

# **DESIGN AND DEVELOPMENT OF BASIC TEACHING MODULES FOR OPEN SOURCE JAAMSIM DISCRETE EVENT SIMULATION SOFTWARE**

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## Declaration

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed ..... (NURUL HAKIMI BINTI IBRAHIM)

Date .....

## **Acknowledgement**

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## **Executive Summary**

This final year project report presents the design of a teaching module of Jaamsim Discrete Event Simulation Software. The objective of this project was to design and develop teaching modules for JaamSim discrete event simulation software. The problem was because there are limited resources of teaching module available and the accessibility of using WITNESS. The next objective of this project, was to build a simulation model using JaamSim simulation software. The teaching module design will help new user to use the module to build a simulation model using Jaamsim simulation software. The design description of this teaching module was to designed step by step to ease the new user. The content of the teaching module is designed based on an industrial case study in a coffee factory. Lastly, the evaluation of the simulation is analyzed based on the functions of the cooling and grinding simulation model.

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### **List of Abbreviations**

CIM	Computer Integrated Manufacturing
FYP	Final Year Project
WIP	Work in Progress
JaamSim	Java Animation Modeling and Simulation
GUI	Graphical User Interface

## **1.0 Introduction**

### **1.1 Project Overview**

For many years, students of Manufacturing Engineering with Management have been using WITNESS Horizon in some of the courses. For an example, Computer Integrated Manufacturing (CIM), Capstone Project and even Final Year Project (FYP). It is undeniable that WITNESS Horizon is one of a good tool for engineering students to learn simulation software [1]. Especially when there is a project or an assignment in the industry. The WITNESS Horizon simulation software will help students to imitate the current condition of the real process system over a time. So, the simulation can be done without disrupting the current operation of the real system. In addition, the students will be able to perform bottleneck analysis in the industry.

However, WITNESS Horizon is very expensive. It is only available in the student version for student to access the simulation software. Thus, JaamSim simulation software is introduced. JaamSim simulation software is an open source software that is available for everyone. It is a free software that everyone can download it anytime. However, there is problem encounter on using JaamSim simulation software. This is because there are not much of resources on using this software. Therefore, simulation modeling and analysis can be time consuming.

Thus, this final year project objective is to design and develop teaching modules for Jaamsim discrete event simulation software. The next goal is to build a simulation model about an industrial case study of JaamSim simulation software. By having its own teaching module. This will make the learning process for the new user easier. In the future, if there is no access to WITNESS Horizon, the

Jaamsim simulation software will be a good simulation tool to imitate the real world system over time. This teaching module will provide step by step procedure to build a simulation model based on an industrial case study in coffee factory.

## 1.2 Problem Statement

Firstly, the students are not able to access the latest full version of the WITNESS Horizon simulation software. This is because it requires the license of the WITNESS Horizon simulation software. Thus, only a student version of the WITNESS Horizon simulation software is available for students to learn about the simulation software. It means that, there are limitations in choosing elements in the simulation model. Consequently, students are not able to do overall simulation if the use of element involves more than 25 elements. Other than that, School of Mechanical Engineering has to pay a huge amount of money for the WITNESS Horizon simulation software license every year. This means that the license for the simulation software is quite expensive. Unless, JaamSim simulation software is introduced to the students.

Although, JaamSim simulation software is an open source software and free access for everyone. Unfortunately, it does not have a lot of sources of the tutorials or the teaching modules available on the internet. Mostly, it is just some general instructions and manual for the new user. This will be a problem, especially for the students who just tries to learn the Jaamsim simulation software. It will take some time to learn the Jaamsim simulation software. This is because there is not much example that can be used to understand develop a simulation model. Therefore, by having a teaching module

for Jaamsim simulation software will help to minimize the time consuming for the new user to learn the Jaamsim simulation software.

### 1.3 Objectives

The objectives of this final year project:

- To design and develop teaching modules for JaamSim discrete event simulation software.
- To build a simulation model using JaamSim simulation software.

