Group 25

Pranav Singh, Cheng Wang,
Arlou Astrologia, Mohammad Rais,
Runze Cui

MAT021 — Operations Research and Analytics Project Report

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Project Name: Simulation of Wankhede International Cricket Stadium

INTRODUCTION:

Simulation can be defined as an experimentation with a simplified imitation of an operations system as it progresses through time, for the purpose of better understanding and improving the system [Robinson, 2004, 4].

The need to simulate arises as many operating systems are interconnected and subjected to both variability and complexity, it becomes difficult to predict the performance of the operation systems. Simulation models can explicitly represent the variability, interconnectedness, and complexity of a system. As a result, through simulation, it becomes possible to predict system performance and to compare alternative system design. [Robinson, 2004, 7]

The simulation model presented in this report is based on Discrete Event Simulation (DES).

Discrete-event simulation creates a model construct of a conceptual framework which describes a system through the utilisation of computational and mathematical techniques. [Babulak & Wang, 2010, 1]

Discrete-Event Simulation quantitatively represents the real world, simulates its dynamics on an event-by-event basis, and generates detailed performance reports. [Babulak & Wang, 2010, 1]

This simulation project deals with the modelling and simulation of Wankhede International Cricket Stadium.

The model is being simulated on Simul8 and through utilisation of Label Based Distributions, Number Based Distributions, Time Based Distributions, Scheduling and Batching, we were able to conceptualise and represent the Wankhede Cricket Stadium.

The Wankhede Cricket Stadium, situated in Mumbai, India is amongst the largest cricket stadiums in the world with a holding capacity of approximately 33,108. The stadium has 8 seating stands and 7 gates for the public to enter the seating stands.

The resources that are required include security personnels & ticket counter machines which vary based on stand capacity and the number of the people going through security.

A schematic of the seating stands and gates is provided below:

