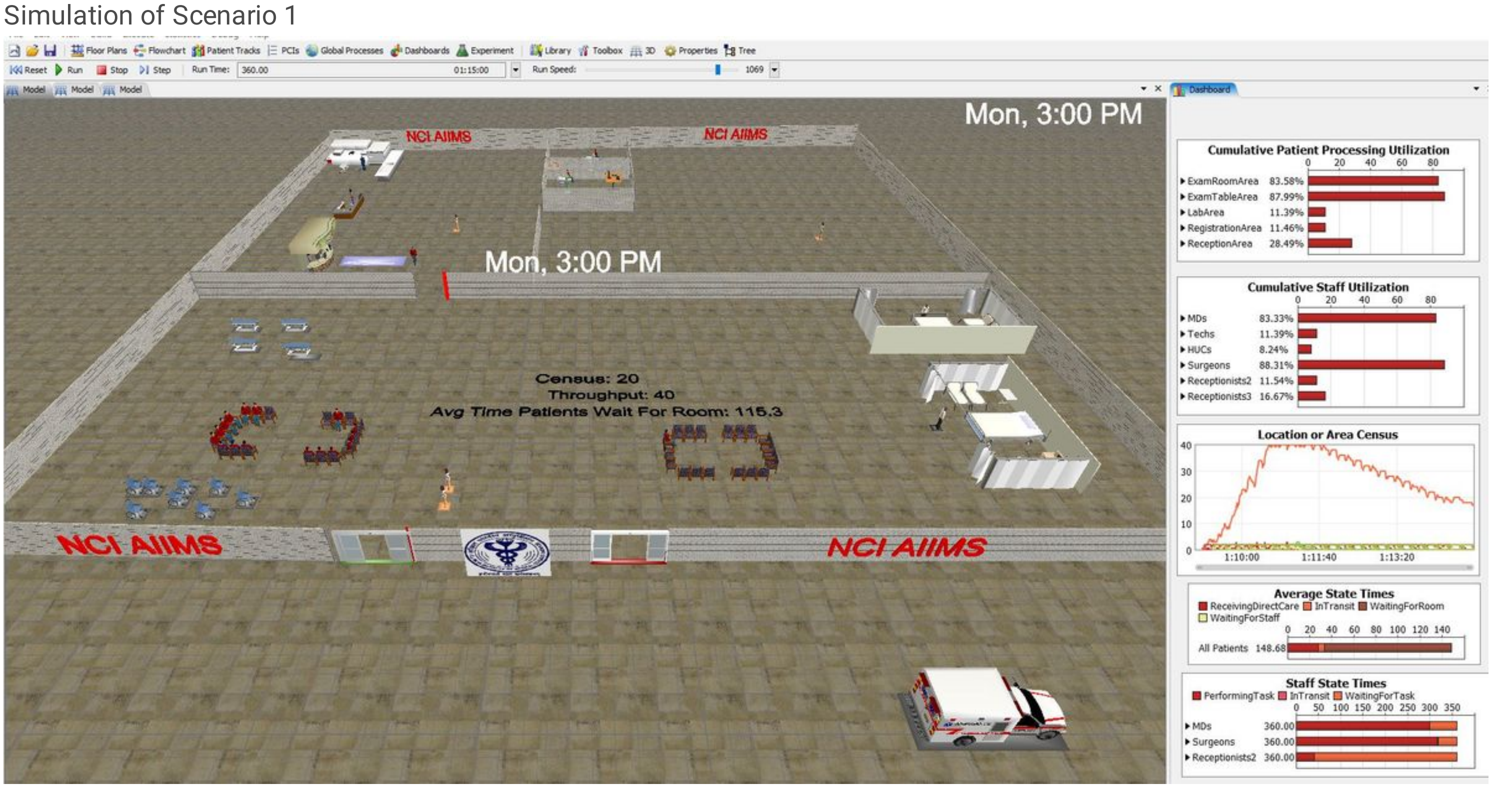

Figure 3

Simulation of Scenario 1