### 1.4 Scope of Work

First and foremost, this project is a continuation of Angles Liew Xin Juan final year project. The purpose here is to extend the topic on design and develop a teaching module for Jaamsim discrete event simulation software. This time, the teaching module is a design based on an industrial case study in coffee factory. Other than that, adding new topic in the teaching panel by collecting data and resources available based on an industrial case study. With this, the teaching module will help new user to create a simulation model. It would be easy for new user to refer by having an example of industrial case study. Moreover, the teaching model will help new user to analyze the results from the simulation model.

Next, to create a video as one of a medium for basic learning in Jaamsim discrete event simulation software. The video will be created based on the teaching module. Therefore, this will help new user to understand JaamSim simulation software faster. Moreover, using various video editing software such as PowerPoint will make the video look interactive. The learning outcome of the video will act as a benchmark of the new user to test their ability themselves.

Lastly, some additional exercise is put along the teaching panel. This will help the new user to test their knowledge. So that the new user can access their learning output that they acquire from the video.

## 2.0 Literature Search

### 2.1 Introduction to Simulation

A simulation is the imitation of the operation of a system over time. [1] The behavior of the system for a certain period can be studied by creating a simulation model. In order to simulate something, a model must be developed [2]. The simulation model is mostly from a set of assumptions from the current condition of the real system. These assumptions will then define in the simulation software using mathematical, logical and symbolic relationship between the entities or objects of the system [1]. It represents key characteristic, behaviors and function of the physical or abstract of the process of a real system [2]. Thus, it means that the simulation represents the operation, whereas model represents the system.

Not just that, simulation can be done manually using hand [1]. This is because there are some simple models that can be solved using a mathematical method such as calculus, probability, algebraic methods and other mathematical theory. Unfortunately, due to the complex system, models of these systems are virtually impossible to imitate the real system mathematically. Throughout the years, an increase amount of simulation software has been developed. The program of the simulation software allows simulation users to observe operation through simulation without performing the operation [3]. There is a lot of simulation software available in the market. For instance, Witness, Arena, SimPy and many more [4]. Not to forget, open source simulation such as JaamSim simulation software.

## 2.2 JaamSim Simulation Software Background

JaamSim (Java Animation Modeling and Simulation) is a discrete event simulation software package. An international engineering firm called Ausenco has developed JaamSim simulation software [5]. It was first developed in 2002. However, in 2011, JaamSim has been released as a free, open source software and licensed under Apache 2.0 [6]. JaamSim target groups are simulation professionals, researchers and students [5].

Other than that, JaamSim is the first open source that provides Graphical User Interface (GUI) to the simulation user [5]. A modern GUI is a method used for computer user to interact with computers [7]. It means that in JaamSim simulation software, it uses the mouse to manipulate windows, icons and menu. By not having a GUI, the JaamSim simulation software will only be appropriate for those who have programming skills. Plus, it would only be appealing for those who have a lot of time to program the simulation model [5]. There are built in objects for simulation model building. It provides object for process flow type models. Thus, it provides the function needed to build in a simulation model.

## 2.3 Areas of JaamSim Simulation Software Application

There are many areas that can apply simulation. Some of the area such as manufacturing systems, public systems, restaurant and entertainment system and other [1]. In manufacturing system, simulation model can be used to model material handling system in a manufacturing system. In JaamSim simulation model software, the simulation model will show the movement of the material on the conveyor from one station to another station [8]. Bottleneck analysis can be performed to track the problematic area. It will help to indicate information on the

number of work in progress. It can also simulate manual work in production line and create order release planning in a production [1]. This would help the production line to plan for their production capacity, production layout and production system.

Another area in public system such as hospital. By doing simulation, it can help to analyse the bottleneck area such as the emergency departments. Thus, it would help to reduce the patient's waiting time to get a treatment from a doctor [1]. By having this, an improvement in the emergency department will help to improve the system. The chances of improving the system in the emergency department would increase the chances of saving people's life. This can reduce the length of stay in the emergency departments. As results, it would give more space to the other patients and doctors to utilize the emergency room. Moreover, this shows in one of JaamSim simulation. JamSim simulation software can also simulate the task in queue for nurses and the number of beds available in a specific department [9].

