Manufacturing System Analysis Experiment

Basic Factory Dynamics (1)

1. Experiment Overview

■ Title

Verification of Little's Law through manufacturing system simulation modeling

■ Objective

- Understand the Little's Law and realize the fundamentals of manufacturing system
- Create a simple manufacturing system model using ARENA, and verify the Little's Law by executing the simulation with environmental changes
- Discuss domain in which the little's law can be applied besides the manufacturing system

2. Theoretical Background

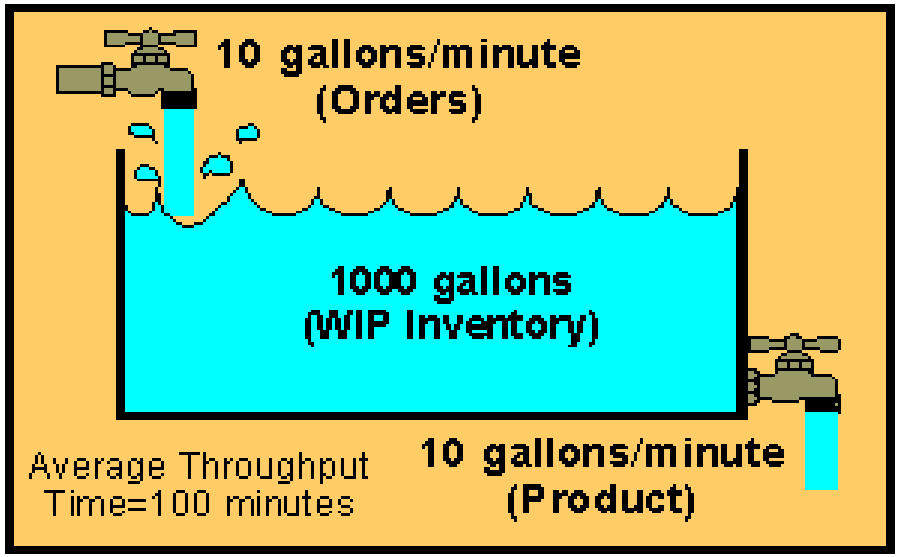
■ Basic Terminology

- **Workstations**: Collection of one or more machines or manual station that perform identical function
- **Part**: A piece of raw material, a component, a subassembly or an assembly worked on at the workstation in a plant
- **Routing**: The sequence of workstations passed through by a part
- **Capacity**: An upper limit on the throughput of a production process
- **Throughput(TH)**: The average output of a production process per unit time
- **Work in process(WIP)**: The inventory between the start and end points of a product routing
- **Cycle Time(CT)**: The average time from release of a job at the beginning of the routing until it reaches an inventory point at the end of the routing
- **Utilization**: The fraction of time workstation is not idle for lack of parts

2. Theoretical Background

■ Little's Law

- Work in process (WIP) = Throughput (TH) X Cycle Time (CT)



Source: http://www.strategosinc.com/littles_law.htm

3. Experiment Design

Yonsei Co. has the sequential manufacturing system consists of 4 workstations. Each machine carries out 1 job at a time and has infinite buffer in front. Also, detailed information of each machine is shown below.

	Workstation 1	Workstation 2	Workstation 3	Workstation 4
# of machine (resource capacity)	5	12	1	4
Processing time	15 min/job	30 min/job	3 min/job	10 min/job

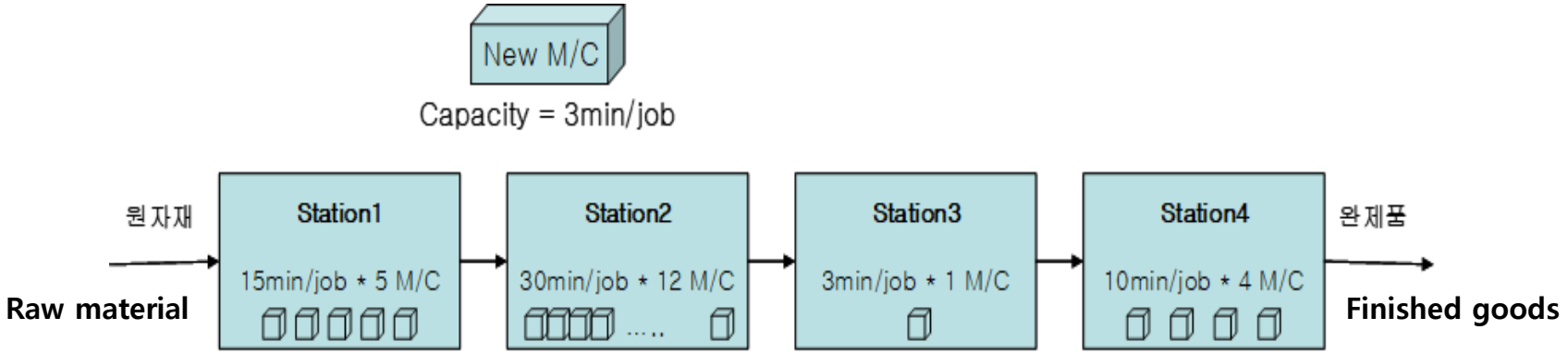
<Table 1> Workstation information of Yonsei Co. manufacturing system