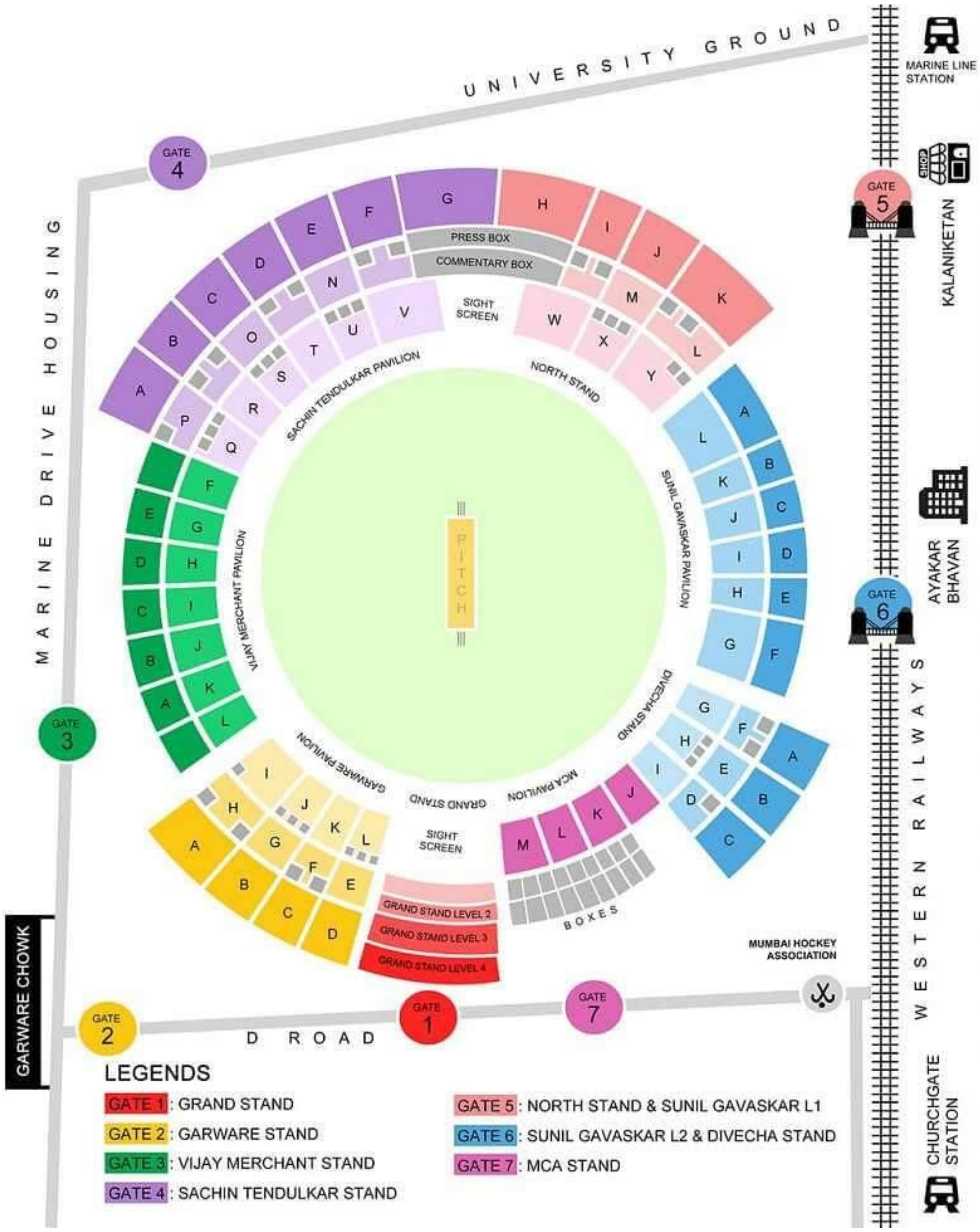

Figure 1. Wankhede International Cricket Stadium Schematics.

The initial main objectives of this simulation project are to analyse the utilisation of resources and to observe and assess the as-built simulated model to further identify opportunities to improve the system.

DATA COLLECTION AND ANALYSIS:

For our as-built simulated model, the following data practices have been employed:

1. Stadium schematics - We based the seat capacity, gate links, and stands according to the schematic shown in Figure 1.

   We based the No. of security checks and ticket machines on the following Tender Application to find the total Number of Door Frame Metal Detectors (DFMD) ordered by the Organising Committee.
   Based on the number of DFMD, we calculated the security checks for individual gates based on the seating ratio to maintain equal flow of traffic from all entry gates and the calculated values can be found in Table 1 below.

2. Average Distance From Gate to Stand and Average Walking time taken from gate to seating pavilions:-

   Using Google Maps to find the distance between seating pavilions and Entry gates as seen in Figure 2, and using the average walking speeds categorised by age groups to simulate realistic crowd movements, and incorporating average viewership patterns by age, we were able to calculate a triangular distribution for the times taken to travel from gates to seating stands as shown in the calculations below.

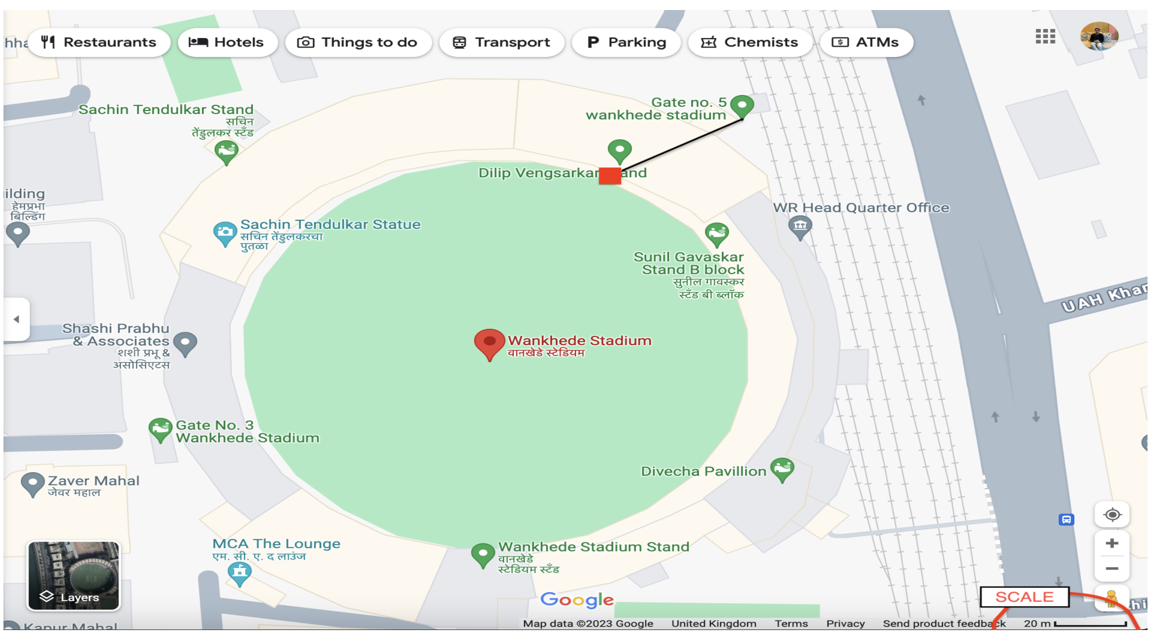

Figure 2. Illustration of using google maps and it's scaling property to measure distances

