Automated Guided Vehicle System Simulation - User's Guide

Introduction

Document Purpose

The purpose of this document is to help communicate to the user, the use of the simulation developed by the team. It provides a comprehensive description of how to use the different elements of the simulation, navigate between them and store the results.

Simulation Description

The system of interest is a Manufacturing plant that has different service/storage areas, hereby referred to as nodes. The five different nodes are the Delivery Node, Storage Node, Manufacturing Node, Buffer Node and the Packaging Node. This system uses Automated Guided Vehicles (AGVs) for material handling and material transportation between different nodes. This system is modeled as a Queueing System with six serial queues (Four AGV based material handling and transportation servers between the nodes, One manufacturing server and One Packaging server). This system is modeled in MATLAB software on a standard PC.

The simulation is that of this MATLAB model.
The output metrics are the **System Lead Time** (Total time in the system), and the **Manufacturing Node Idle Time** (Total time the Manufacturing Node remained idle) which are dependant on various AGV design and Environment parameters described in detail in the further sections. The service provided at each of the nodes are:

- Material handling by AGV at the Delivery node
- Material handling by AGV at the Storage node
- Manufacturing, and Material handling by AGV at the manufacturing node (two services at this node)
- Material handling by AGV at the Buffer node
- Packaging at the packaging node

The output metrics of interest are

- Manufacturing lead time (total time in the system)
- Manufacturing idle time (server utilization ratio).

Referenced Documents

The following documents serve as references for this User's guide :

1. 623 HW 12 User's Manual Template - 161025- Dr. John MacCarthy
2. HW 3 - AGV System Simulation Concept Description (Version-1), Group 3
3. HW 11 - AGV System Simplified Validation Test Plan (Version-1), Group 3
4. MathWorks website (MATLAB Documentation)
5. Working MATLAB model of Group 3 (https://github.com/samvrit/agv/tree/agv_working/MATLAB)

Document Structure

This section provides a brief description of how the document is structured and in accordance to the template provider by Dr. John MacCarthy

- Section 1 provides an introduction to the document, brief description of the system and simulation of interest,the referenced documents, and the document's structure.
- Section 2 explains the different modes of operation and how to navigate between them
- Section 3 describes how to use the Analytical Model
- Section 4 explains how to use the Monte Carlo Model
- Section 5 explains how to use the Sensitivity Analysis
- Section 6 explains how to use the Trade-off Analysis

Simulation Navigation

The simulation can be run in four different modes - the Performance Analysis in two modes - Analytical Mode and the Monte-Carlo model, Sensitivity Analysis, and Tradeoff Analysis . In order to use the simulation, the user needs to place all the project files in a single directory (The folder containing all the project files can be found in the link mentioned in reference-5). In order to run the simulation, the user needs to run the "agv_simulation.m" file in MATLAB software on at the least, a standard PC. The user will encounter a GUI window as shown in fig 1.