Moreover, simulation also can be done in the restaurant and entertainment system. It can simulate the rate of service. This will provide the restaurant traffic analysis [1]. Restaurant owners would be able to predict the number of labour requirements in their restaurant [1]. In JaamSim simulation, it can help to insert different input into the simulation model. Input such as the number of customers can seat per table or the number of waiters available. As a result, it would run the simulation to get the number of waiting customers over time or even the number of customer queue to pay [10].



## 2.4 Importance of a Simulation

There is a lot of importance of simulation. Simulation is a choice for most people in the industry as a method for problem solving. It is appealing to most people because it can mimic and make improvement on the real system without having to change the real system.

For an example, new working procedures, strategies or choice rules can be explored without disturbing the operation of the real system [1]. The simulation will help new operating procedures to find the correct parameters before applying the new procedures. It means that a variety of input can be verified in the simulation model, in order to identify the outcome of the performance of the system. This is very useful to answer the “What if” questions about the model system. Thus, simulation study can help user to understand how the new model system operates. This would help to avoid user misunderstanding of the operation.

In terms of time, simulation can help to compress or expand the time to adjust the speed of the simulation model. This will help simulation users to investigate on the certain areas that is crucial for the simulation model.

### **3.0 Design Description**

#### 3.1 Overview

This teaching module is the continuation design of Angles Liew Xin Juan. This Teaching Module designed for JaamSim Discrete Event Simulation Software new user. This design is suitable for building a simulation model in manufacturing industry. For this teaching module, it specifies on an industrial case study in a coffee factory. This teaching module focus on cooling and grinding department.

In the beginning of the teaching module, it introduces a question on how to produce a coffee in an industry. This idea is to test the general knowledge of the new user on some basic manufacturing process. It helps them to visualize the basic operation that involves in a coffee factory.

Other than that, problem statement in the production line in order to gain attention of the teaching module user, to solve a problem. By having a problem statement for the teaching module. It will help the new user to focus on creating and finding solutions throughout the learning process using the teaching module.

Moving on to the next section, cooling and grinding department is introduced as one of the process to make a coffee in a production. This section will describe about the current condition and what is happening in the production line. The current condition of the cooling and grinding process is explained in terms of process flow chart. The process in the cooling and grinding will go deeper and more specific task mentioned. Therefore, the time data of the process in the cooling and grinding is tabulated. The data collection act as a parameter for the input data in the cooling and grinding simulation model.

Next, a list of entities is described based on the process flow task. From this, the new user will be able to relate what entity is suitable for which task. Other than that, it is to familiarize the new user with the functions and icons available in JaamSim Discrete Event Simulation Software. For an example, the model builder, object selector, input editor and output viewer.

This teaching module is best appropriate for the new user that wants to learn JaamSim Simulation Software for the first time. The teaching module provides a step-by-step method to build cooling and grinding simulation models. It allows new users to refer to the teaching module while creating a simulation model of a system. At the end of this teaching module, the user is free to experiment with the simulation model.

### 3.2 Detail Design Description

The detail design description of the teaching module uses the step in Figure 3.1 as a guideline. Problem formulation is made. There are limited sources of teaching module software that explained about the real case study. Thus, the objective of this teaching module is to produce a teaching module regarding manufacturing industry. Thus, this teaching module is based on a case study in a coffee factory.

Then, the data collection is made in a coffee factory. The data collection is collected in the cooking, cooling and grinding department. For an example, the working hours, the number of workers available, the process flow of cooking, cooling and grinding, time study of process and other. Then, the data is used for model conceptualization. The component of the system is needed to understand. Table 3.1, show the components and the system in the coffee factory. The model is built using JaamSim Discrete Event Simulation. The current system is translated in a simulation process. Before that, a selection of entity is made of every task. Based on Table 3.2, it shows the selection of entity for every task. The simulation is then built. A several changes is made in order to verify and validate the simulation model.