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Calculations

Fastest Speed :- 1.34 m/s (4.82 km/hr)
Mode :- 1.26 m/s (4.54 km/hr)
Slowest Speed :- 0.95 m/s (3.42 km/hr)
Reference for average walking speeds categorised by age.
Reference for average viewership patterns by age.

<table>
<tr><th>GATE NUMBER</th><th>SEATING PAVILIONS</th><th>CAPACITY</th><th>SECURITY CHECKS</th><th>DISTANCE</th><th>Time (Seconds) (Least, Mode, Most Time)</th></tr>
<tr><td>Gate No 1</td><td>Grand Stand</td><td>980</td><td>2</td><td>14.78 m</td><td>(11,12,16)</td></tr>
<tr><td>Gate No 2</td><td>Garware Pavilion</td><td>4588</td><td>6</td><td>33.84 m</td><td>(25,27,36)</td></tr>
<tr><td>Gate No 3</td><td>Vijay Merchant Pavilion</td><td>4052</td><td>5</td><td>20.76 m</td><td>(16,17,22)</td></tr>
<tr><td>Gate No 4</td><td>Sachin Tendulkar Pavilion</td><td>13338</td><td>16</td><td>19.25 m</td><td>(14,15,20)</td></tr>
<tr><td rowspan="2">Gate No 5</td><td>North Stand</td><td rowspan="2">4450</td><td rowspan="2">5</td><td>36.29 m</td><td>(27,29,38)</td></tr>
<tr><td>Sunil Gavaskar Pavilion L1</td><td>50.37 m</td><td>(38,40,53)</td></tr>
<tr><td rowspan="2">Gate No 6</td><td>Sunil Gavaskar Pavilion L1</td><td rowspan="2">4146</td><td rowspan="2">4</td><td>61.73 m</td><td>(46,49,65)</td></tr>
<tr><td>Vithal Divecha Stand</td><td>53.91 m</td><td>(40,43,57)</td></tr>
<tr><td>Gate No 7</td><td>MCA Pavilion</td><td>1634</td><td>2</td><td>21.6 m</td><td>(16,17,23)</td></tr>
</table>

Table 1: Table describing the gate numbers with their respective seating pavilions, their capacity, number of security checks, the distances between the gates and stands, and the calculated time taken to walk from the gate to the stand.

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Data Assumptions

In making our simulation, we drew from firsthand observations to make certain Data assumptions. We assumed Ticket Scanning times, Security Clearance Time and Number of Ticket checks turnstiles.

The Fastest Time and Mode is assumed using the fastest time it took in our personal experience and slowest time is based on if some error occurs, for instance if the ticket checking machine doesn't work the first time, then it would take around 30 seconds to pass through a ticket check.

The parameters used in the triangular distribution for the different activities are stated below:

1. Security Clearance Time
   Fastest Time :- 15 sec
   Mode:- 20 sec
   Slowest Time :- 60 sec

2. Ticket Checks Time
   Fastest Time :- 3 sec
   Mode:- 5 sec
   Slowest Time :- 30 sec

3. Number of Ticket Checks Turnstiles
   Maintaining balance between the number of ticket checks turnstiles and security checks is crucial to prevent bottlenecks and ensure a smooth entry process and hence we assumed alignment between the two elements. This approach reflects the realistic flow of spectators and guarantees that the overall entry is the same as what has been experienced in Wankhede Stadium.

4. The cricket match is assumed to start at 12:00 pm, with the gates opening 4 hours prior to the start of the match. As such we have assumed that :
   1. 30% of the audience will arrive at the 8:00 am i.e at the opening of stadium gates.
   2. 60% of the audience will arrive at 10:00 am i.e 2 hours prior to the starting of the cricket match.
   3. 10% of the audience will arrive at 13:00 pm i.e 1 hour after the start of the cricket match.

MODEL DESCRIPTION

The model used to simulate the system in Wankhede Stadium is shown in Figure 3 below.