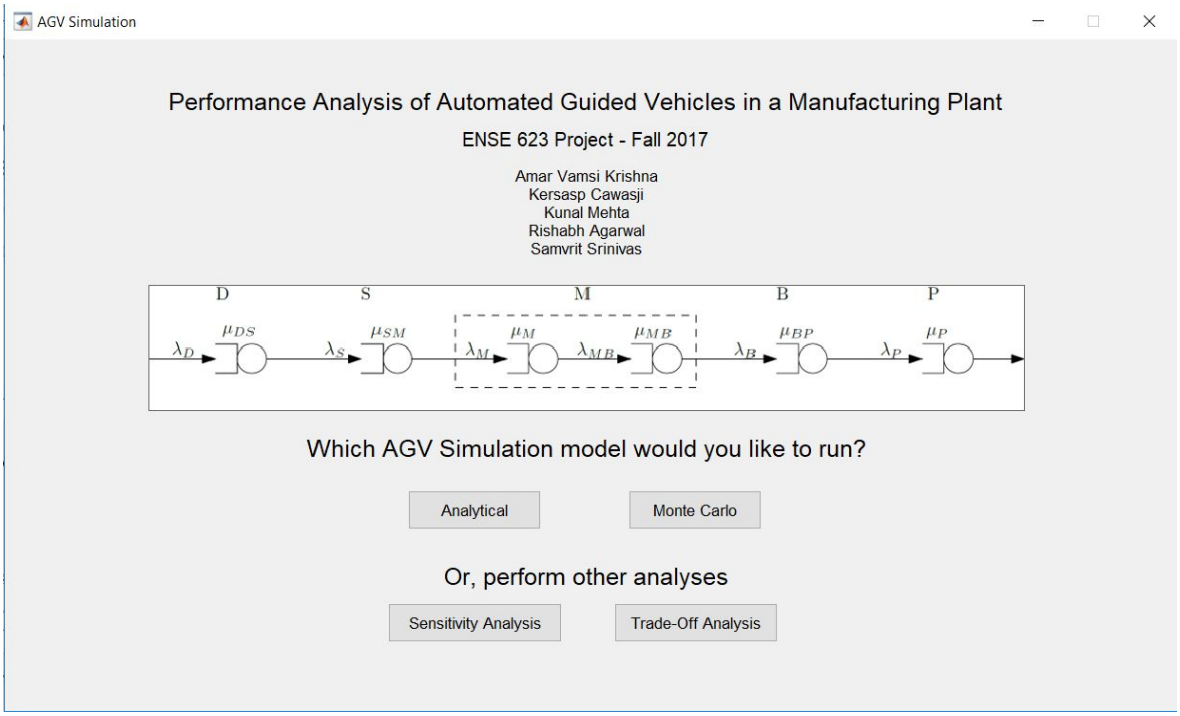

Fig: 1 - AGV System Simulation Main Menu GUI

The user can now select the desired model to run. The team would recommend to run the Analytical Model first followed by the Monte Carlo Model. These two combined form the Performance Analysis. Other two Analyses include Sensitivity Analysis and Tradeoff Analysis. The user can navigate between the Analytical Model GUI (shown in fig 2) and the Monte-Carlo Model GUI (shown in fig 5) by pressing the "Go to Monte-Carlo" and the "Go to Analytical" buttons.

Using the Analytical Module

Analytical Simulation Inputs

The Graphical User Interface (GUI) of the Analytical Model looks as shown in fig 2.

