INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

SIMULATION LAB PROJECT

SIMULATION OF NALANDA CLASSROOM COMPLEX AS A SYSTEM

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Abstract

This study simulates the operation of the famous "Nalanda" classroom complex of IIT Kharagpur to analyse its functioning. It further offers suggestions for future enhancements that could be made to effectively alter how the system as a whole operates. The techniques adopted by the team members included segmenting the system into three subsystems (classrooms, parking lots and the eateries) to study each one separately through the use of independent simulations. Statistical parameters and their related values were observed following successful simulations of the subsystems under consideration. Based on the observations, inferences and suggestions for the future were formed. This study underlines the need to consider the impact of these observations and outcomes as well as the expert's adaptability from an economic standpoint.

Introduction

Simulation: Simulation refers to the process of imitation of the operation of a real-world process or system over time.It involves generation of an artificial history of the system and observation of this history to draw inferences concerning the operating characteristics of the real system. It takes the form of a set of assumptions of mathematical, logical, and symbolic relationship between the entities of interest, of the system.It is used to estimate the measures of performance of the system with the simulation generated data.Simulation modelling can be used as an analysis tool for predicting the effect of changes to existing systems and as a design tool to predict the performance of new systems.

Simulation enables the study of, and experimentation with, the internal interactions of a complex system, or of a subsystem within a complex system. Informational, organisational, and environmental changes can be simulated, and the effect of these alterations on the model's behaviour can be observed.

System: A collection of distinct objects which interact with each other for doing a well defined task. A system could be an Engineering system, Queuing system in a bank/supermarket, Production system, Inventory system, Transportation system, Communication system, Banking system, Social system; etc.
The paper aims at investigating Nalanda as a system.To identify its flaws and make suggestions to enhance its performance (based on the simulation values obtained), is the focal point of discussion.

System Details: Nalanda is one of the biggest complexes with a capacity of 30,000 Students. The rooms are equipped with centralised air conditioning. The complex has two main entrances, one of which can be reached by going straight from the Agriculture department/Nehru Museum and the other by taking a right turn at the

same place. The complex is divided into a total of 7 blocks, of 3 types: Academic, Rectangular and Circular. It has 4 floors including the ground floor. Each block on each floor consists of 4 classrooms. There are a total 4 Circular blocks, 2 Rectangular blocks and 1 Academic block. The food facilities include subway, Nescafe, MFS canteen, in the vicinity of the Complex, all of which are present in the ground floor. Most of the classes take place in Nalanda Rectangular and Circular blocks.
A video demonstration of the system and its surrounding systems->
https://www.youtube.com/watch?v=3aQvqGCGlcg&t=14s

Drawbacks of the system:
Too many classes scheduled during the same intervals often cause

- Overcrowding problems in the cycle stand (parking zone).
- Long queues in food facilities like the Subway, MFS canteen, and the Nescafe.

Preliminary Ideas Proposed

The initial plan was to simulate the events that would occur in Nalanda over the course of a day. This would be achieved by obtaining real-world data and analysing it over a variety of parameters, according to the assumptions taken into account. The simulation procedures would be carried out for each of the five working days (Monday-Friday).

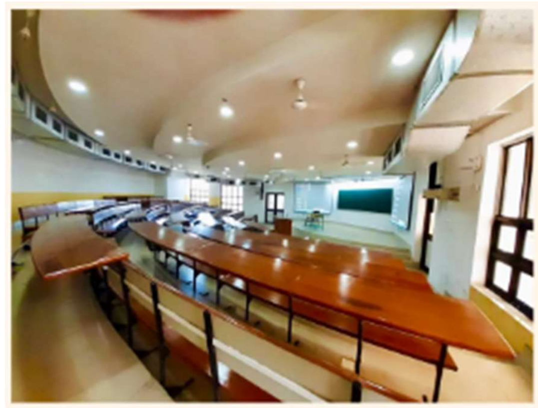
Implementing the simulation procedure with complications:

- Very large number of entities to simulate over the entire system simultaneously.
- Data collection over a couple of months to be more reliable for such an extensive system.

Objectives and Approaches

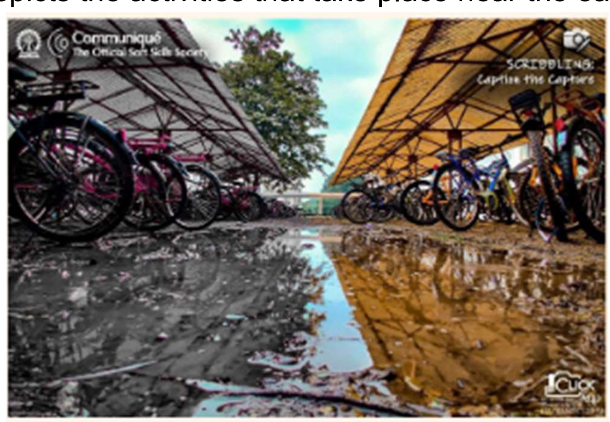
- Breaking the system into subsystems to carry out a number of simulations.For this purpose, the system was divided into three separate components:

1. Classrooms -Classroom Simulation depicting the distribution of students inside nalanda for a 1 hour or 2 hour period class



2. Parking Areas (i.e.,cycle stands)- howcases the the distribution of the cycles and their arrival and departure over the cycle stand

3. Food facilities and shops (Subway, Shiru Cafe, coffee shop, etc) - Coffee shop Simulation depicts the activities that take place near the eateries



- Consideration and analysis of 3 sub-models.
- Suggestions for further improvements.

