Plant Layout Design with Simulation

Uttapol Smutkupt, and Sakapoj Wimonkasame

***Abstract*—In the past, there were many techniques to design industrial plant layout. The most popular was CRAFT (Computerize Relative Allocation Facilities Technique). However, the result from CRAFT was limited. The result of design showed only minimum total transfer cost between departments. As a result, the simulation technique is added to plant layout design to show more information about the design such as total time in system, waiting time, and utilization. To add the simulation to a plant layout design, Microsoft Visual Basic is used to develop a design system based on CRAFT model. Then, it is used to link the design system to a simulation system in Arena. Finally, the simulation system send back overall results to a report system in Microsoft Visual Basic output form.**

***Index Terms*— Plant Layout, Simulation, Arena, VBA**

I. Introduction

In the past, there were many techniques to design industrial plant layout. The most popular was CRAFT (Computerize Relative Allocation Facilities Technique). However, the result from CRAFT was limited. The result of design showed only minimum total transfer cost between departments. The calculation is based on the following equations:

$$\text{Minimize } C = \sum_{i=1}^{n} \sum_{j=i+1}^{n} f_{ij} c_{ij} d_{ij} \qquad (1)$$

C : Total Transfer Cost
f_{ij} : Transfer Rate From i To j
c_{ij} : Cost of Transfer From i To j
d_{ij}: Distance From i To j (From Centroid)

If the distance between departments are rectilinear, d_{ij} is calculated based on Equation (2).

$$d_{ij} = |\Delta x| + |\Delta y| \qquad (2)$$

If the distance between departments are euclidean, d_{ij} is calculated based on Equation (3).

$$d_{ij} = \sqrt{(\Delta x)^2 + (\Delta y)^2} \qquad (3)$$

To calculate the distance between departments, centroid of each department is calculated using equation(4) and (5).

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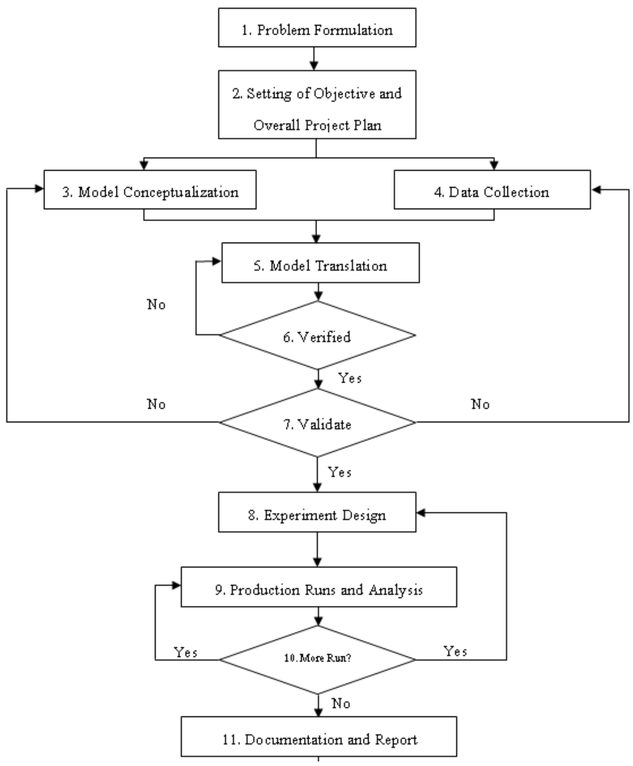
$$X = \frac{1}{A}\int_{y_1}^{y_2}\int_{x_1}^{x_2} x\,dx\,dy = \frac{1}{2A}(x_2^2 - x_1^2)\times(y_2 - y_1) \qquad (4)$$

$$Y = \frac{1}{A}\int_{x_1}^{x_2}\int_{y_1}^{y_2} y\,dy\,dx = \frac{1}{2A}(y_2^2 - y_1^2)\times(x_2 - x_1) \qquad (5)$$

Based on these calculations, the result design will show only a transfer cost between departments. The good result design means less transfer cost between departments. However, there are other parameters missing such as total time in system, waiting time, or utilization.