Company plans to buy an additional machine ("New machine") with average processing time of 3 min/job. This machine can be placed into any places. Observe the changes throughout the system with different raw material input rates when the "New machine" is installed, and verify the Little's Law.

3. Experiment Design

Yonsei Co. has the four sequential process, and number of each workstation and capacity is shown in <Figure 1>. We will collect the statistic values TH, WIP, and CT for the system.

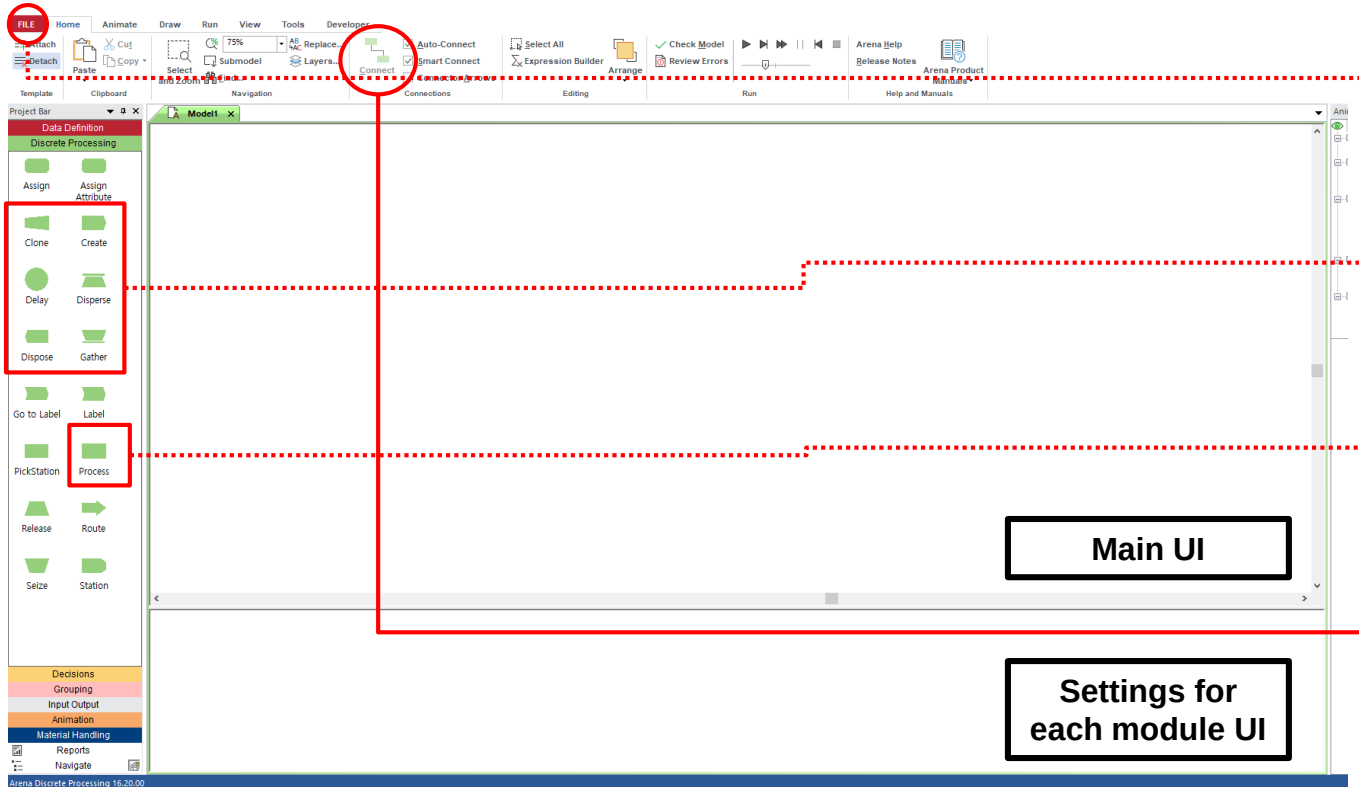
We will run the simulation for 1000 minutes, and set the warm-up time as 100 minutes for system stabilization and accuracy.