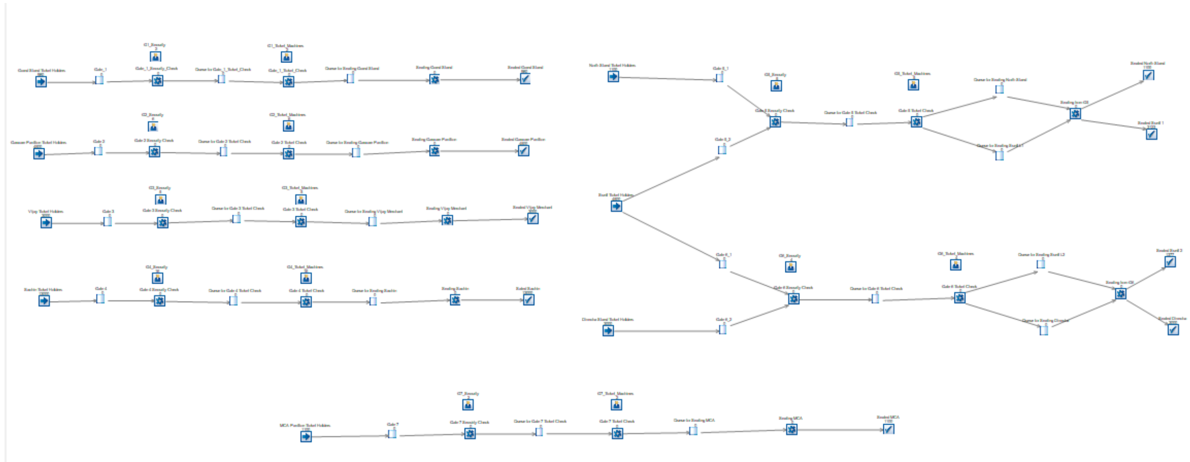


Figure 3. Schematic of Simul8 model used to reproduce the system at Wankhede Stadium.

The components of the model above are described in Table 2 below:

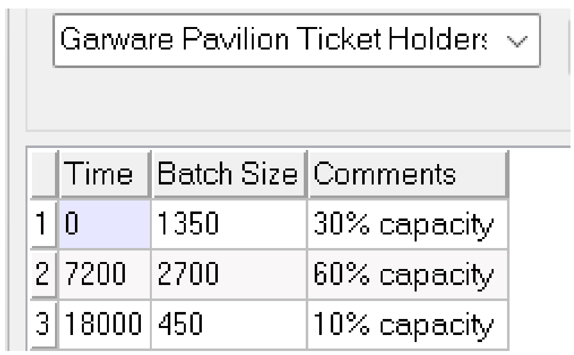
Components	Description
Activities	Security Check, Ticket Check and Seating (Walking to seats)
Work Item	Audience (People)
Resources	Security Staff, Ticket Checking Machine
Clock	Component that marks the passage of time (seconds)
Queues	Places where the audiences wait

Table 2: Description of the different entities in the Simul8 model and their relationship to the real life parameters.

<u>Model Logic</u>

The audience come from the start point in batches and queue for entry where they are faced with a security check. Passing the security check, they queue for a ticket check and once the activity is available, they go through the ticket check activity. After ticket checking the audiences go to sit in their respective stands.

At the starting points, we use the scheduling functionality to achieve the arrival of spectators. The scheduling we implemented can be seen in Figure 4 below.



	Time	Batch Size	Comments
1	0	1350	30% capacity
2	7200	2700	60% capacity
3	18000	450	10% capacity

Figure 4. Scheduling implemented for the Garware Pavilion Stand ticket holders given the arrival assumptions stated in the data section.

We modelled the security check and ticket check with their respective triangular distributions as stated in the data assumptions sections above.

The number of seating activities matches the capacity of the corresponding stand. We modelled it like so because people can all sit at the same time. For instance, if it was just 1 activity, this would translate to real-life as only 1 person is allowed to go to their seats at a time.

Furthermore, we modelled the seating activity depending on the time taken to walk from the gate to the stand based on the data we collected.

Gates 5 and 6 are a bit more complicated compared to Gates 1,2,3,4 and 7 due to the fact that the stadium allows for people to access multiple stands from these gates.

A more focused image of Gates 5 and 6 are shown in Figure 5.