Methodology

1. Classroom Model

➢ **Brief Overview:**
- It is a model based on the entry and exit of students from the classrooms.
- Parameters of the model are as follows:
  1) Time-gap between two successive classes for a day.
  2) Total number of classes taking place in every 1 hour slot.

- Simulation values are calculated considering the maximum possible strength of a class (taking max value of all departments).
- Input value represents the total number of classes completed per day.
- Total number of students coming to and exiting from Nalanda per day = Input value obtained after simulation * maximum possible strength
- It was discovered from the departmental timetables that classes ended at or before 5 p.m.
- Other classes were scheduled in the respective department buildings, or Takshshila, etc.

➢ **Data Collection and Generation:**
- Time-Tables of all departments were observed to find out the number of classes taking place per 1 hour slot for each of the 5 days.
- Number of 2 hour classes and 1 hour classes were found out.
- The image below shows the busy/ idle state of the classrooms involved for Monday.

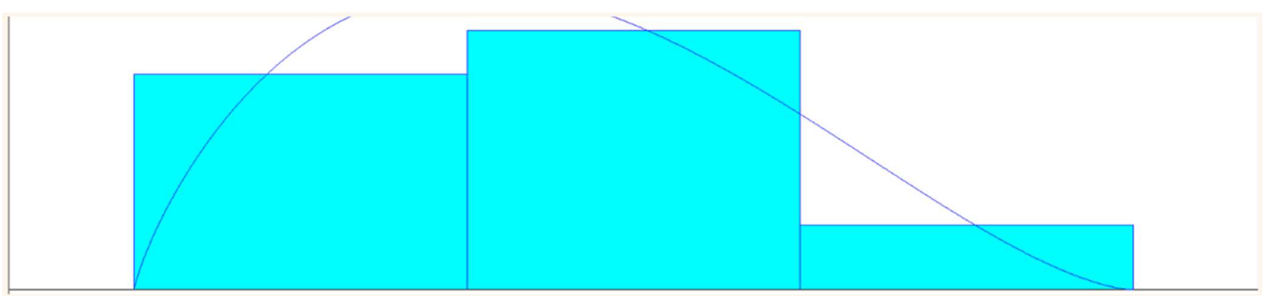
	Time Slots for Monday				
Room No.	8-9	9-10	10-11	11-12	12-1
NR121	1	1	0	0	1
NR214	1	1	1	0	1
NC412	1	1	1	0	1
NC224	1	1	0	0	0
NR414	0	0	1	0	0
NC444	0	0	1	0	0
NR312	0	0	1	0	0
NC222	0	0	1	0	0
NC341	0	0	0	1	0
NC241	0	0	0	1	0
NC424	0	0	0	1	0
NR421	0	0	0	0	1
NC413	0	0	0	0	1
NR322	0	0	0	0	1
NC221	0	0	0	0	1
NC414	0	0	0	1	0
NC442	0	0	0	1	0
NC141	0	0	0	0	1
Total Classes	4	4	6	5	8
Time gap between successive entries	0	0	2	1	1

- Similarly, data was calculated for Tuesday- Friday.
- Numbers were then fed into the input analyzer to find the best-fit distributions for each of the two parameters.