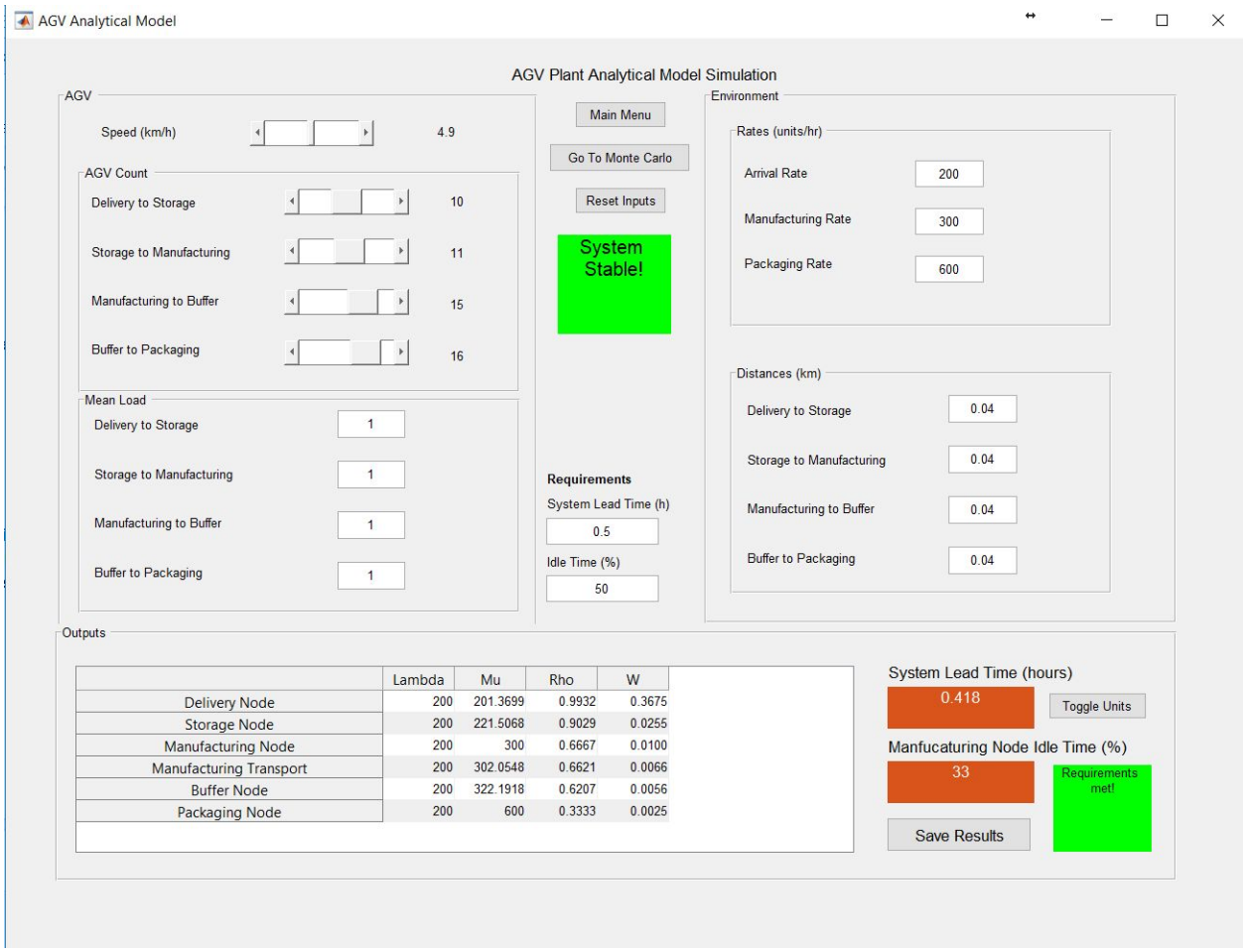

Fig-2: AGV System Simulation Analytical Mode GUI

The Analytical Mode of the simulation is capable of taking the following inputs

1. AGV Design Factors
    a. AGV Speed (Units - Km/hr) (Using the slider button in the GUI)
    b. Number of AGVs between each of the nodes
        i. Number of AGVs between the Delivery Node and the Storage Node (Units - Number)
        ii. Number of AGVs between the Storage Node and Manufacturing Node (Units - Number)

iii. Number of AGVs between the Manufacturing Node and the Buffer Node (Units - Number)
iv. Number of AGVs between the Buffer Node and the Packaging Node(Units - Number)

c. The Mean Load carried by the AGVs (Using keyboard input into the box)
i. Mean Load carried by the AGV running between the Delivery Node and the Storage Node (Units - Number of items)
ii. Mean Load carried by the AGV running between the Storage Node and the Manufacturing Node (Units - Number of items)
iii. Mean Load carried by the AGV running between the Manufacturing Node and the Buffer Node (Units - Number of items)
iv. Mean Load carried by the AGV running between the Buffer Node and the Packaging Node (Units - Number of items)

2. Requirements (Using keyboard inputs into the box)
   a. The required System Lead Time (Units - hrs)
   b. The required Manufacturing Idle time (Units - % of total hours running)
3. AGV Environmental Factors (Using keyboard inputs into the box)
   a. The arrival rate of items at the Delivery Node (Units - items/hour)
   b. The manufacturing rate at the Manufacturing Node (Units - items/hour)
   c. The packaging rate at the Packaging Node (Units - items/hour)
   d. Distance between the Delivery Node and the Storage Node (Units - Km)
   e. Distance between the Storage Node and the Manufacturing Node (Units - Km)
   f. Distance between the Manufacturing Node and the Buffer Node (Units - Km)
   g. Distance between the Buffer Node and the Packaging Node (Units - Km)
4. Misc inputs : These are the input buttons that require an input of a click on their buttons. These help the user better use and navigate through the simulation
   a. Main Menu Button - pressing this button will result in the display of the main menu as shown in fig 1.
   b. Go to Monte -Carlo - pressing this button will result in the display of the Monte-Carlo mode of the simulation as shown in fig 3
   c. Reset inputs - pressing this button results in the input factors reset to the default values (The default values as shown in fig 1)
   d. Toggle units - pressing this button results in the change of units of System Lead Time from hours to minutes and vice versa
   e. Save Results - pressing this button results in creation of an excel worksheet with all the results stored in it

The simulation is set to a default set of input parameters as shown in fig 2. The user can change the inputs by either sliding the bar or by entering the text input in the box

Analytical Simulation Outputs

The simulation outputs are seen in the bottom part of the AGV System Simulation Analytical Model GUI as shown in fig 2.
The outputs can be classified into two groups

1. Quantitative outputs
    a. System Lead Time - This refers to the total time an item spent in the manufacturing plant from arrival to the end of packaging
    b. Manufacturing Node idle time - this refers to the fraction of the time the manufacturing node remained idle

    The outputs are displayed on a red background to catch the attention of the user.
    c. The simulation also gives the output of the arrival rate, service rate, utilization ratio and the total time in the node for each of the nodes in the form of a tabular column
2. Qualitative outputs
    a. Stability - The simulation is capable of displaying if the System is stable or unstable. If the system is stable, the display is on a green box (refer to fig 2). But, if it is unstable, the display is on a red box (refer to fig 3)
    b. Requirements met - The simulation is also capable of displaying if the System requirements have been met or not. If the requirements are met, the display is on a green box. But, if the requirements are not met, the display in on a red box (refer to fig 4).