<Figure 1> Manufacturing system of Yonsei Co.

4. Experimental Procedure

■ Basic Information



1 New: Create new model

2 Create/Dispose: Start and end of simulation configuration

3 Process: process comprising the production system

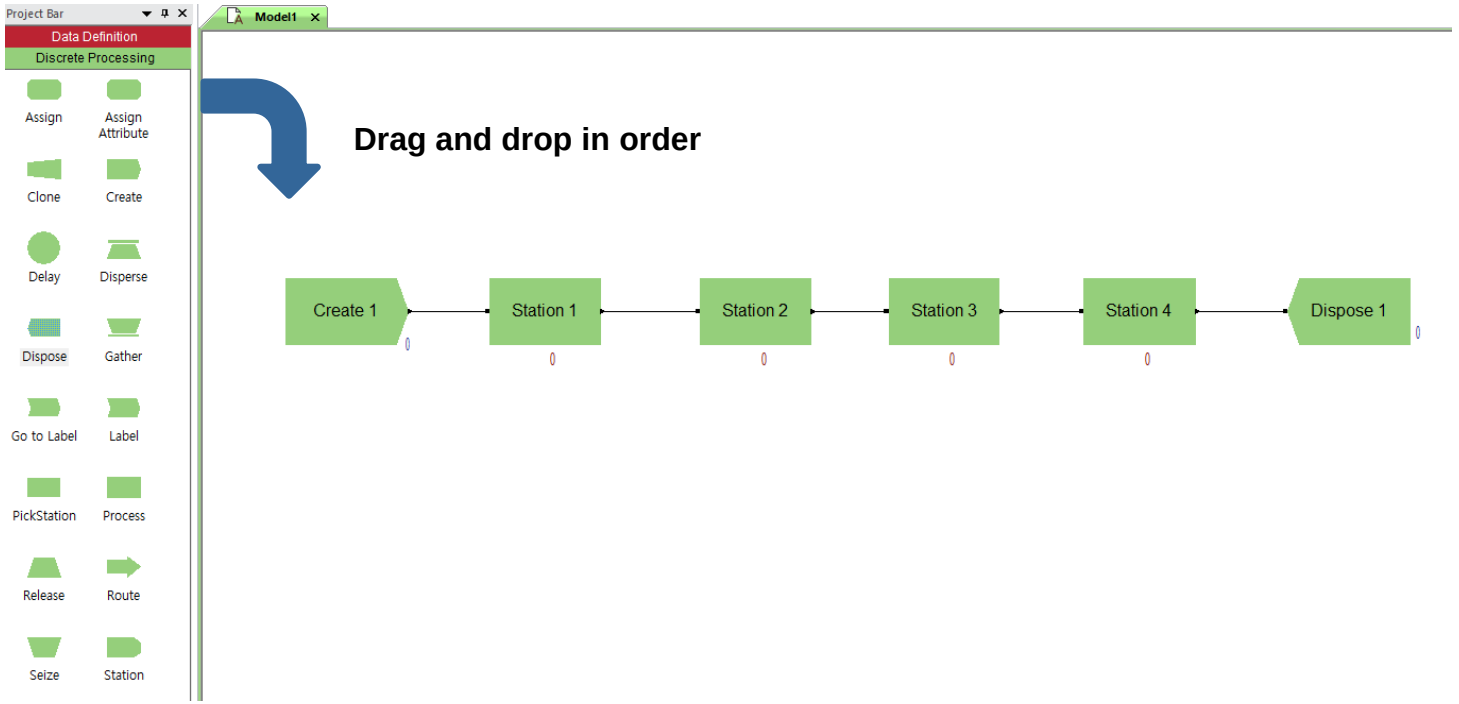
4 Connect: connect between modules

(or Object → Auto-connect)