Moving on to the next section, a step by step documentation and reporting for the simulation is done. A clear information about the current condition is informed and explained in the teaching module.

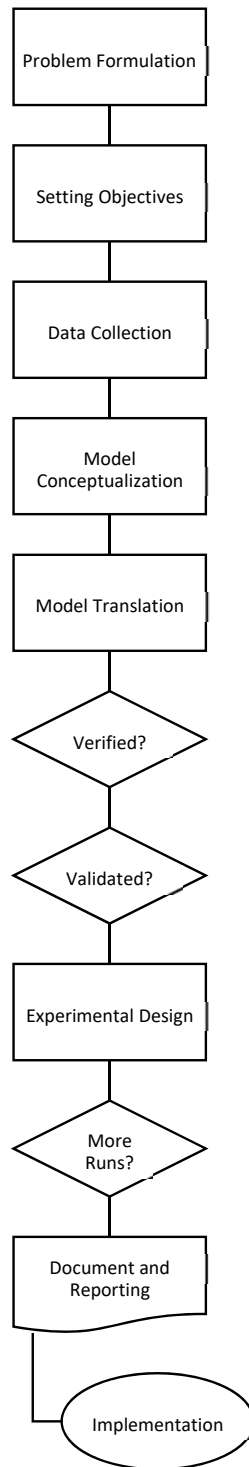



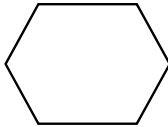

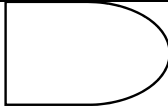









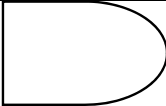







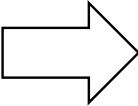

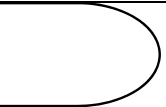



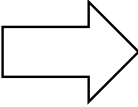

Figure 3.1: Steps to Do in a Simulation Study

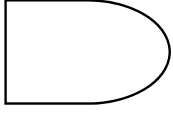









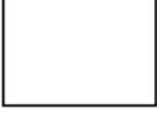

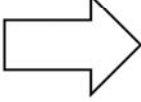

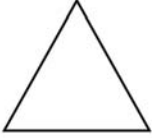

Table 3.1: Shows the systems and components

System	Coffee Production
Entities	Worker Machine
Attributes	Capacity
Activities	<ul style="list-style-type: none"> <li>• Flattening</li> <li>• Cooling</li> <li>• Scooping</li> <li>• Packing</li> <li>• Grinding</li> <li>• Recording</li> <li>• Labeling</li> </ul>
Events	<ul style="list-style-type: none"> <li>• Coffee Demand</li> <li>• Coffee Burnout</li> <li>• Breakdown Machine</li> </ul>
State Variables	<ul style="list-style-type: none"> <li>• Number of grind coffee per day</li> <li>• Number of orders</li> <li>• Number of occupied machines</li> <li>• Number of coffee waiting to be processed</li> </ul>

Table 3.2: Matching process flow charts symbol and objects

No.	Task	Symbol	Object
1.	Starting of simulation.		
2.	The cooked coffee is waiting the set-up of machine		
3.	The grind Machine A and Grind Machine B is set up.		
4.	The cooked coffee is waiting from flattened		
5.	The cooked coffee is flattened		

6.	The cooked coffee is waiting to cool down		
7.	The cooked coffee is cooled down		
8.	The cooked coffee is waiting to crushed		
9.	The cooked coffee is crushed		
10.	The crushed coffee is waiting to scooped		
11.	The crushed coffee is scooped in a Tupperware		
12.	The crushed coffee is put in Machine A		
13.	The crushed coffee in Machine A is waiting to complete		
14.	The crushed coffee is ground in Machine A		
15.	The crushed coffee is put in Machine B		

16.	The crushed coffee in grind Machine B is waiting to complete		
17.	The crushed coffee is ground in Machine B		
18.	The ground coffee is waiting to recorded the weight		
19.	The weight of the ground coffee is recorded		
20.	The ground coffee is waiting to labeled		
21.	The ground coffee is labeled		
22.	The Tupperware is transferred in the Finished Goods Storage		
23.	Finished coffee is kept in Finished Goods Storage		