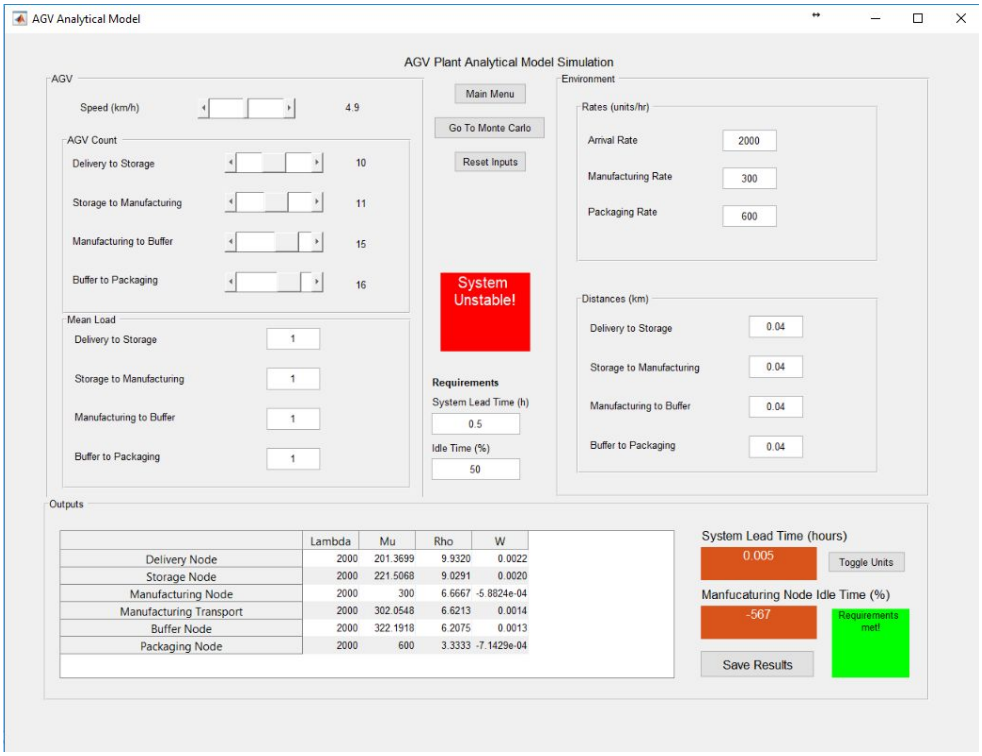

Fig - 3: AGV System Simulation System Unstable

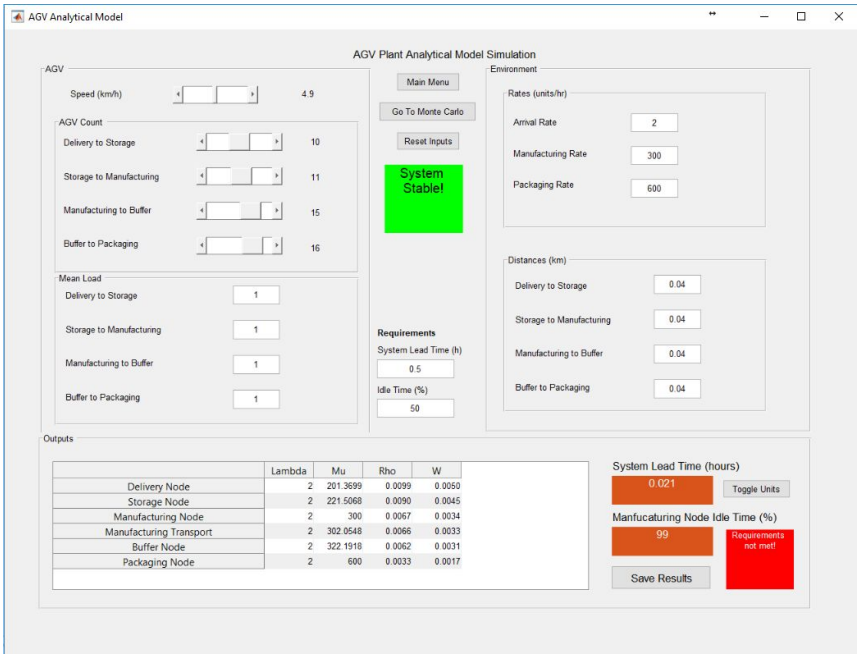

Fig - 4: AGV System Simulation System Requirements not met

Using the Monte Carlo Module

Monte Carlo Simulation Inputs

The Graphical User Interface (GUI) of the Analytical Model looks as shown in fig 5.