4. Experimental Procedure

■ Step 1. Create basic simulation model & resources

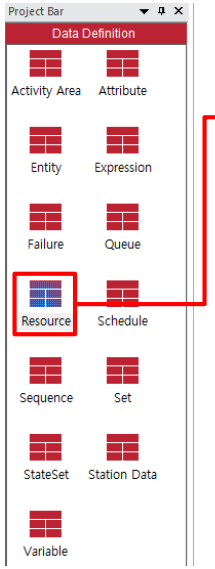
- Drag and place the modules (one Create, four Process, one Dispose) from basic process in the Main UI for the basic simulation model
- Check Auto-Connect (Object tab → Auto-Connect), and connect line between modules automatically appear



4. Experimental Procedure

■ Step 1-1. Create basic simulation model & resources (cont')

- Click the Resource icon from Basic Process Panel and add Resource by double clicking settings for each modules UI
- Set the Name (Station ID) and Capacity (# of Machine) for each Resource (=Machine) from the manufacturing system
- Create "New Machine" Resource now for later



	Name	Type	Capacity	Busy / Hour	Idle / Hour	Per Use	StateSet Name	Failures	Report Statistics	Comment
1	MC1	Fixed Capacity	5	0.0	0.0	0.0		0 rows	☑	
2	MC2	Fixed Capacity	12	0.0	0.0	0.0		0 rows	☑	
3	MC3	Fixed Capacity	1	0.0	0.0	0.0		0 rows	☑	
4	MC4	Fixed Capacity	4	0.0	0.0	0.0		0 rows	☑	
5 ▶	New MC	Fixed Capacity	1	0.0	0.0	0.0		0 rows	☑	

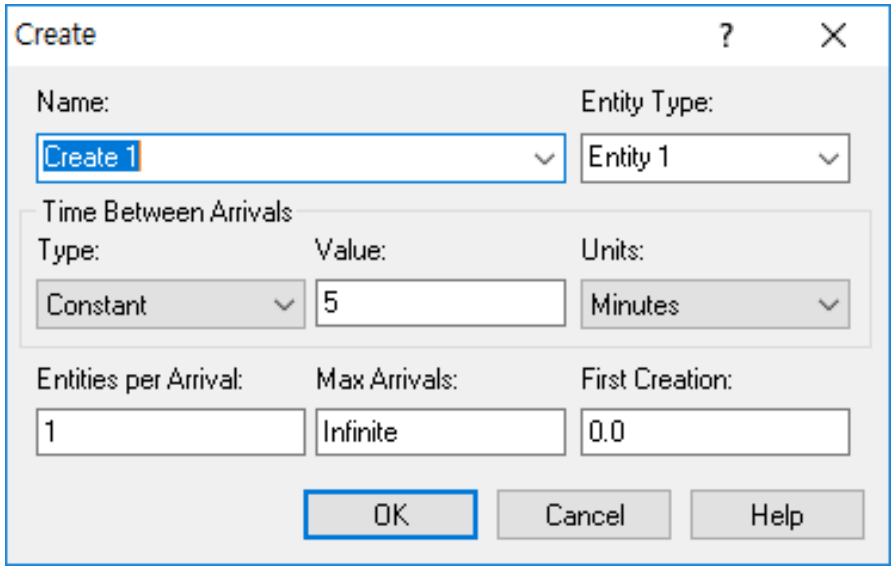
※ Capacity data → reference Table 1 from Slide 5

	Workstation 1	Workstation 2	Workstation 3	Workstation 4
# of machine (resource capacity)	5	12	1	4
Processing time	15 min/job	30 min/job	3 min/job	10 min/job

4. Experimental Procedure

■ Step 1-2. Create module (double click Create module)

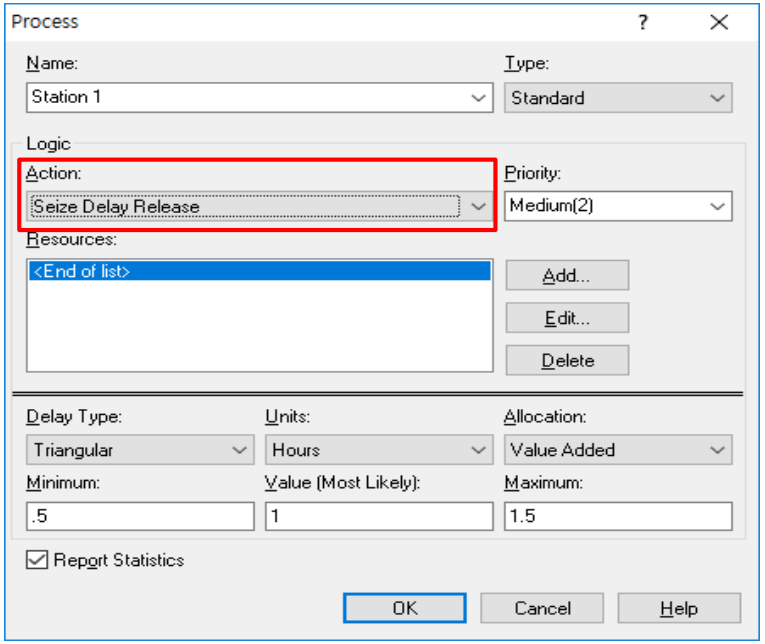
- Create module creates the entity going into the manufacturing system
- Leave the Entity Type since Entity going into the manufacturing system of Yonsei Co. is only one
- Time Between Arrivals sets the input rate of the entity
- Leave the value as shown below, we will proceed the experiments by changing this value