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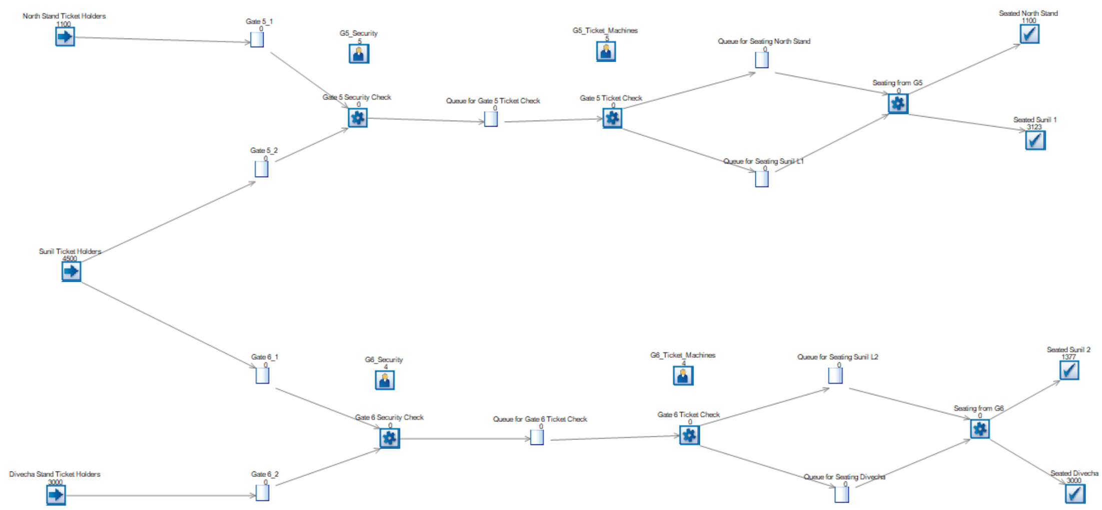

Figure 5. Focused image of Gates 5 and 6 and the connecting stands.

In order to model this section of Wankhede stadium, we employed number and text labels and distributions. The labels and relevant distributions implemented in this section can be seen in Figure 6 below.

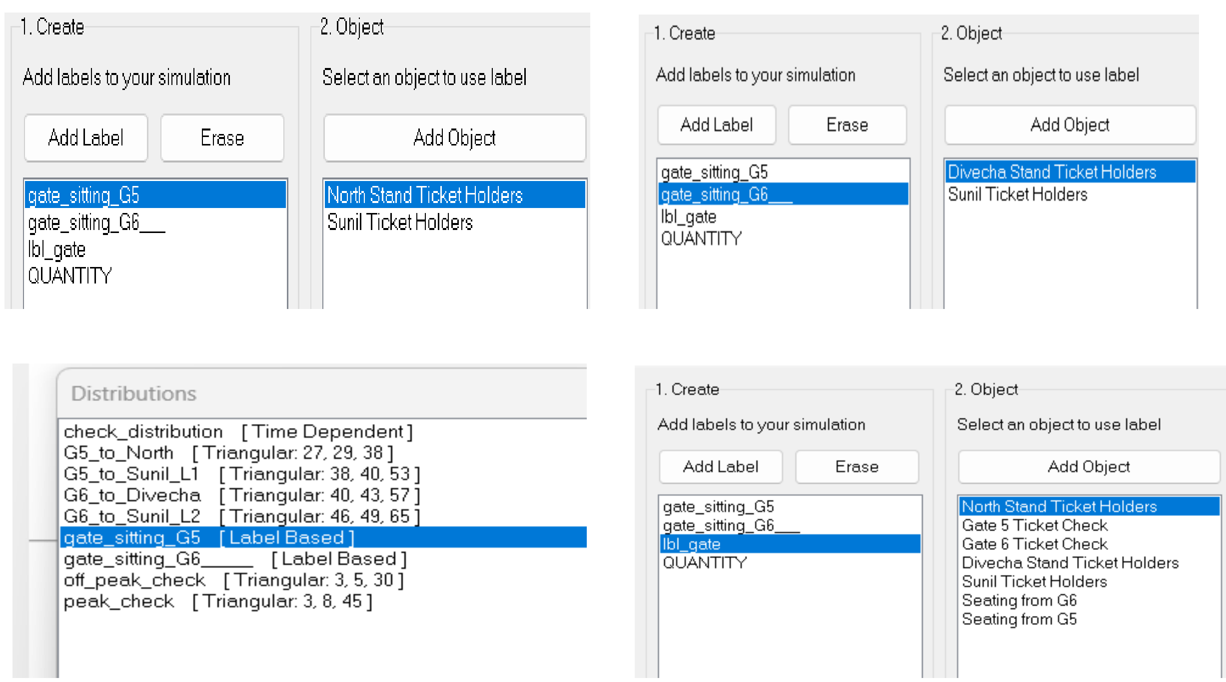

Figure 6. Figure illustrating the different labels and their corresponding objects used in the model with the relevant distributions used on the bottom right.