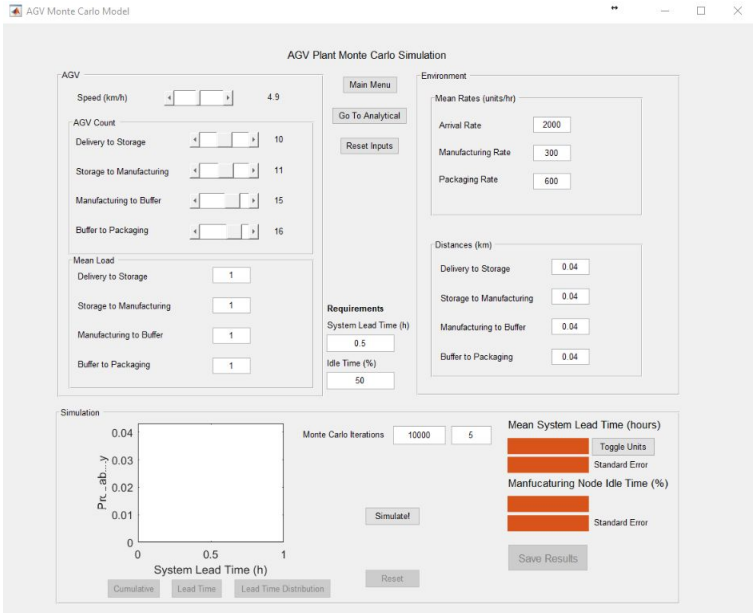

Fig - 5: AGV System Simulation Monte Carlo Mode GUI

In order to maintain interface consistency, the Monte Carlo mode of the simulation is capable of taking the same inputs as that of the Analytical mode. The default input values are the same as those set to the analytical mode. Changing the inputs in this window and clicking on the “Go to Analytical” mode will result in the same inputs being used for the calculations of the Monte Carlo mode. In addition to the inputs described in the section 3.1, there are the following additional inputs

1. Monte Carlo Iterations:
   This input has two boxes. The left box takes the value of the number of arrivals of different items into the system for the simulation (escape condition). The right box takes the value of the number of runs of the simulation that the user wants.
2. Simulate button
   This button initiates the simulation process
3. Cumulative
   Pressing this button results in the display of the Cumulative Average of the Lead Time v/s Number of iterations
4. Lead time
   Pressing this button results in the display of Lead Time v/s number of iterations
5. Lead time distribution
   Pressing this button results in the display of a Probability v/s System Lead time graph
6. Reset
   Pressing this button results in clearing the GUI and prepares the simulator to take a new set of input values

Monte Carlo Simulation Outputs

Like the Analytical Mode, the Monte Carlo Mode also consists of quantitative and qualitative outputs (refer to section 3.2) . The Monte Carlo mode, in addition, is capable of displaying the standard error associated with the outputs - Mean System Lead Time and the Manufacturing Node Idle Time.
The Monte- Carlo mode, upon pressing the “Simulate!” button, is capable of displaying a text “Running Simulation” to indicate that the simulation is still being processed (as shown in Fig 5)

Once the simulation completes the run successfully, the user can look at the graphs that characterize the system. The three graphs of Cumulative Average of the Lead Time v/s Iteration as shown in fig 6 (Pressing the cumulative button), Lead Time v/s Iteration as shown in fig 7 (Pressing the Lead Time button), and the Probability v/s System Lead Time as shown in fig 8 (Pressing the Lead Time Distribution button) can be appropriately toggled.
Just like the Analytical Mode, the user has the provision to save the results into an excel file by pressing “Save Results” button.