II. SIMULATION TECHNIQUE

Simulation refers to a broad collection of methods and applications to mimic the behavior of real systems, usually on a computer with appropriate software. Today, simulation is more popular and powerful than ever since computers and software are better than ever. Simulation has many aspects that do tend to come up frequently as follows:



III. SIMULATION WITH ARENA

Arena, the simulation software from Rockwell Software Company, is the simulation software which combines the ease of use found in high-level simulators with the flexibility of simulation languages and even all the way down to general-purpose procedural language like the Microsoft Visual Basic programming system. It does this by providing alternative and interchangeable templates of graphical simulation modeling and analysis modules that you can combine to build a fairly wide variety of simulation models. For ease of display and organization, modules are typically grouped into panels to compose a template. By switching panels, you gain access to a whole different set of simulation modeling constructs and capabilities.

IV. PLANT LAYOUT DESIGN WITH SIMULATION

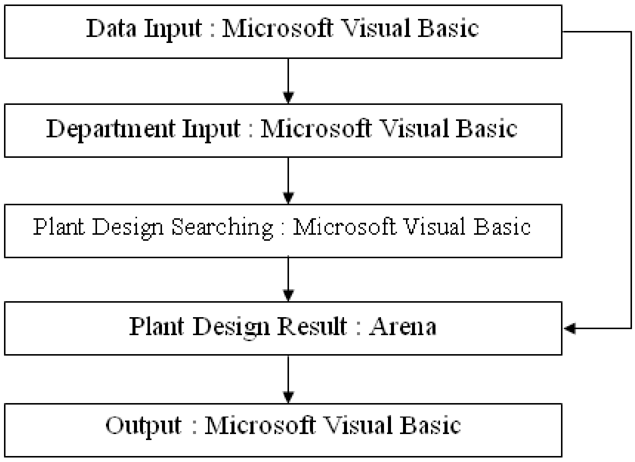
Based on the missing of some information from the traditional plant layout design, the simulation technique is added to the traditional plant layout design to show more information such as total time in system, waiting time, and utilization. As a new concept, there must be a system that can search for a good layout and then can show more important information about production. Both concepts are implemented as computer software with the plant layout design module and the plant layout simulation module. These modules are developed based on Microsoft Visual Basic program. First, there is a Microsoft Visual Basic Graphic User Interface (GUI) to receive input such as product type, product quantity, department list, department dimension, From-To Chart. Then, the plant layout design module is called. This module is also developed based on Microsoft Visual Basic program to swap all departments to get minimum total transfer cost between departments. The number of swap can be calculated using equation (6)

$$M = \frac{N(N-1)}{2} \quad (6)$$

N: Number of Department

After each swap, the total transfer cost of each swap is recorded. After the final swap, the plant layout design which gives the minimum total transfer cost is listed. Next, the link between the design module and the simulation module is setup. This link is developed based on Microsoft Visual Basic program to submit the best design from the design module to the simulation module.

At the simulation module, Arena is used to calculate total time, waiting time, or utilization from the plant layout design from previous module. Finally, the result from Arena is sent back to Microsoft Visual Basic form to give the answer. Overall concepts are shown below.

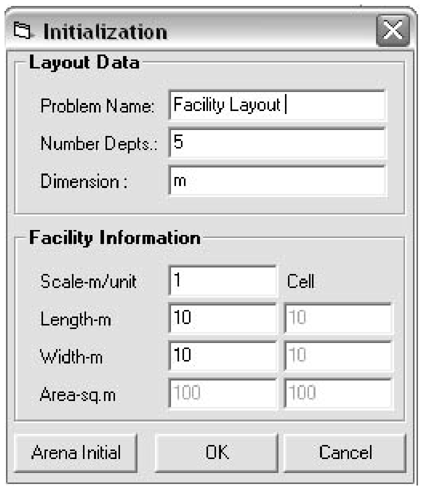


V. PLANT LAYOUT DESIGN MODULE

In the plant layout design module, there are many inputs those are needed for searching an optimal plant layout such as total area, number of department, department area, department location, number of product, production rate of each product, production sequence of each product and production rate of each sequence. After that, all inputs will be used to calculate a total transfer cost from the original plant layout. Next, the new total transfer cost of a new plant layout which one department is swapped by another department is calculated. Finally, after the entire swaps are done, the minimize total transfer cost is selected. Then, the best plant layout design is found. All steps are shown below.