➢ **Input analysis of the collected data:**

Parameter 1: Time Gap between successive classes ->

<u>Obtained Distribution curve:</u>



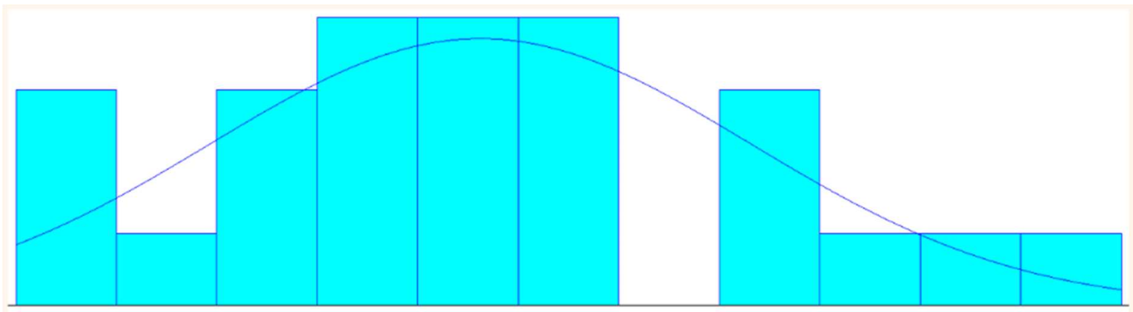
<u>Obtained Distribution Summary:</u>

Distribution:	**Beta**
Expression:	**-0.5 + 3 * BETA(1.82, 2.6)**

Square Error:	**0.000393**

Parameter 2: Total number of classes taking place for every 1 hour slot ->

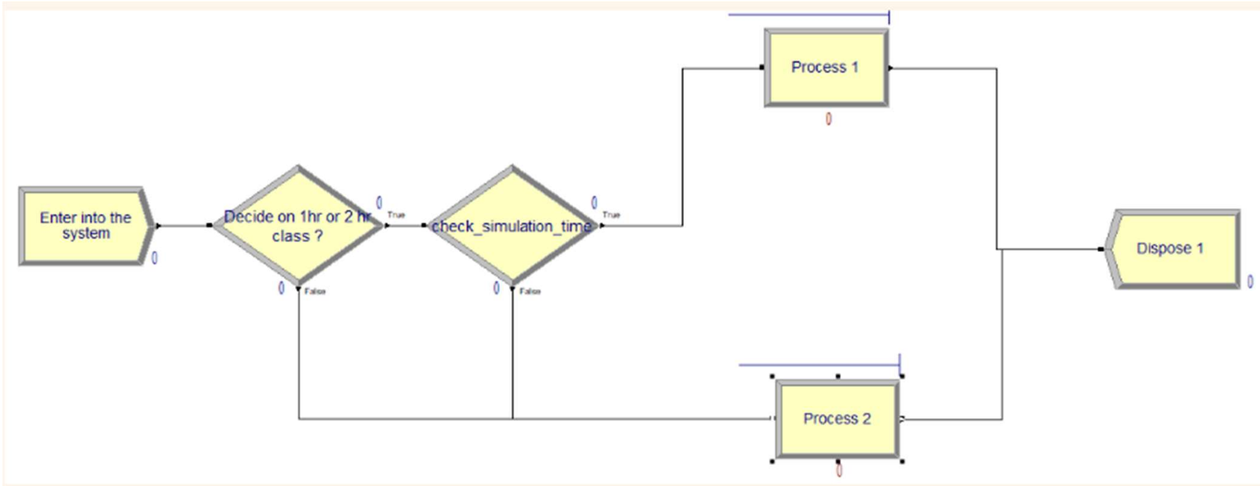
Obtained Distribution curve:



Obtained Distribution Summary:

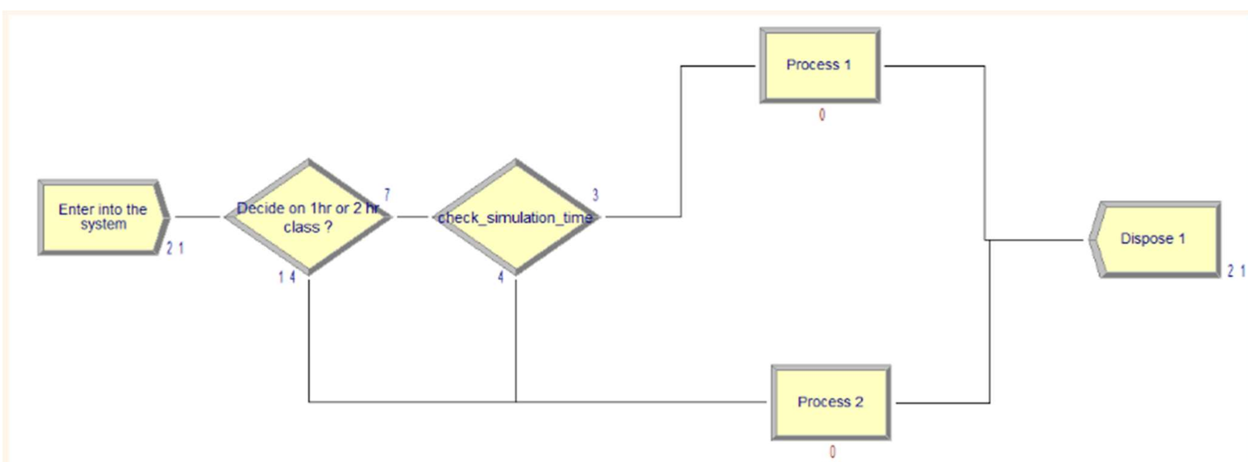
Distribution:	**Normal**
Expression:	**NORM(5.12, 2.69)**
Square Error:	**0.023738**

➢ **Simulation Model:**



- The first '**Decide**' module is used to check if a class is scheduled for a duration of 1 hour or 2 hours.
- The second '**Decide**' module is used to check for the time parameter:
- For a class of 2 hours, the maximum possible time it can start at is 11 a.m. (considering the classes to be scheduled up to 1 p.m.)

Screenshot of the model after simulation is complete ->



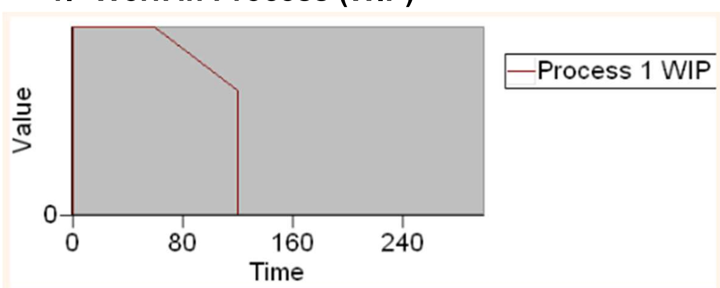
- The model is run for a time period of 5 hours.
- 21 represents the total number of classes that take place on a day of the week (Monday- Friday).

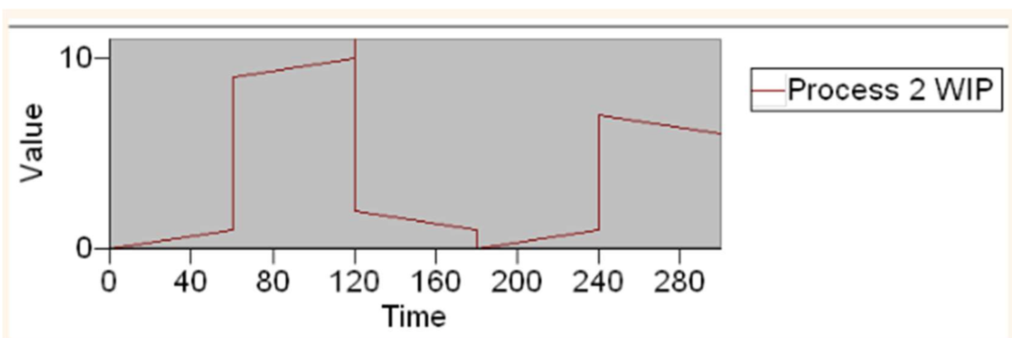
- The maximum number of students who entered into the system and left the system on Monday = 21*maximum possible strength of all classes that took place for all departments =21 * 132 =2772
- The **highest** number of people who could possibly access the Nalanda Classroom Complex on a given day is **2772.**
- The number of entities entering into the system and leaving the system are equal.