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In order to control the movements of Sunil ticket holders, we assigned it the number label 1 at the start point. At the “Gate 5 ticket check”, we controlled its routing out by assigning the number 1 to “Queue for Seating Sunil 1” and controlled the routing out at “Gate 6 Ticket Check” by also assigning the number 1 to Queue for Seating Sunil 2.

At North Stand ticket holders' start point, they were assigned the number 2 and the Divecha stand ticket holders were also assigned the number 2.

At the routing out of “Gate 5 Ticket Check”, the “Queue for Seating North Stand” was assigned the number 2 and at the routing out of “Gate 6 Ticket Check”, the “Queue for Seating Divecha” was also assigned the number 2.

Implementing these number based labels allowed us to control the movement of the different ticket holders entering the same gates. Also, to ensure a specific queue wasn’t prioritised, we split the gate into two queues and set the routing of the security check to the circular discipline.

Now to control the different seating times, we utilised the text based labels and text based distributions.

Let’s first discuss the “Seating from G5” activity. We controlled the routing out by assigning the correct numbers to the end points, i.e. the “Seated North Stand” end point was assigned the number 2 and the “Seated Sunil 1” end point was assigned to number 1.

Of course, from gate 5 to the North Stand takes a different amount of time compared to gate 5 to the Sunil stand and it was the label based distribution which allowed us to model this.

We did so by doing as follows — At the “North Stand” start point, we assigned it the text label of “gate_sitting_G5” and set the value “G5_to_North” whose distribution can be seen in Figure 6. At the “Sunil Ticket Holders” start point, we also assigned it the label of “gate_sitting_G5” and set the value to “G5_to_Sunil” whose distribution can also be seen in Figure 6.

Finally, we set the distribution of Seating from G5 to be “gate_sitting_G5”.

Applying the number and text based labels and distributions like so allowed us to ensure that at the “Seating_from_G5” activity, the paths of the ticket holders were correct and the seating times depended on their corresponding stand.

The implementation for gate 6 is completely analogous.

We also implemented time-dependent distribution to reflect the different times taken for ticket checks at different times. Due to different peak time hours and off-peak time hours, the distributions vary due to which we have implemented time-dependent distributions at ticket checking activities.

Based on assumptions as mentioned in the data collection and analysis section, we assumed the off-peak hours to be 8:00-10:00 & 13:00-20:00 and the peak-hour time is assumed to be 10:00-13:00. This is represented in Figure 7 below.

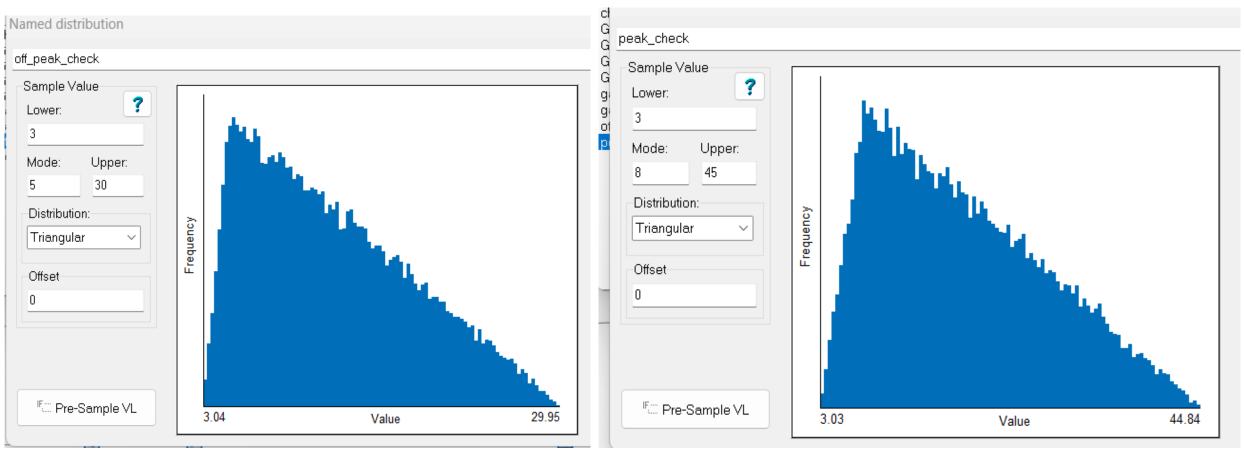

Figure 7. Graph of triangular distributions used in the off-peak and peak time based distributions.