### 3.2.1 Teaching Module Content Outline

In the beginning of the teaching module, the title page of the teaching module is introduced. Then a brief overview about the purpose of using teaching module is mentioned. Table 3.3 shows the content outline of the teaching module. Then in teaching module, it explained about the problem statement and the objectives of the module. Moreover, it also informed the new user about the list of entities that they will learn in the teaching module. After that, the instruction is provided for using teaching module. The gain attention process is made in the teaching module. This help them to understand and recall some the basic process of cooking making process. This is because to recall some knowledge about the process of coffee making.

Table 3.3: The content outline of the teaching module

Purpose	Outline
Title Page	JaamSim Discrete Event Simulation Software Teaching Module
Overview of Module	Purpose of the Teaching Module- The Teaching Module is about a learning module for JaamSim Discrete Event Simulation Software. This teaching module will cover the part of cooling and grinding process in a coffee factory. Different entities are used for every simulation model.
Gain Attention	Ask basic questions. Are you a coffee fan? Do you know how coffee made?

Stimulate Recall	Stimulate recall of simple process in coffee cooling and grinding process  □ Flattening
	<ul style="list-style-type: none"> <li>• Cooling</li> <li>• Scooping</li> <li>• Grinding</li> </ul>
Inform new users of Objective	The objectives of this video are to understand and investigate the behaviour of simulation models in coffee factory.  List of entity involve in the Teaching Module
Learning Outcome	The new user will be able to choose an entity according to the process task given. Brief descriptions of the topic, learning outcomes and types of assessment
Present the content	<ul style="list-style-type: none"> <li>• Present the process flow of the coffee making process.</li> <li>• Step by step procedure for building simulation model.</li> </ul>
Assess Performance by Asking Questions	Ask Questions  1. What happened if there is a bottleneck?  2. Would the company be able to send the finished goods on time?  3. Which part of the process that has a room for improvement?  4. What are the ways to improve the simulation model?

### 3.3 Use of Design

This teaching module is about building a simulation model. The simulation model is about a coffee making process in a factory. It only focuses on cooling and grind department.

This is because to get a detail view on to build a simulation model based on a real case study.

The new user can build a simulation model for any scenario that they want. After that, they can try to play with the simulation by putting different input. They can estimate a lot of things on that they want in the near future. They can estimate the number of products that they can produce in a day. Next, they can also perform the bottle neck analysis in the simulation produced using the teaching panel.

Moreover, they can use this basic teaching model to develop building other simulation model. After completing this teaching module, the new user will gain skills to develop new models for different process.

Lastly, the target audience for this teaching module is for anyone who is interested in learning Jaamsim discrete event simulation software. This teaching module is great for new user that want to learn the JaamSim simulation software. This teaching module also suitable for Manufacturing Engineering with Management students. This teaching module can help them visualize the situation in the manufacturing industry

## 4.0 Evaluation

### 4.1 Overview

The evaluation of design is made by using computer simulation. Thus, JaamSim Discrete Event Simulation Software is used to evaluate the cooling and grinding simulation model. When using JaamSim Discrete Event Simulation Software it will verify the model before running the simulation. The notification appeared before the run button that indicate the input error. The input error is corrected and the simulation is running.

Next, the cooling and grinding process simulation models is evaluated by observing the animation of the output. The movement of the SimEntity1 (Coffee) is observed. The SimEntity1 (Coffee) is moved from the first process that is flattening process until the end of the process that is keeping coffee in the finished goods area. The SimEntity1 (Coffee) is making sure to undergo the overall process sequence and the task time for each station. Lastly, the cooling and grinding simulation is analysed in a short run. The key design requirement in the cooling and the grinding simulation model is tabulated in Table 4. 1.