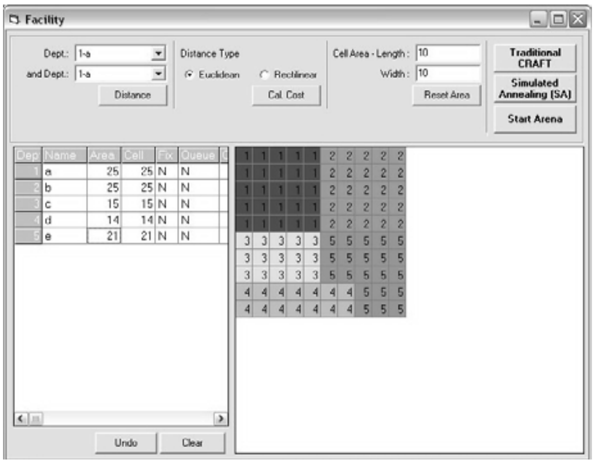
- Initial Setup Window

This window asks for a total area and a number of departments in the plant.



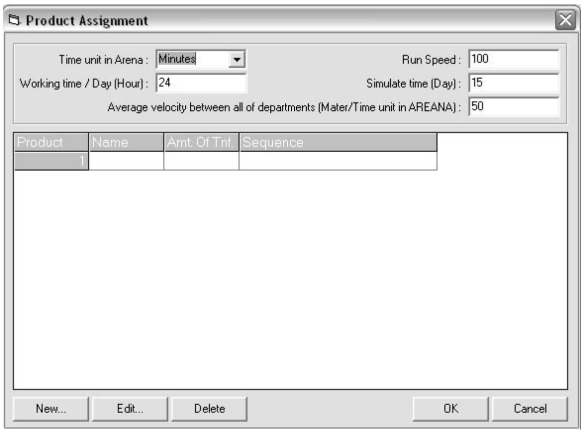
- Initial Facility Layout Window

This window asks for an area of each department, information of each department, and a location of each department in the plant.



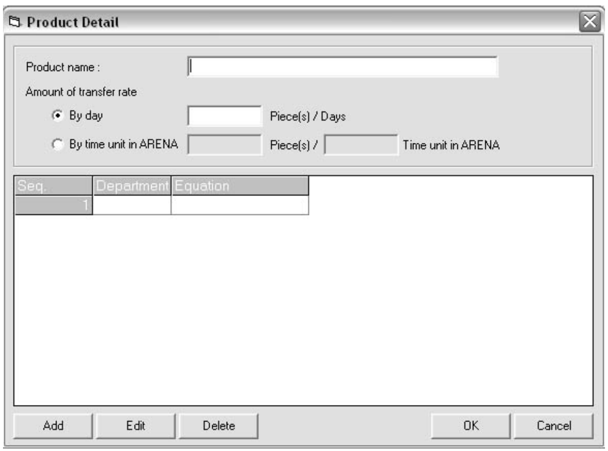
- Product Assignment Window

This window asks for a number of products, production amount of each product and a sequence of department that each product need to be passed.



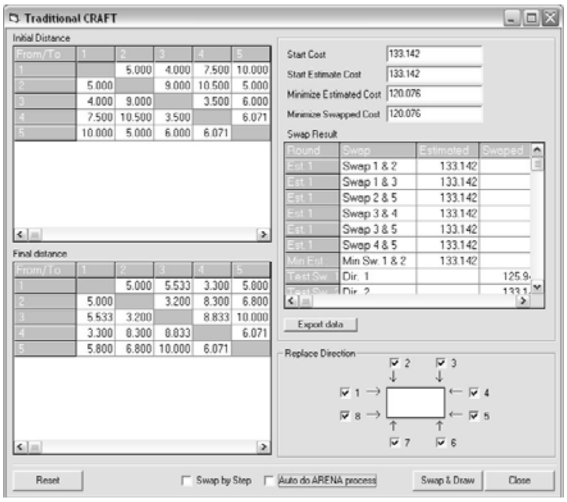
- Product Detail Window

This window asks for a production transfer rate of each product through all department in the plant and a production time at each department.