Finally, because the security staff cannot work the whole game, we implemented the resource shifts option on Simul8 with the shift patterns as shown in Figure 8 below.

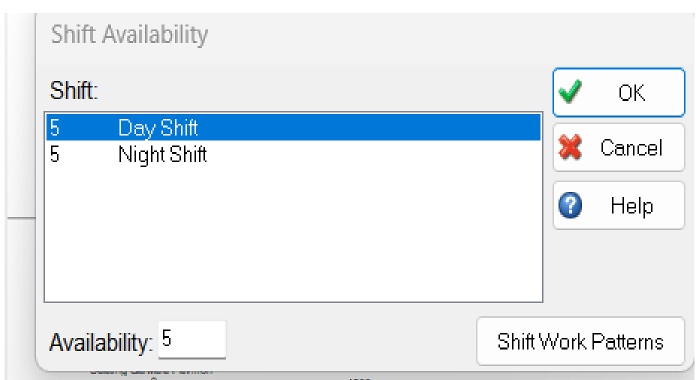

Figure 8. Shift patterns for the security.

SIMULATION EXPERIMENTS, RESULTS & MODEL VALIDATIONS

The first thing we wanted to analyse was the resource utilisation of the system and the parameters used to achieve these results are described in the data assumptions section and shown in Table 1 above.

The resource utilisation of the system is summarised in Table 3 below.

Gate	Security Utilisation	Ticket Utilisation
1	44% (Full sim) 78% (Gate full sim)	18% (Full sim) 32% (Gate full sim)
2	69% (Full sim) 99% (Gate full sim)	27% (Full sim) 40% (Gate full sim)
3	54% (Full sim) 92% (Gate full sim)	22% (Full sim) 37% (Gate full sim)
4	74% (Full sim) 100% (Gate full sim)	30% (Full sim) 40% (Gate full sim)
5	77% (Full sim) 100% (Gate full sim)	37% (Full sim) 48% (Gate full sim)
6	100% (Full sim = Gate full sim)	46% (Full sim = Gate full sim)
7	50% (Full sim) 88% (Gate full sim)	20% (Full sim) 34% (Gate full sim)

Table 3: Table illustrating the security and ticket utilisation at each gate. *Full sim* means running the simulation until everyone is seated. *Gate full sim* means running the simulation only until the full gate is seated. Gate 6 was last to sit down so the full simulation was essentially just ending the simulation once all of Gate 6 was seated.

The initial insight we observed was that ticket machines are not being utilised effectively.

This insight formed the basis of our rationale for the next set of experiments which was to test the effects of having less ticket machines on the time taken to seat people, and to measure the change in utilisation of the ticket machines.

After experimenting with different numbers of ticket machines, the results were summarised and the remaining insightful results can be found in Table 4 below.

Gate	Number of Ticket Machines	Ticket Utilisation	Time to Sit All Stand
1	2 (standard)	18% (Full sim) 32% (Gate full sim)	13:26
1	1	36% (Full sim) 64% (Gate full sim)	13:26
2	6 (standard)	27% (Full sim) 40% (Gate full sim)	14:41
2	2	82% (Full sim) 100% (Gate full sim)	15:59
2	3	55% (Full sim) 79% (Gate full sim)	14:41
3	5 (standard)	22% (Full sim) 37% (Gate full sim)	13:44
3	3	37% (Full sim) 62% (Gate full sim)	13:44
3	2	55% (Full sim) 92% (Gate full sim)	13:48
4	16 (standard)	30% (Full sim) 40% (Gate full sim)	15:11
4	4	100% utilisation (Full sim = Gate full sim)	19:29
4	7	58% (Full sim) 91% (Gate full sim)	15:11
5 (70,30 split)	5 (standard)	37% (Full sim) 48% (Gate full sim)	15:30
5 (70,30 split)	2	88% (Full sim) 100% (Gate full sim)	16:33

5 (70,30 split)	3	62% (Full sim) 80% (Gate full sim)	15:30
6 (70,30 split)	4 (standard)	46% (Full sim = Gate full sim)	17:40
6 (70,30 split)	2	90% (Full sim= Gate full sim)	17:40
7	2 (standard)	20% (Full sim) 34% (Gate full sim)	13:30
7	1	39% (Full sim) 69% (Gate full sim)	13:30

Table 4: Table illustrating the effects of varied number of ticket machines on their utilisation and time taken to seat the spectators. The highlighted parts of the table indicate the rows containing the ideal number of ticket machines at the corresponding gate.