A video demonstration of the classroom model ->
https://youtu.be/bA3NslWG3po

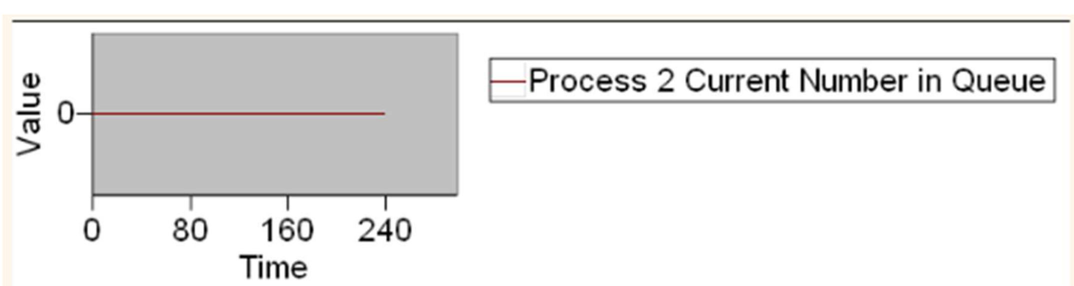
➢ **Relevant Plots:**

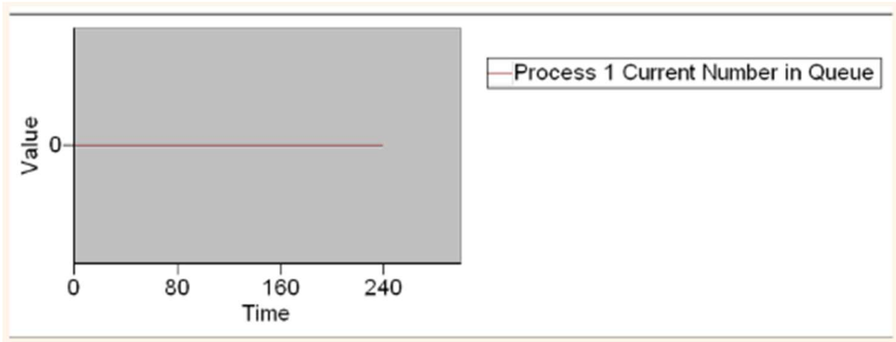
1. **Work in Process (WIP) ->**





2. **Number in Queue->**





The corresponding current number in queue plots are straight lines having 0 value because classes take place simultaneously and individually in different classrooms.

➢ **Statistical Parameters' values obtained:**

- For entity:

Statistical Parameter	**Minimum Value**	**Average Value**	**Maximum Value**
Entity WIP	0	27.6	63

- For Process 1:

Statistical Parameter	**Minimum Value**	**Average Value**	**Maximum Value**
Number in Queue	0	0	4
Queue Waiting Time	0	0 mins	0 mins

- For Process 2:

Statistical Parameter	**Minimum Value**	**Average Value**	**Maximum Value**
Number in Queue	0	7.2	29
Queue Waiting Time	0	2.9214 mins	6 mins

- Total number of resources (classes) = 30
- Average number of classes per hour =total number of classes/ total number of hours= 27.6/ 5= 5.52

- Accordingly, **resource utilisation** of each of the 30 classrooms was obtained from the simulation report.

➢ **Assumptions and Drawbacks of the Model:**

- Exit time of entities from the classroom have been considered to be the same.
- For a particular class, the entities are considered to be arriving at a particular time.
- The inter-arrival time is calculated for the time gap between successive classes scheduled.

➢ **Checking accuracy of the model:**
Based on the simulation results,
Average number of classes per hour taking place in Nalanda = 5.52
Whereas, the actual number of classes taking place in an hour in Nalanda = 5.54 (obtained from the department statistics)
This shows the simulation model works accurately with an **error** percentage of **2.22 %.**

2. Coffee Shop Model

➢ **Brief Overview:**
- Model based on entry and exit of students from the Coffee Shop.
- This Model can be a Representative of all the three eateries located in the vicinity of the Nalanda Complex.
- Parameters of the model:
  1) Inter-arrival times of the students
  2) Time duration for Coffee Preparation
  3) Time duration that a student stays in the Coffee Shop for drinking coffee
  4) Wash time of utensils
- The other two eateries can be assumed to be following a similar flowchart for the models, with slight differences in their distribution types and parameters.
- The differences in distribution parameters could be due to the takeaway or dine-in systems, processing time for food items, etc.