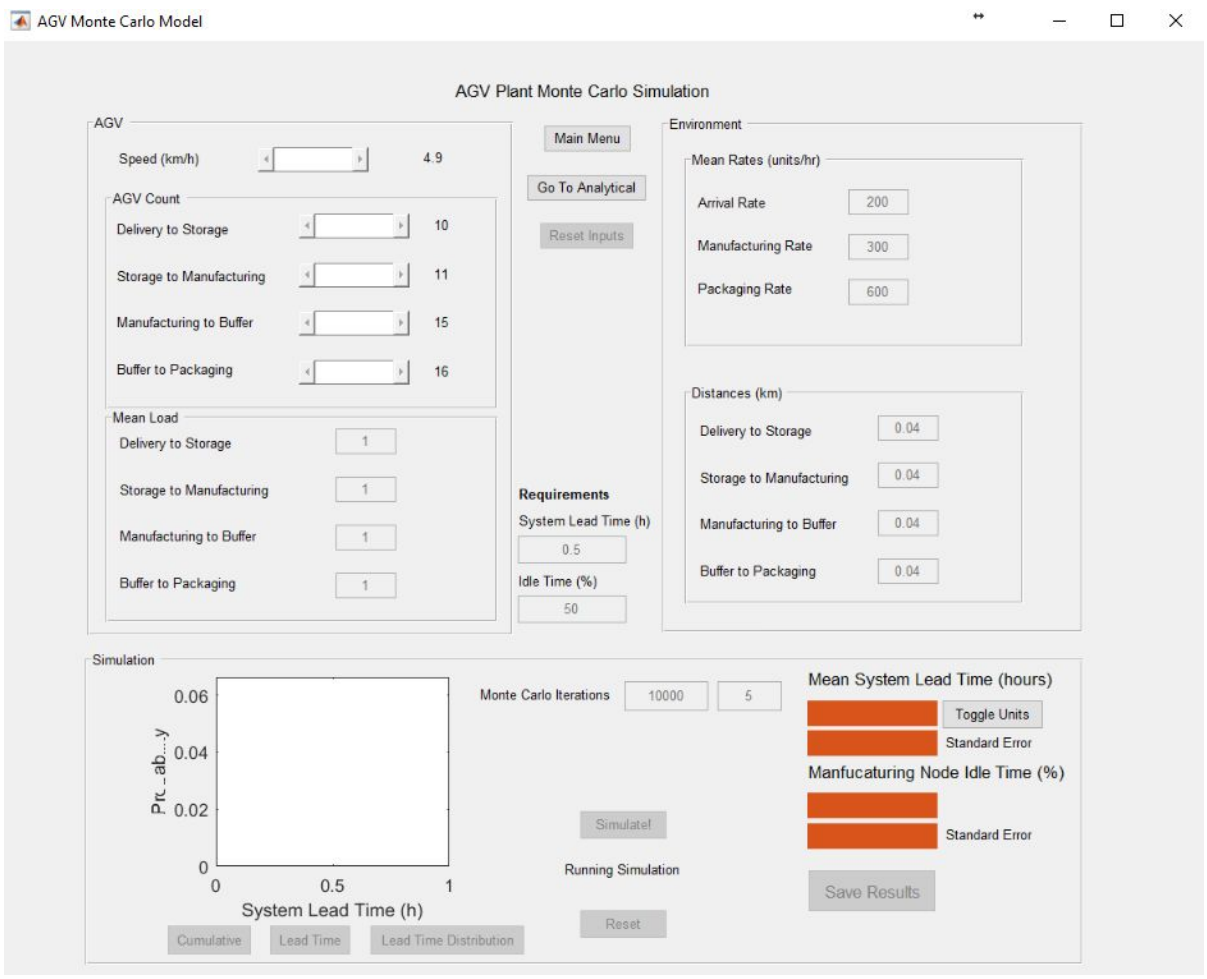

Fig - 5: AGV System Simulation Monte Carlo Mode- Running Simulation

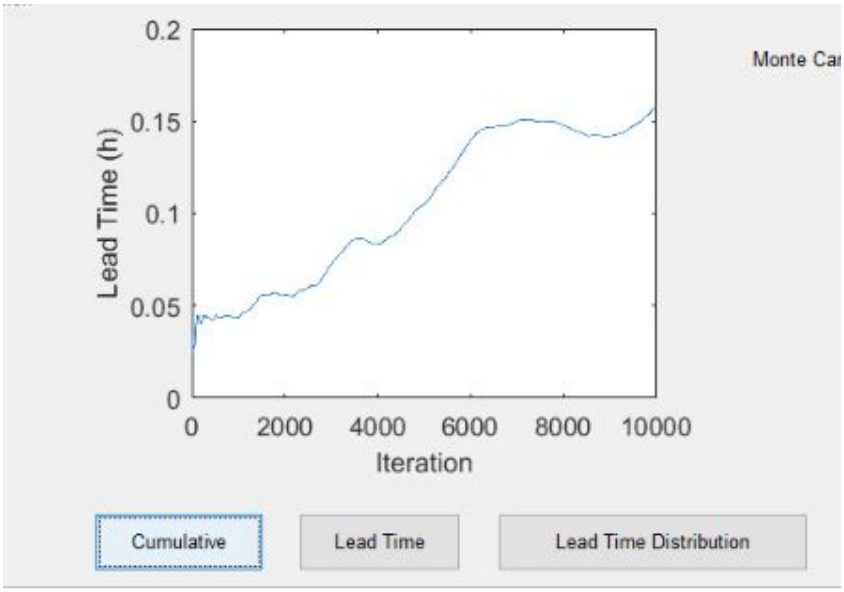

Fig 6 : Monte Carlo Mode - Lead time v/s Number of Iterations

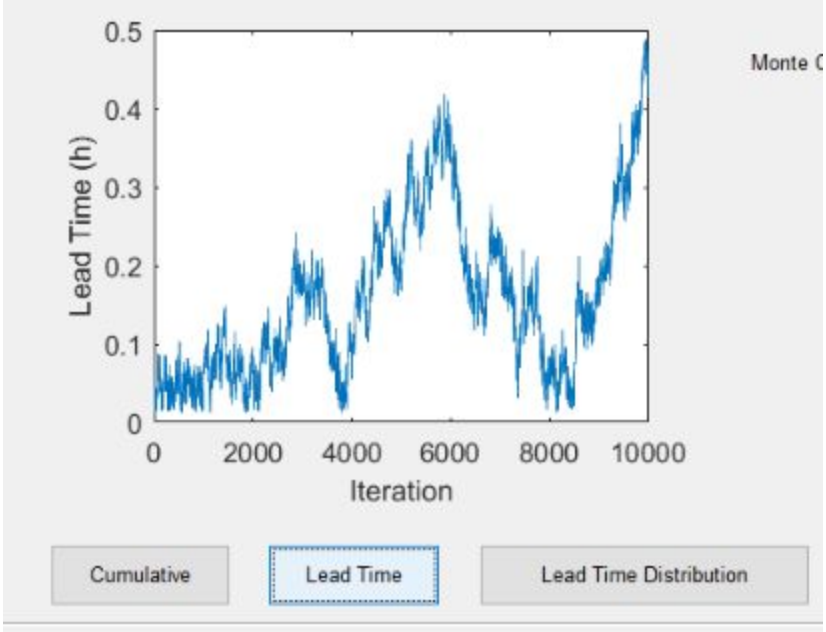

Fig 7 : Monte Carlo Mode - Lead time v/s Number of Iterations

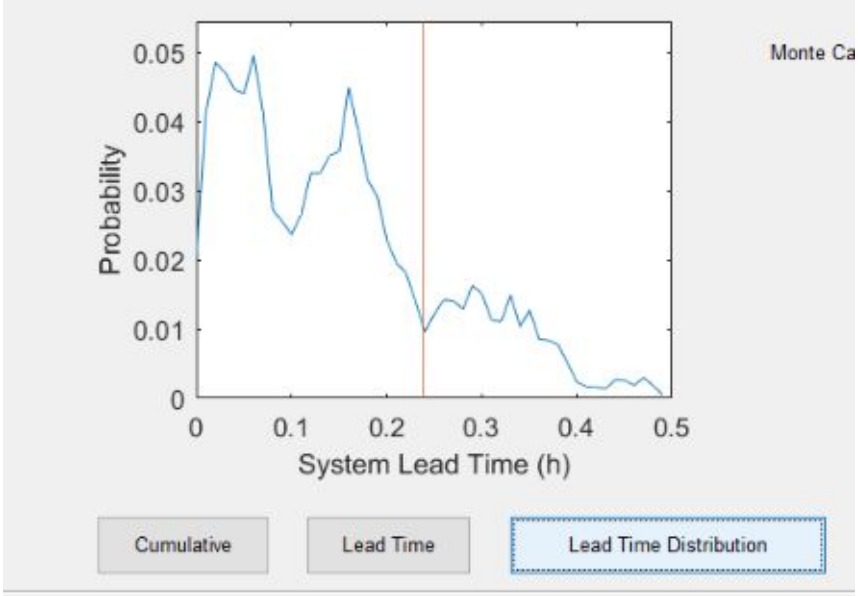

Fig 8 : Monte Carlo Mode - Probability v/s System Lead Time

Using the Sensitivity Analysis

The Graphical User Interface (GUI) of the Sensitivity Analysis is through an Excel Worksheet that opens up when you click on the “Sensitivity Analysis” button on the Main menu screen as shown in Fig 9 .

	Ref	Low	High
Speed	5.4	4.9	5.9
Count DS	11	10	12
Count SM	12	11	13
Count MB	16	15	17
Count BP	17	16	18

Fig - 9: Input section of Sensitivity Analysis