Table 4.1: Shows the Key Design Requirement

Major Requirement from Problem Statement	Possible Design Requirement
Able to analyse data	The graph is available to analyse
Easy to use	The Input Box for entity generator is added
Easy to understand	The object is labelled according to specific tasks
Object sequences must be correct	The entity is chosen based on process flow

## 4.2 Prototype

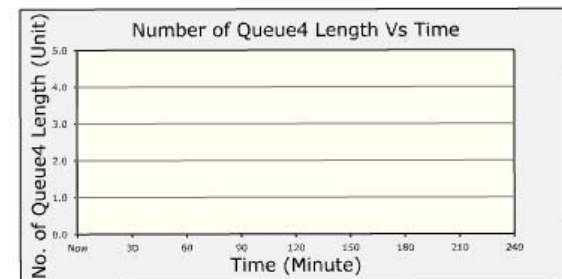
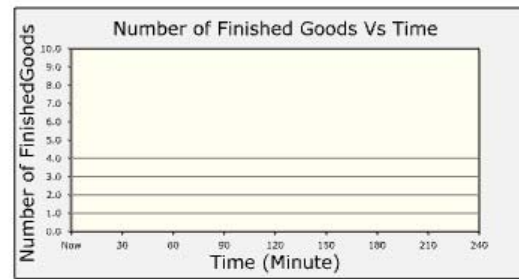
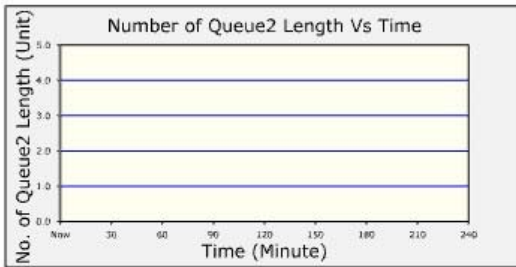
The final cooling and grinding simulation model is built using JaamSim Discrete Event Simulation Software. The process flow object in the simulation software is used to create the cooling and grinding simulation model. Based on Figure 4.1, shows the complete design of a simulation model for cooling and grinding process. Other key features such as input box and graph is added to improve the simulation design. It has a built in graph to analyse the performance of the production line. The input box will have the ability to key in the value in the view window. The simulation user will not have to key in the value in the input editor one by one.

Other than that, this simulation model helps to observe the work in process in all stations. It provides the waiting time if we want to extract it in a graph. The graph would show a pattern of the incoming entity.

The function for each entity is referred using Table 4.2. The entity of the simulation is chosen according to the process flow chart of cooling and grinding process. Each entity has different types of function. Each task is identified and is arranged according to the group of entity. Then, the entity is arranged, starting from the first process until the last process.

From this simulation model, new user able to know the performance of the production line. Other than that, the new user will be able to identify the bottleneck process by observing the simulation model and the graph available. Lastly, the new user will be able to get the solution of “What if” scenario happened in the cooling and grinding process.