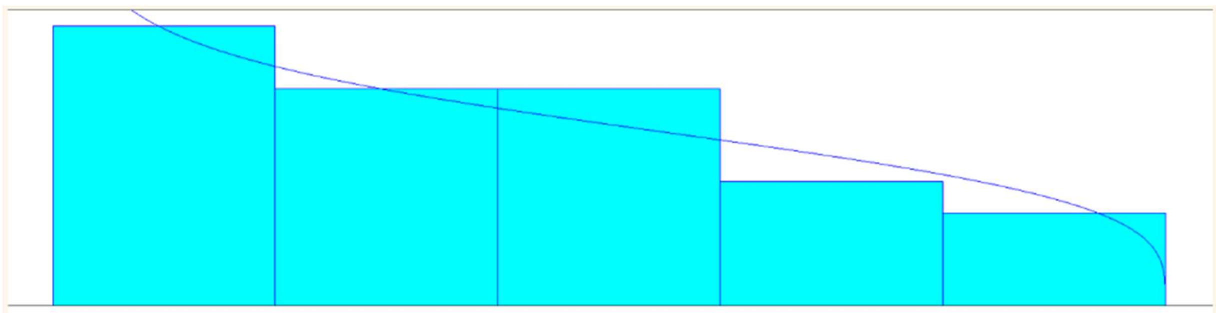
➢ **Data Collection and Generation:** Data collection for the Coffee shop or the eatery model was based on the physical arrival of the students in the Shiru

Cafe. The information was gathered manually by counting the number of entries and by questioning the shop employees.

➢ **Input analysis of the collected data:**

Parameter 1: Inter-arrival time between students->

Obtained Distribution curve:

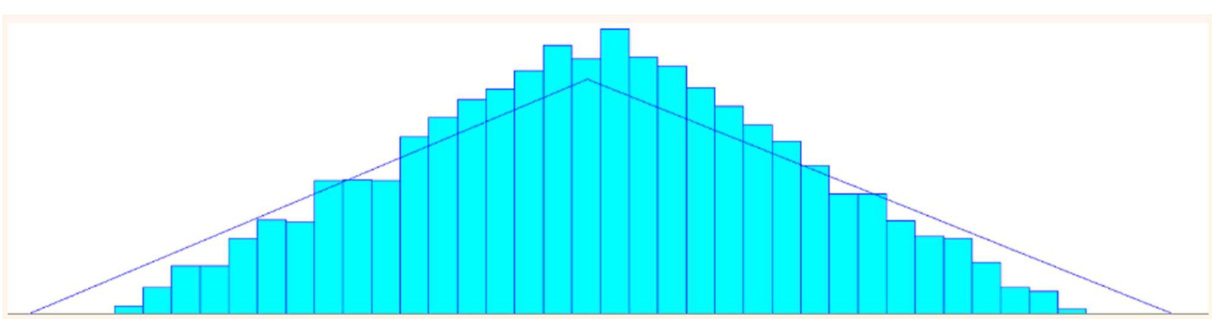


Obtained Distribution Summary:

Distribution:	**BETA**
Expression:	**BETA(0.835, 1.26806)**
Square Error:	**0.002809**

Parameter 2: Coffee Preparation time ->

Obtained Distribution curve:

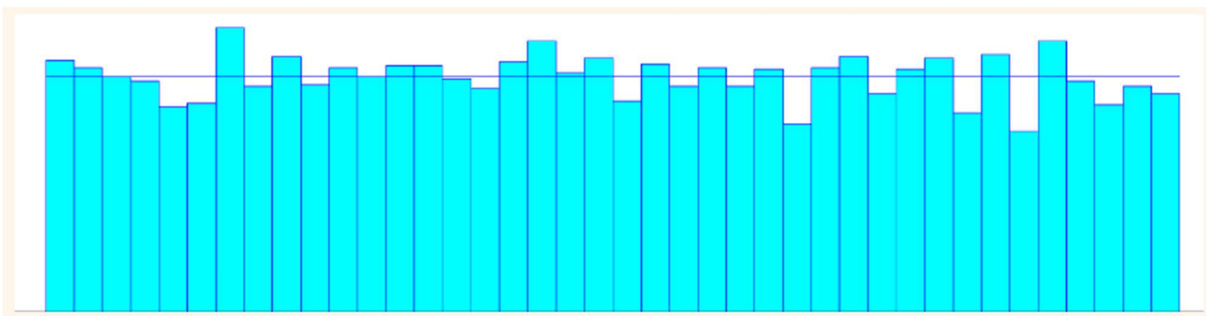


Obtained Distribution Summary:

Distribution:	**TRIANGULAR**
Expression:	**TRIA(2, 3, 5)**
Square Error:	**0.001296**

Parameter 3: Drinking Coffee time ->

Obtained Distribution curve:

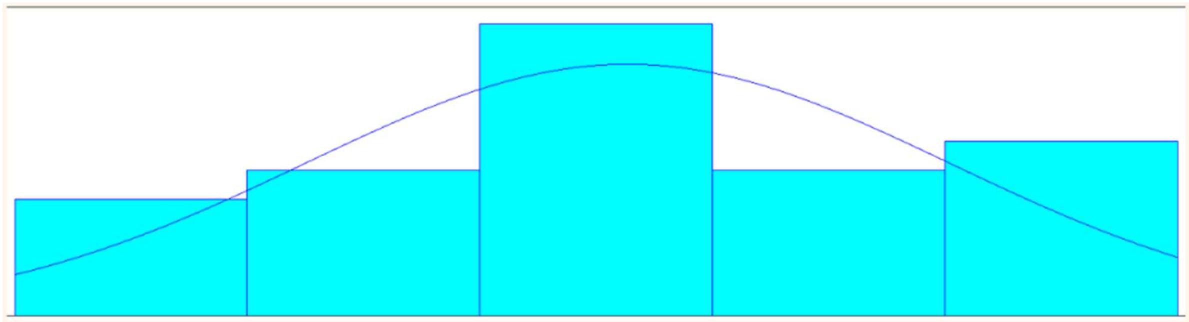


Obtained Distribution Summary:

Distribution:	**UNIFORM**
Expression:	**UNIF(2,5)**
Square Error:	**0.000215**

Parameter 4: Washing time of utensils ->

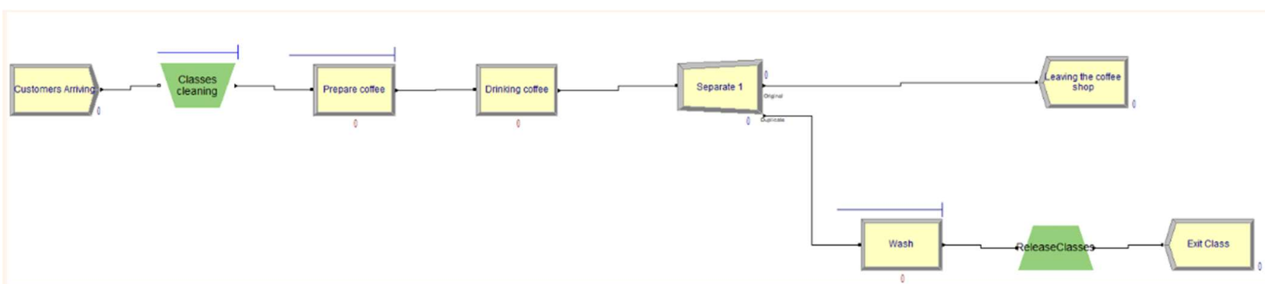
Obtained Distribution curve:



<u>Obtained Distribution Summary:</u>

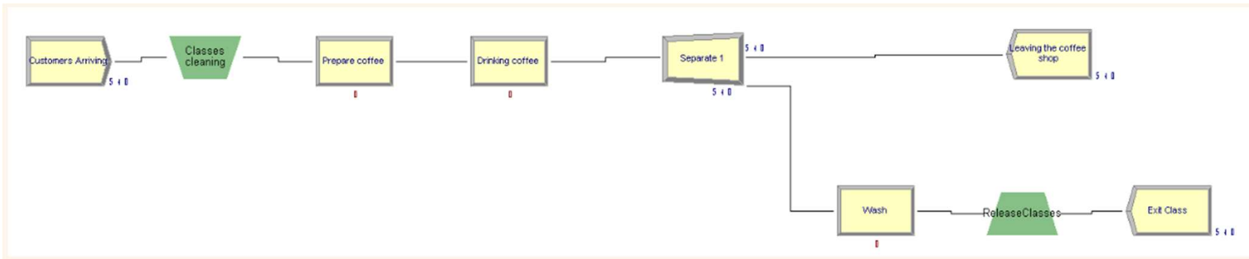
Distribution:	**NORMAL**
Expression:	**NORM(0.527, 0.277)**
Square Error:	**0.017226**

➢ **Simulation Model:**



- Students Randomly arrive at the Coffee Shop.
- Based on data collection and Input Analysis, best-fit distributions are found for each of the processes and passed into the model.
- Use of '**Separate**' , '**Seize**' and '**Release**' modules to keep track of the process of washing utensils and separating entities who get serviced and who have to wait during the wash process.

Screenshot of the model after simulation is complete ->

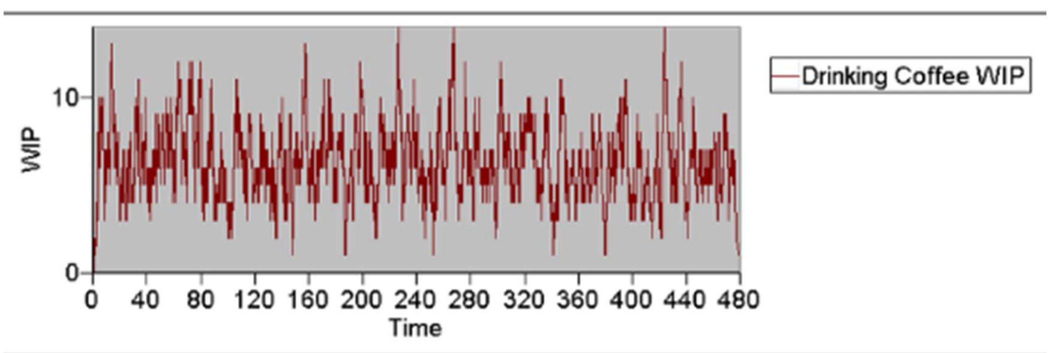


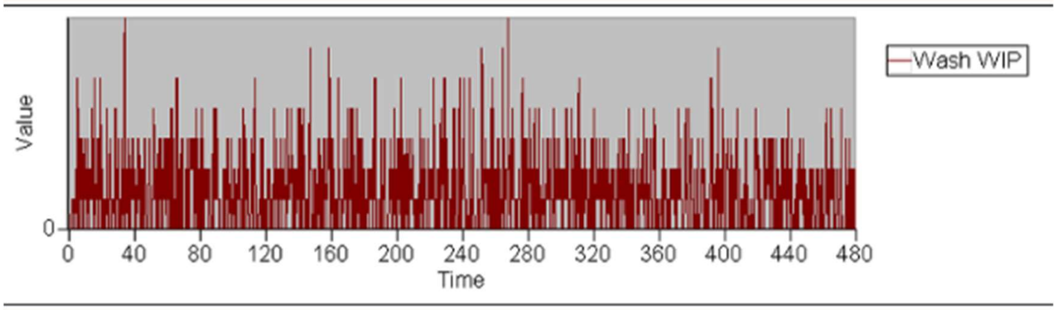
- The model is run for a duration of 8 hours, considering inflow of entities into the system from the opening time of the eateries (10 a.m.) till 6 p.m.
- Every customer gets in the queue at the counter until the counter is free.
- There are **2 cycles** in modelling -Washing cycle and Service cycle
- **Washing** cycle- Utensils are washed and made available to use again.
- **Service** cycle-Service to a customer, customer drinking time and leaving the Coffee shop.
- Here, **540** represents the total number of students who visit the Coffee Shop on a day of the week (Monday-Friday).