The Excel sheet contains a set of default reference, high and low values for five of the factors on which the team had prepared a sensitivity analysis. In order to use the Sensitivity Analysis, the user has to change the values in the worksheet named “Data” in the input space as shown in Fig 9 and save the document and close it. By pressing the “Sensitivity Analysis” button on the Main Menu, a new updated excel sheet is opened which contains a tornado diagram corresponding to the sensitivity analysis as shown in Fig 10.

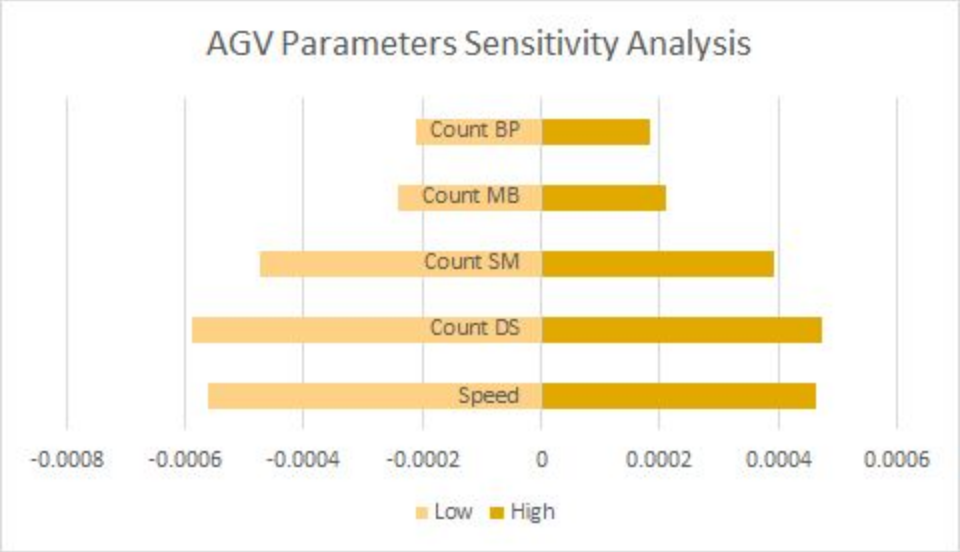

Fig - 10: Output section of Sensitivity Analysis

Sensitivity Analysis Inputs

As shown in Fig 9, the inputs for the Sensitivity Analysis are the Reference, Low and High values for The speed of AGV, the Number of AGVs between each pair of serial nodes.