## Coffee Cooling & Grinding Process



First Arrival Time = 83 min

Inter Arrival Time = 83 min

Entities Per Arrival = 1

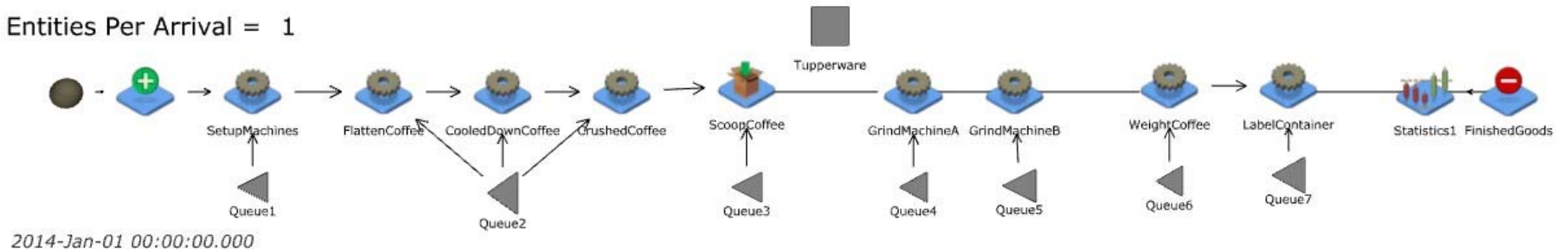


Figure 4.1: The Final Cooling and Grinding Simulation Model

Table 4.2: Shows the Function of Object

Object Type	Function of Object
SimEntity	The basic entity use in a simulation model. In cooling and grinding simulation, it represents the Coffee.
EntityGenerator	It represent the cooking process that is a process before cooling and grinding process. In simulation, it creates copies of a SimEntity (Coffee) at specified intervals.
Queue	Work In Progress (WIP) for every station. It stores received SimEntity (Coffee) until needed.
Server	Task or operation involves in the cooling and grinding process. It processes received SimEntity (Coffee) over a specified duration. Server is use to imitate task such as flattening, cooling, crushing and grinding process.
Pack	Inserts or scoops SimEntity (Coffee) in a Tupperware
EntityContainer	An entity that represent the Tupperware in the simulation model.
EntityConveyor	Transports a received SimEntity(Coffee) along a specified duration from one station to another station.
EntitySink	Keeping Tupperware in the Finished Goods Area

### 4.3 Testing and Results

The time duration running the simulation is 4 hours. This is set according to the working hours of the workers in the coffee factory. Based on Table 4.3, it shows the results of running the simulation with different variables for number of worker, first arrival time, inter arrival time and the incoming entities per arrival.

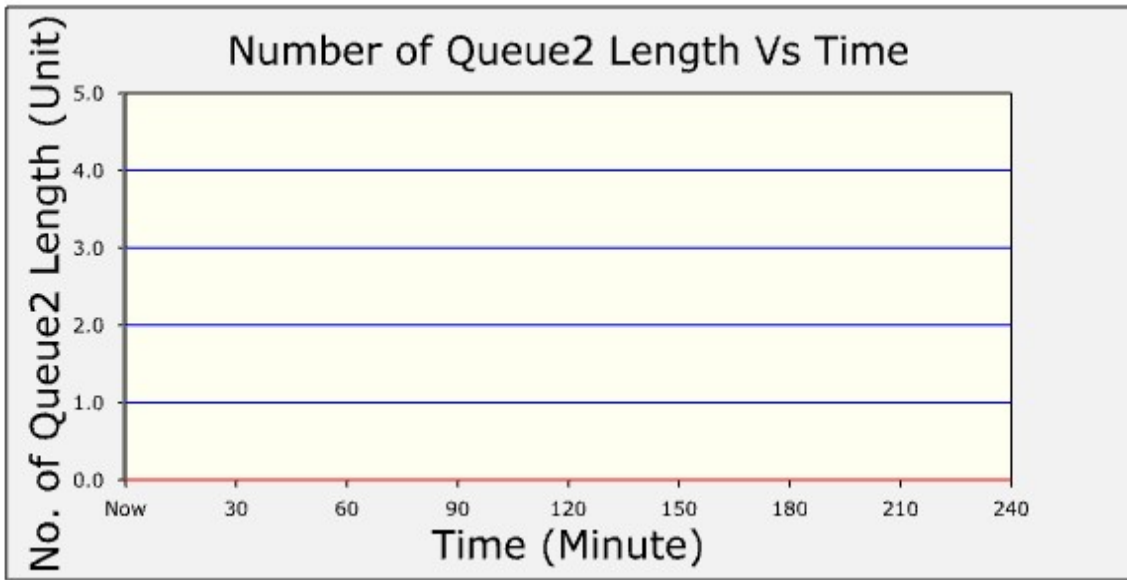
Table 4.3: Shows the Tabulated Results in Cooling and Grinding Simulation Model