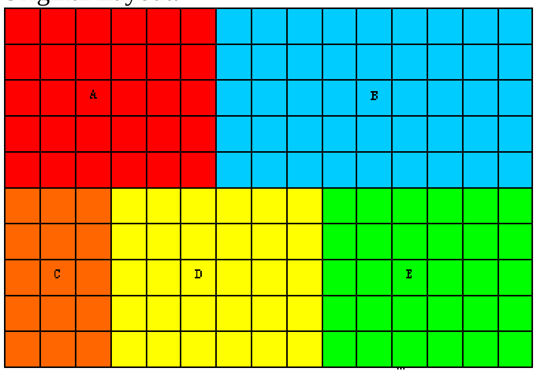
- Calculated Facility Layout Window

This window create a From-To chart of all departments and calculate a total transfer cost for the original plant layout and all the possible swap of each department. After the calculation, all swap results are listed.

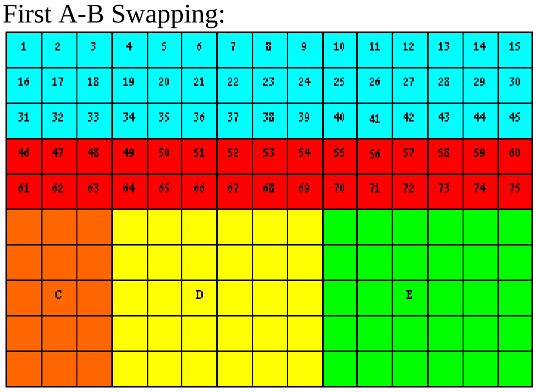


For swapping one department with another department, there are 8 swaps that are needed to be done. Examples of a swap between Department A and Department B are shown below.

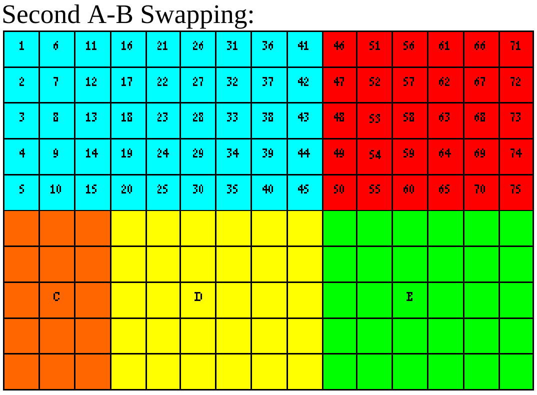
Original Layout:



First A-B Swapping:



Second A-B Swapping:



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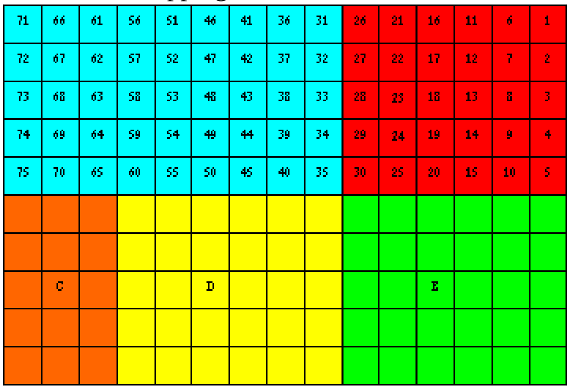
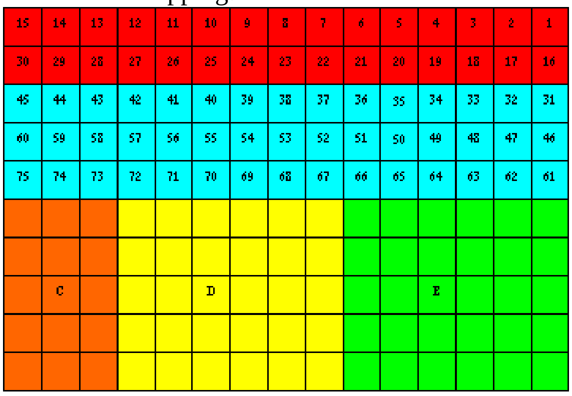
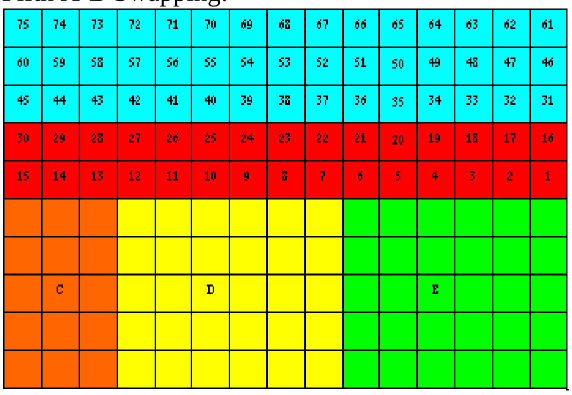
Third A-B Swapping:



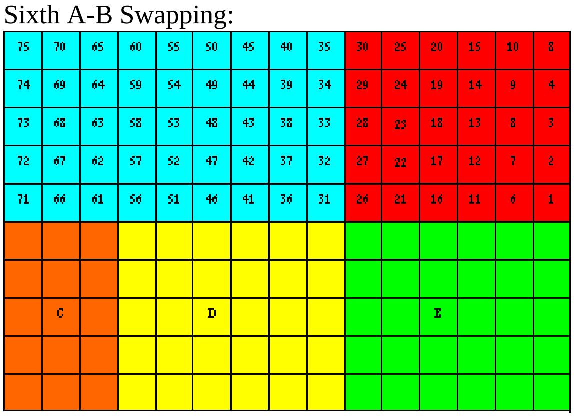
Forth A-B Swapping:



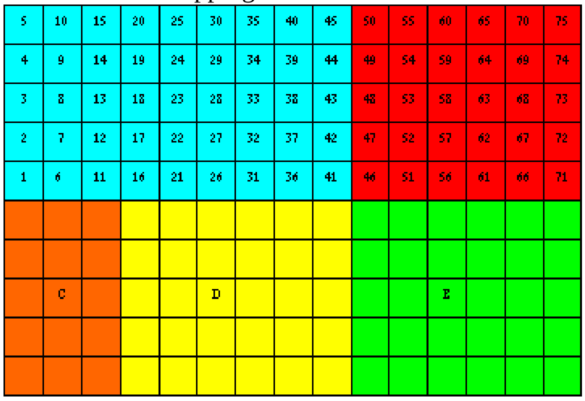
Fifth A-B Swapping:



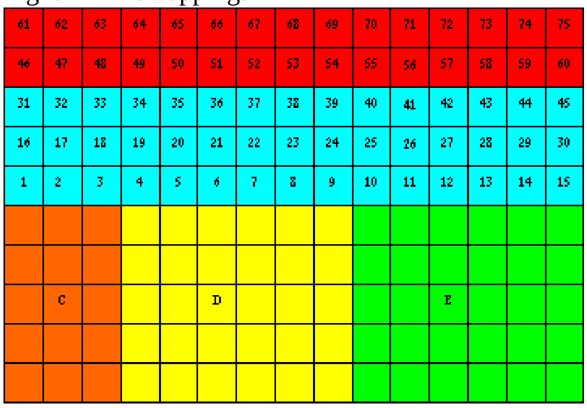
Sixth A-B Swapping:



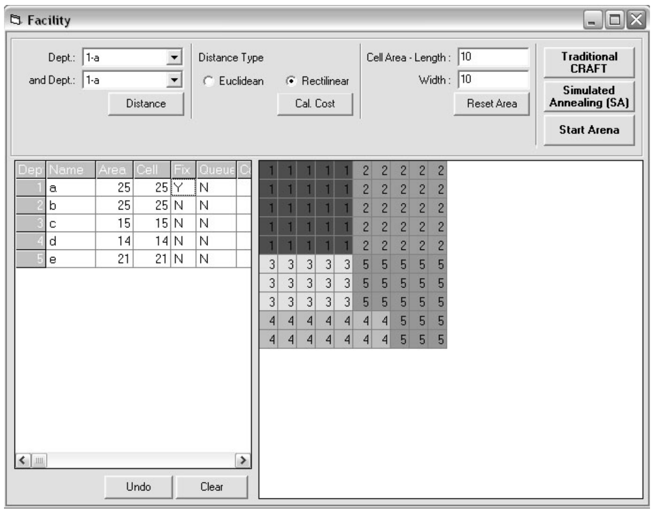
Seventh A-B Swapping:



Eighth A-B Swapping:



Finally, after the calculation, the layout which minimizes a total transfer cost is displayed.

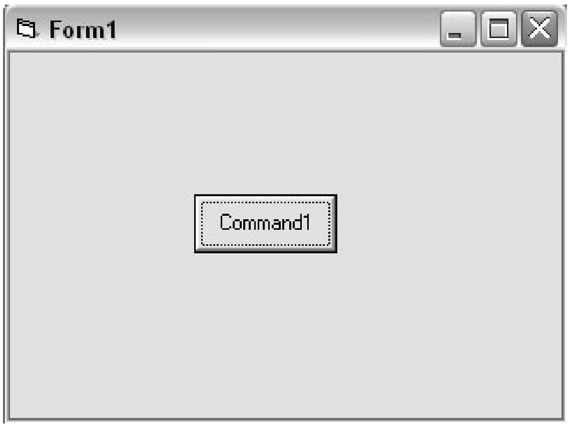


VI. PLANT LAYOUT SIMULATION MODULE

After the best plant layout design is viewed, the simulation model is used to calculate production information such as total time, waiting time and department utilization.

- Arena Starting Button

The simulation model is started by clicking the Start Arena button. This button links between Microsoft Visual Basic and Arena.



This button passed commands that will use to create a flow chart of simulation model and passed all input information to define a value of simulation model from Microsoft Visual Basic to Arena. Example of commands is shown below.

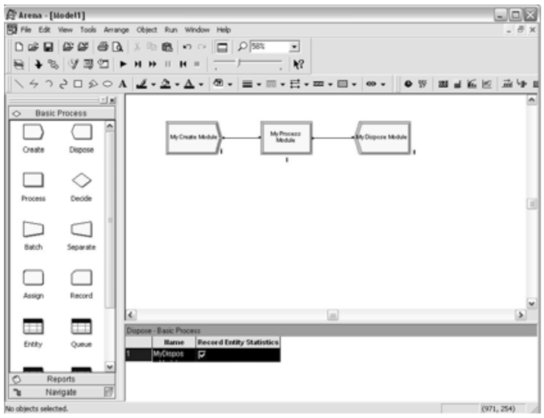
```
Private Sub Command1_Click()
Dim arenaApp As Arena.Application
Dim arenaModel As Arena.Model
Set arenaApp = CreateObject("Arena.application")
Set arenaModel = arenaApp.Models.Add
Dim createmod As Arena.Module
Dim procmod As Arena.Module
Dim disposmod As Arena.Module

Set createmod = arenaModel.Modules.Create
("BasicProcess", "Create", 0, 100)
    createmod.Data("Name") = "MyCreate Module"
    createmod.Data("Value") = "3"
    createmod.Data("Units") = "Minutes"
Set procmod = arenaModel.Modules.Create
("BasicProcess", "Process", 1000, 100)
    procmod.Data("Name") = "MyProcess Module"
    procmod.Data("DelayType") = "Normal"
    procmod.Data("Value") = "10"
    procmod.Data("StDev") = "2"
    procmod.Data("Units") = "Minutes"
Set disposmod = arenaModel.Modules.Create
("BasicProcess", "Dispose", 2000, 100)
    disposmod.Data("Name") = "MyDispose Module"
    createmod.UpdateShapes
    procmod.UpdateShapes
    disposmod.UpdateShapes
 End Sub
 Private Sub Form_Load()
 End Sub
```

By this code, there is no need to learn how to program simulation model. The code from the design module will create simulation model automatically.