Sensitivity Analysis Outputs

As shown in Fig 10, the output for the Sensitivity Analysis is a tornado diagram for the metric - System Lead Time in hours.

Using the Tradeoff Analysis

The Graphical User Interface (GUI) of the Trade Off Analysis is through an Excel Worksheet that opens up when you click on the “Trade-off Analysis” button on the Main menu screen as shown in Fig 11 . The Trade off Analysis is based on Multi Attribute Utility Analysis.

Alternatives							
	Speed	Count DS	Count SM	Count MB	Count BP	Mean Load	Cost/AGV
AGV Model 1	6	10	11	15	16	1	1000
AGV Model 2	5.2	11	12	16	17	1	1500
AGV Model 3	4.5	12	13	17	18	1	2000
	Distance DS	Distance SM	Distance MB	Distance BP	Arrival Rate	Mfg Rate	Pkg Rate
Environment Parameters	0.04	0.04	0.04	0.04	50	200	550
	Weights (0-100)						
System Lead Time	80						
Manufacturing Node Idle Time	60						
Total Cost	80						
Analysis Type	Analytical						

Fig - 11: Input section of Trade off Analysis

The Excel sheet contains a set of default values for a set of three alternatives amongst which the trade off is to be performed. The simulation allows the user to compare three different AGV configurations. In order to use the Trade-off Analysis, the user has to change the values in the worksheet named “Alternatives” in the input space as shown in Fig 11 and save the document and close it. By pressing the “Trade-off Analysis” button on the Main Menu, a new updated excel sheet is opened which contains an output section displaying the value function for each of the value diagram corresponding to the sensitivity analysis as shown in Fig 10.

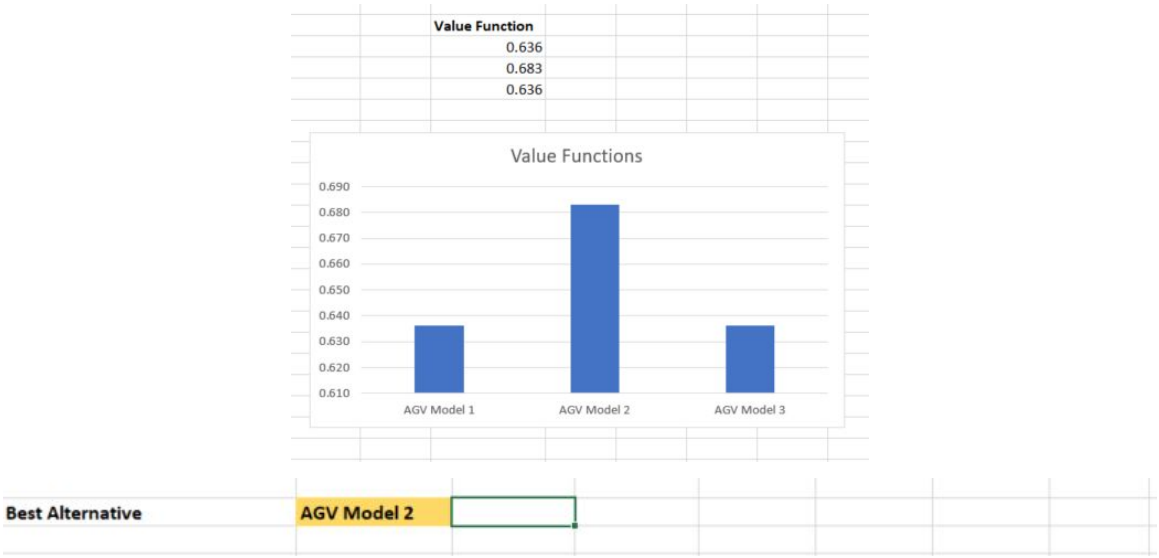

Fig - 12: Output section of Trade off Analysis

Trade off Analysis Inputs

As shown in Fig 11, the inputs for the Trade Off Analysis are the design parameters for the three AGV configuration alternatives - Speed, the number of AGVs between a pair of serial nodes and the cost per AGV, the environmental factors - Distance between nodes, the arrival rate, manufacturing rate and the packaging rate. Additionally, the user has to provide the weights for the relative preference of the metrics of interest which are the two System MOEs - System Lead Time and the Manufacturing Node Idle time along with the total cost of the AGV system. Using a drop down menu, the user has to select between the Analytical and the Monte Carlo modes of performance analysis.

Trade off Analysis Outputs

As shown in Fig 12, the output for the Trade off Analysis is a table containing the the Value function for the three alternate designs. Also, a graphical bar chart is plotted showing the values associated with each of the alternatives.
At the bottom of the input section, a highlighted cell displays the Recommended Alternative from the Trade-off Analysis.