During these experiments, one interesting thing we observed was that even though the ticket machines were being decreased, the time taken to seat the stands was not changing (up until a certain point) which can be observed from the results from Gate 4.

We can see that 16 and 7 ticket machines lead to the same time to seat everyone from this gate; however, at 4 ticket machines, the time taken to seat increases significantly.

This observation makes sense intuitively because the ticket check is faster than the security check. For instance, when one security check takes 30 seconds and the other 20 seconds, the person out of the security first can go through the ticket check in 5 seconds and sit straight away so whether or not there were 2 ticket machines, it wouldn't make a difference.

Also, to validate our model, we observed the queue for the ticket check during the experiments. We did this because we should see the queue for the ticket check increase even though the time to sit at the stand wasn't decreasing. This was exactly what we saw, and thus validated that our model was working as expected.

The insights we drew from the results of these experiments is that we can remove some ticket machines at the gates without significantly compromising the seating times and the ideal number of ticket checks per gate is highlighted in Table 4.

Reducing the number of ticket machines allows for more effective budget management and allows for the expenditure on other things which would have a more significant impact on improving the efficiency of Wankhede stadium.

While running the simulations, we also noticed that those entering through Gate 6 were last to sit. We noticed this was due to the split of Sunil stand ticket holders.

Sunil stand ticket holders are allowed to go through Gates 5 and 6 and the split of the people going through each gate determines the seating time of the connecting stands. For instance, if 100% of all Sunil ticket holders were to go through Gate 5, then the stands connected to Gate 5 would be last to sit, and vice versa for Gate 6.

To identify the most efficient split of Sunil ticket holders going through Gate 5 and 6, we experimented with different percentage splits and recorded the time taken to seat the connecting stands. The results from these experiments can be seen below:

Percentage into Gate 5	Percentage into Gate 6	Time taken to sit fully sit connecting stands (4 security)	Time taken to fully remaining stands (5 security)
100	0	08:00 - 17:55 (9 hr 55 min)	08:00 - 17:55 (9 hr 55 min)
90	10	08:00 – 17:08 (9 hr 8 min)	08:00 – 17:08 (9 hr 8 min)
80	20	08:00 – 16:38 (8 hr 38 min)	08:00 – 16:20 (8 hr 20 min)
70	30	08:00 – 17:40 (9 hr 40 min)	08:00 – 15:44 (7 hr 44 min)
60	40	08:00 – 18:36 (10 hr 36 min)	08:00 – 16:29 (8 hr 29 min)
50	50	08:00 – 19:36 (11 hr 36 min)	08:00 – 17:16 (9 hr 16 min)

Table 5: Illustration of time taken to fully seat stands connected to gates 5 and 6 with a highlight on the percentage split which leads to the fastest time.

We noticed that the most efficient percentage split is the (70,30) split however, we saw that it was still taking too long to seat the stands and we observed this is due to the lack of security.

From this observation, we decided to run the same experiments but with extra security with the results shown in the final column of Table 5 above.

We can see that the extra security guard at gate 5 significantly improves the seating time and the best percentage split still remains at (70,30).

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CONCLUSION

So in conclusion, through the use of the Simul8 software and its functionalities, and data assumptions based on experienced intuition and calculated estimates, we were able to model the entry system of Wankhede stadium and found some useful insights.

From our simulation and analysis, we believe that Wankhede Stadium would benefit from reducing the budget for ticket machines and allocate the saved budget into extra security at other gates, especially gate 6.

Also, when selling the tickets for the Sunil stand, 70% of them should be allocated to enter through Gate 5 with the other 30% allocated to enter through Gate 6.

We definitely believe that with access to better data, we can improve our model and create a more accurate representation of the system and be able to gather more reliable and accurate insights and truly be able to improve the Wankhede Stadium entry system and ultimately, have happier cricket fans and create better memories on culturally significant games.