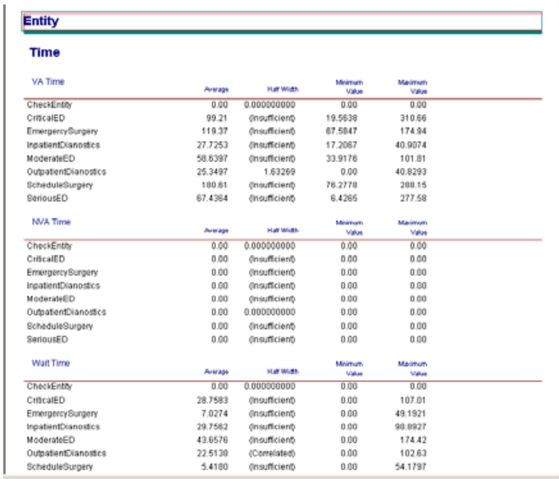
- Arena Flow Chart

From the Arena Starting Button, an Arena flow chart that will use to calculate production time is created like the following figure.



- Arena Report

After the simulation flow chart is developed, the simulation is run automatically and the report is created.



Entity

Time

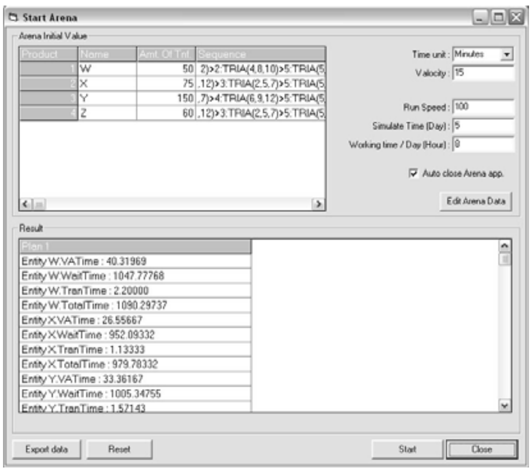
VA Time	Average	Half Width	Minimum Value	Maximum Value
CheckEntity	0.00	0.000000000	0.00	0.00
CriticalED	99.21	(Insufficient)	19.5638	310.66
EmergencySurgery	119.37	(Insufficient)	67.5847	174.94
InpatientDianostics	27.7253	(Insufficient)	17.2067	40.9074
ModerateED	58.6397	(Insufficient)	33.9176	101.81
OutpatientDianostics	25.3497	1.63269	0.00	40.8293
ScheduleSurgery	180.61	(Insufficient)	76.2778	288.15
SeriousED	67.4364	(Insufficient)	6.4265	277.58

NVA Time	Average	Half Width	Minimum Value	Maximum Value
CheckEntity	0.00	0.000000000	0.00	0.00
CriticalED	0.00	(Insufficient)	0.00	0.00
EmergencySurgery	0.00	(Insufficient)	0.00	0.00
InpatientDianostics	0.00	(Insufficient)	0.00	0.00
ModerateED	0.00	(Insufficient)	0.00	0.00
OutpatientDianostics	0.00	0.000000000	0.00	0.00
ScheduleSurgery	0.00	(Insufficient)	0.00	0.00
SeriousED	0.00	(Insufficient)	0.00	0.00

Wait Time	Average	Half Width	Minimum Value	Maximum Value
CheckEntity	0.00	0.000000000	0.00	0.00
CriticalED	28.7583	(Insufficient)	0.00	107.01
EmergencySurgery	7.0274	(Insufficient)	0.00	49.1921
InpatientDianostics	29.7562	(Insufficient)	0.00	98.8927
ModerateED	43.6576	(Insufficient)	0.00	174.42
OutpatientDianostics	22.5138	(Correlated)	0.00	102.63
ScheduleSurgery	5.4180	(Insufficient)	0.00	54.1797

VII. VB REPORT MODULE

From Arena report, there are so many outputs shown. As a result, Microsoft Visual Basic report is used for getting back important results from Arena to show in VB report. Along with this link, there is no need for users to learn simulation to get the answers. All information is created directly.



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