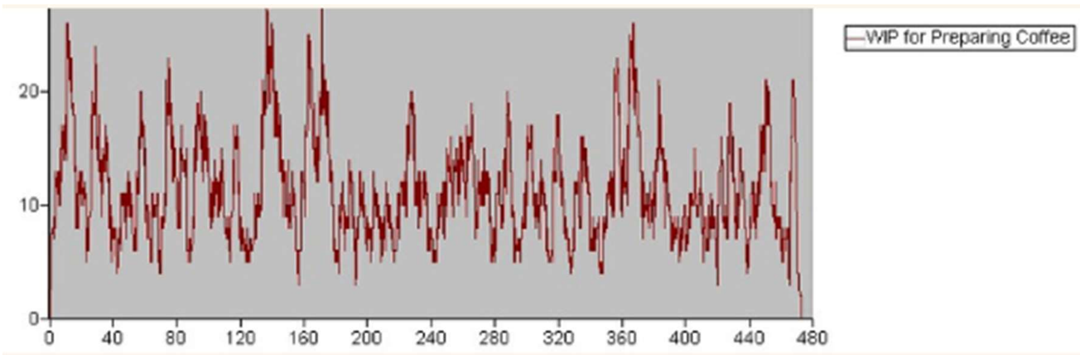
A video demonstration of the Coffee Shop model ->
https://youtu.be/xigB9Ni_-M0

➢ **Relevant Plots:**

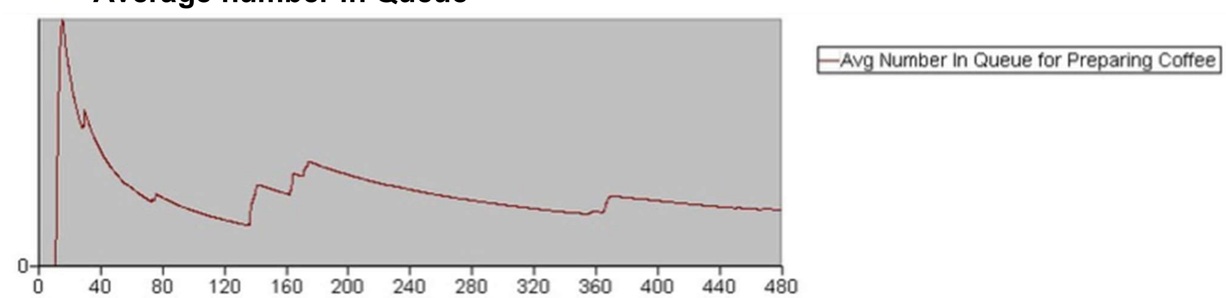
Work in Process (WIP) ->







Average number in Queue ->



➢ **Statistical Parameters' values obtained:**

- For Customers:

Statistical Parameter	Minimum Value	Average Value	Maximum Value
Entity WIP	0	13.25	25

- For Preparation of Coffee :

Statistical Parameter	Minimum Value	Average Value	Maximum Value

Number in Queue	0	0.187	10
Queue Waiting Time	0	0.068 mins	1.65 mins

- For Washing of Utensils (cups):

Statistical Parameter	**Minimum Value**	**Average Value**	**Maximum Value**
Number in Queue	0	0.175	10
Queue Waiting Time	0	0.064 mins	1.43 mins

➢ **Assumptions and Drawbacks of the Model:** Taking a smaller dataset to predict the distributions followed by inter-arrival times and the service times.

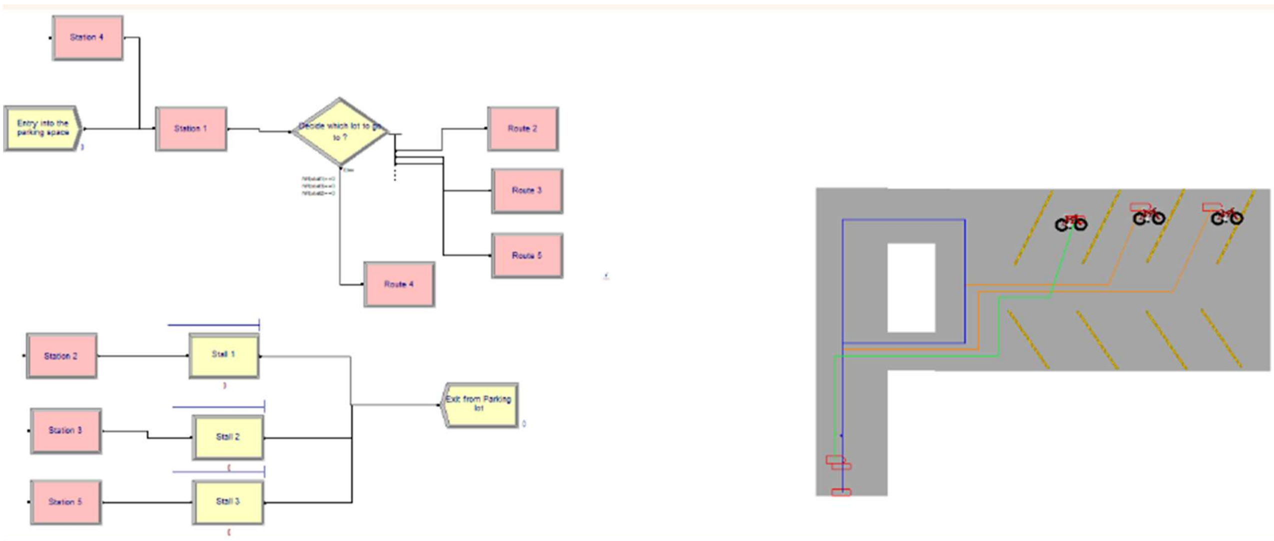
➢ **Checking accuracy of the model:**
Based on the simulation results,
Average number of people coming to the coffee shop= 540
Whereas, the actual number of people coming to the eateries (as obtained from the actual data collection procedure)= 550
This shows the simulation model works accurately with an **error** percentage of **1.85 %.**