<b>Experiment</b>	<b>Number of Worker</b>	<b>First Arrival Time (Minute)</b>	<b>Inter Arrival Time (Minute)</b>	<b>Incoming Entities Per Arrival</b>	<b>Time (Minute)</b>	<b>Number of Finished Goods (Unit)</b>
<b>A</b>	<b>1</b>	<b>83</b>	<b>83</b>	<b>1</b>	<b>30</b>	<b>0</b>
					<b>60</b>	<b>0</b>
					<b>90</b>	<b>0</b>
					<b>120</b>	<b>0</b>
					<b>150</b>	<b>0</b>
					<b>180</b>	<b>0</b>
					<b>210</b>	<b>1</b>
					<b>240</b>	<b>1</b>
<b>B</b>	<b>1</b>	<b>83</b>	<b>55</b>	<b>1</b>	<b>30</b>	<b>0</b>
					<b>60</b>	<b>0</b>
					<b>90</b>	<b>0</b>
					<b>120</b>	<b>0</b>
					<b>150</b>	<b>0</b>
					<b>180</b>	<b>1</b>
					<b>210</b>	<b>1</b>
					<b>240</b>	<b>2</b>
<b>C</b>	<b>2</b>	<b>83</b>	<b>83</b>	<b>2</b>	<b>30</b>	<b>0</b>
					<b>60</b>	<b>0</b>
					<b>90</b>	<b>0</b>
					<b>120</b>	<b>1</b>
					<b>150</b>	<b>1</b>
					<b>180</b>	<b>1</b>
					<b>210</b>	<b>2</b>
					<b>240</b>	<b>2</b>
<b>D</b>	<b>4</b>	<b>83</b>	<b>55</b>	<b>4</b>	<b>30</b>	<b>0</b>
					<b>60</b>	<b>0</b>
					<b>90</b>	<b>0</b>
					<b>120</b>	<b>2</b>
					<b>150</b>	<b>2</b>

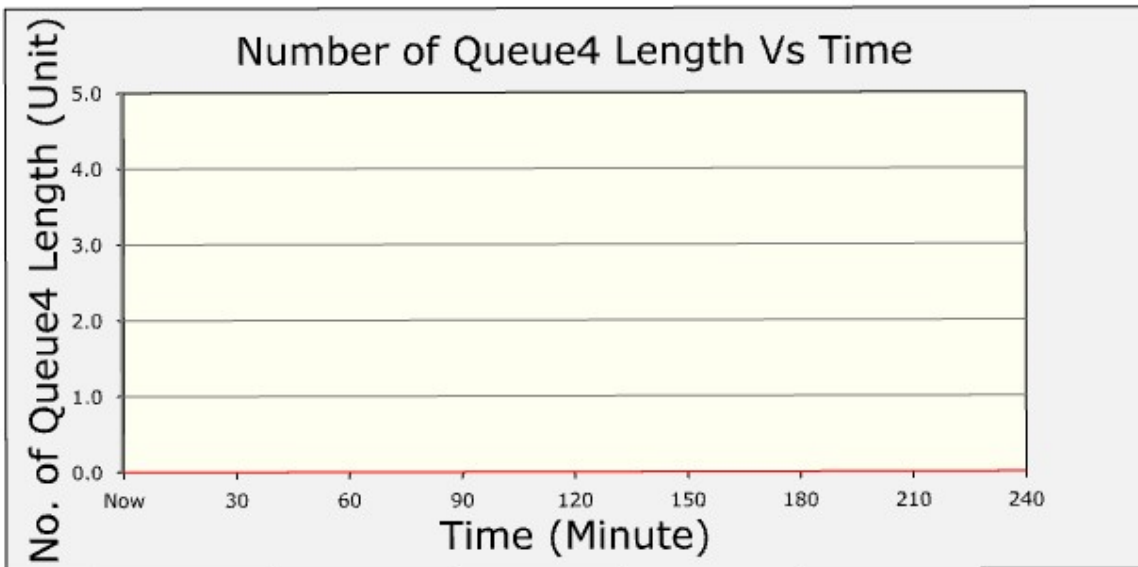


					180	4
					210	6
					240	9

**Experiment A**



Graph 4.1: Shows the Number of Queue2 Length Vs Time



Graph 4.2: Shows the Number of Queue4 Length Vs Time