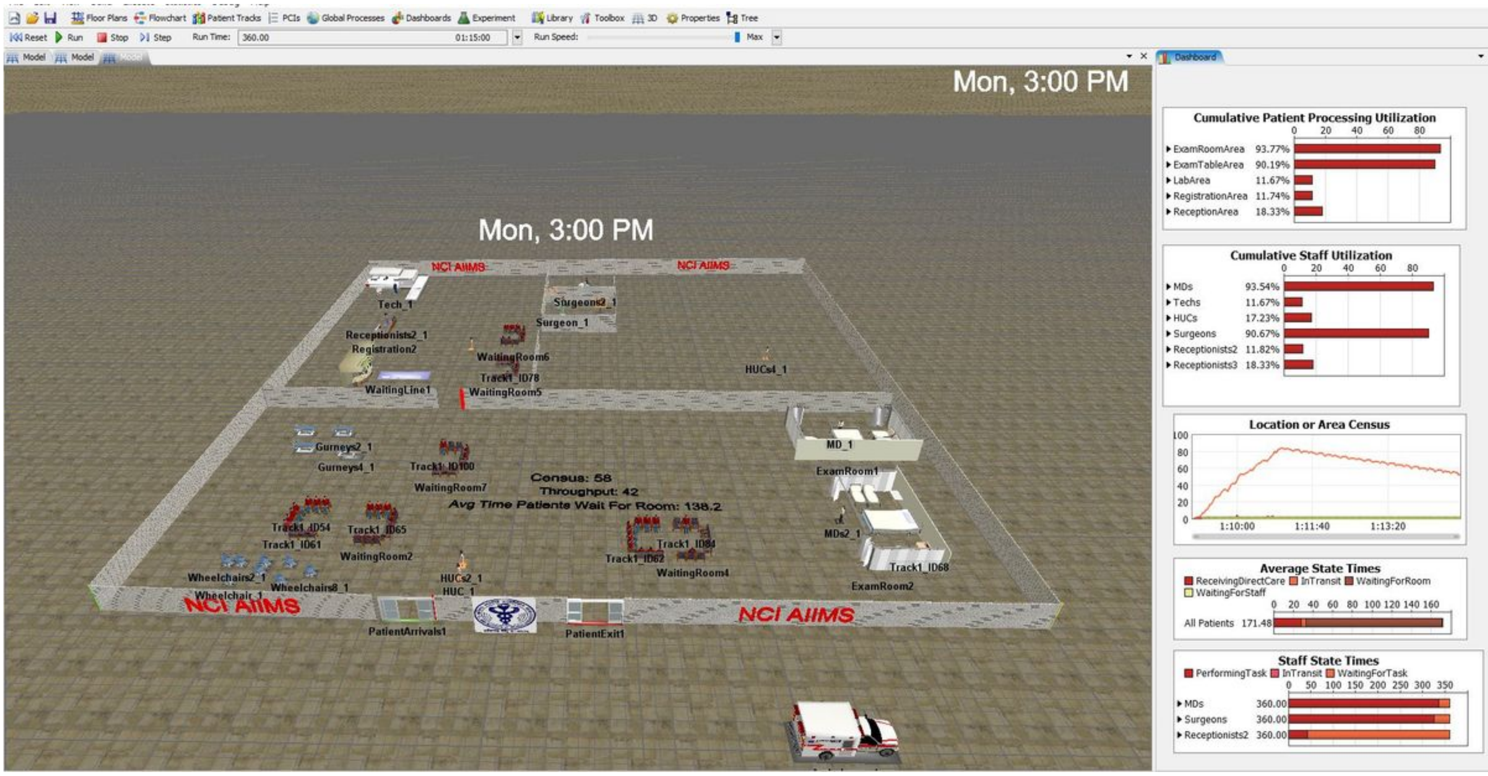

Figure 4

Simulation of Scenario 3

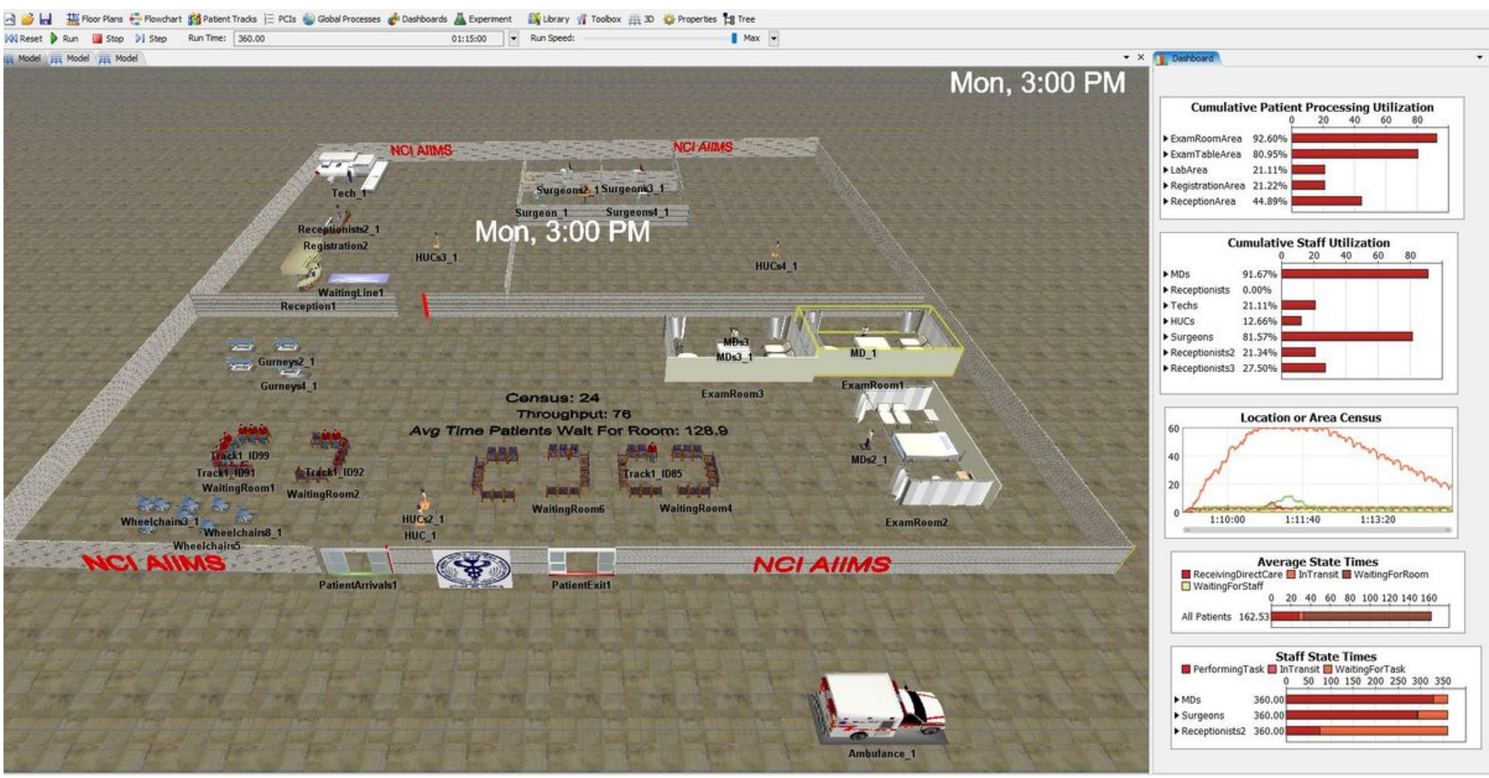

Figure 5

Simulation of Scenario 4

Figure 6

Simulation of Scenario 5