3. **Parking lot Model**

➢ **Brief Overview:**
- Model based on entry and exit of students from the Cycle stand.
- Distribution types of the processes are determined from the pre-collected data.
- In the model ->
- Process- indicates how long a cycle stays in the cycle stand.
- Resources -are used to choose the cycles to know when the lot is actually busy (occupied) or free (empty).

- Route 4 - used to represent a loop. When all routes are busy, the cycle returns to station 1.

➢ **Simulation Model:**



A video demonstration of the Parking Lot model -> https://youtu.be/JNNf1GtIDNI

Results

Results and Scope of improvement for the three subsystems:

1) For the Classroom model:

- The inter-arrival time between all entities can be considered for each of the classes.
- The data collected for the process considering the above point will be quite extensive.
- It would yield a more precise result with more reliable simulation results.
- However, since there would be an **enormous amount** of data involved if we go by this method, further delays in **simulation times** and a higher likelihood of **input analysis procedure errors** could result from this.

2) For the Coffee Shop model:

- Including larger data sets, collected for a longer duration of time to avoid any discrepancies in the distribution parameters would lead to more accurate input analysis results.
- Consideration of disposable paper-cups, plates, etc. can be made to avoid the Washing cycle process.
- This would reduce the waiting time of the entities in the system.

3) **<u>For the Parking Lot model:</u>**

- The parking lot model and its simulation procedure (as demonstrated in the video) can help us to identify the pressing problems persistent with the current parking lot of the Nalanda complex.
- Lack of space is one of the most self-evident concerns associated with the system.
- **Increased parking lot space** and more **methodical parking lot design** are two corrective measures to combat the effects of parking lot overcrowding.

Discussions

Three separate subsystems of our system were successfully simulated, and this allows us to draw the following conclusion:

- Simulation modelling can be used as an analysis tool for predicting the effect of changes to existing systems and as a design tool to predict the performance of new systems.
- These well-defined models based on real-world data simulation can be used for exploring the operating procedures, new policies and information flows of a real system (as wide and extensive systems as '**NALANDA'**) without disrupting ongoing operations of the real system.
- Simulation models of our system helped us analyse New hardware designs, physical layouts, transportation systems, etc without committing resources for their acquisition.
- Insight was obtained about the **interaction of variables** and about the importance of variables to the performance of the system.
- **Bottleneck analysis** was performed indicating where work-in-process, information, materials, and so on were being excessively delayed.

Future Vision

Using the simulation findings from the three subsystems, we arrived at a few recommendations in the form of prospective scenarios:

- Using larger sets of data to arrive at a more accurate and conclusive simulation result.

- Using 2 sets of data for classroom simulation - exam pattern , semester classes pattern.
- Increasing the number of parking lots in the parking stand model and simulating again.
- Considering variable service time for each independent student in the Classroom Model.

Acknowledgment

First and foremost, we would like to express our sincere gratitude to Respected Professor Dr. Anand Jacob Abraham, who assigned to us this intriguing piece of work. He pushed us to think imaginatively and urged us to do this project without hesitation. His vast knowledge, extensive experience, and professional competence in the field of Industrial Engineering enabled us to successfully accomplish this project based on the concept of Simulation and Simulation models for real world systems. This endeavour would not have been possible without his help and supervision. Along with the Respected Professor, our Teaching Assistants were very amiable and helping throughout the project. We could not have asked for finer mentors in our studies.This initiative would not have been a success without the contributions of each and every individual member of the group. We were always there to cheer each other on, and that is what kept us together until the end.

We would like to thank the Indian Institute of Technology, Kharagpur and the Department of Industrial and Systems Engineering, IIT Kharagpur for providing us with the opportunity to work on this project (Simulation of Nalanda Complex as a system) under Professor Dr. Anand Jacob Abraham. Last but not the least, we would like to express our gratitude to our families, siblings, friends, seniors and fellow batchmates for their invaluable assistance. We are deeply grateful to everyone who has contributed to the successful completion of this project.

References

1. https://ieeexplore.ieee.org/abstract/document/7019957
2. https://www.researchgate.net/publication/283099202_Simulation_by_example_for_complex_systems
3. Discrete-Event System Simulation: Jerry Banks Carson II Nelson Nicol Fifth Edition