4. Experimental Procedure

■ Step 1-3. Process module (double click Process module)

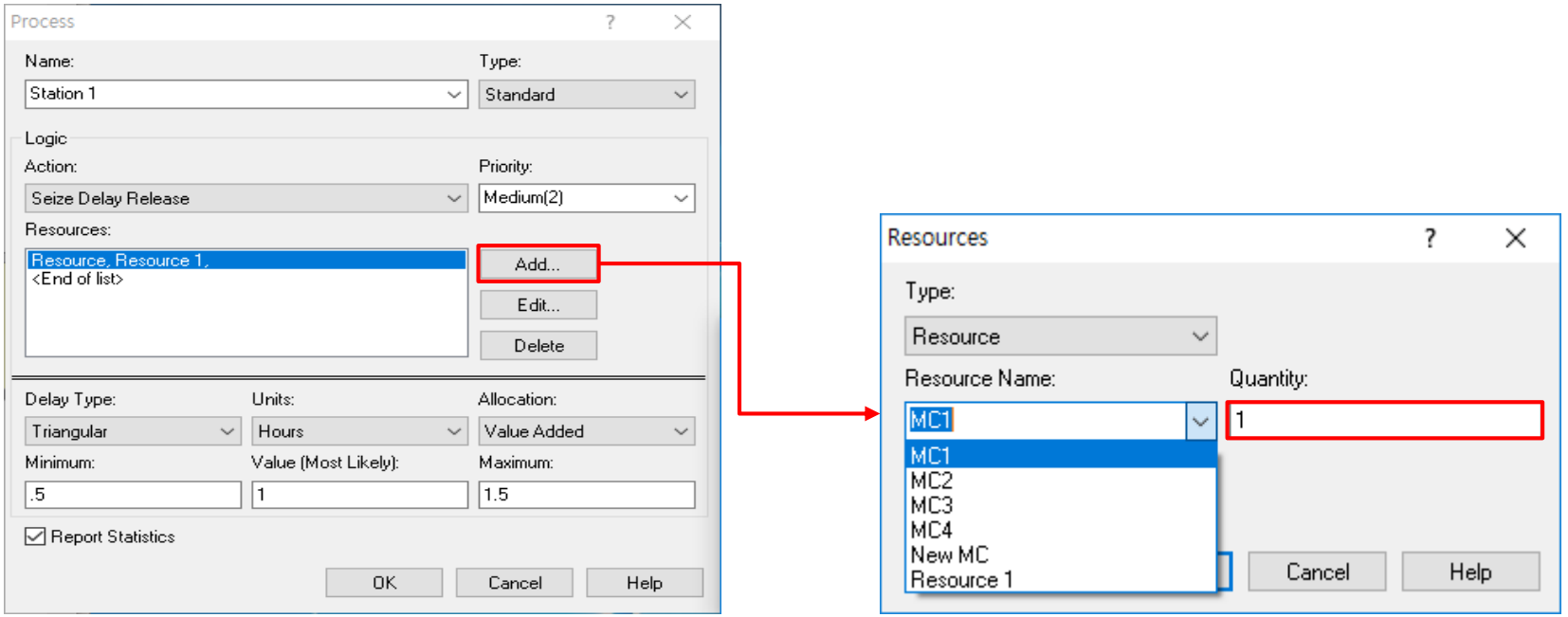
- Process module sets up the processing logic of the station and processing time (Delay for entity)
- Set Action under Logic as "Seize Delay Release"
- For this case, Entity seizes the resource and delays as long as the processing time, then releases to the next step and becomes idle



4. Experimental Procedure

■ Step 1-3. Process module (cont')

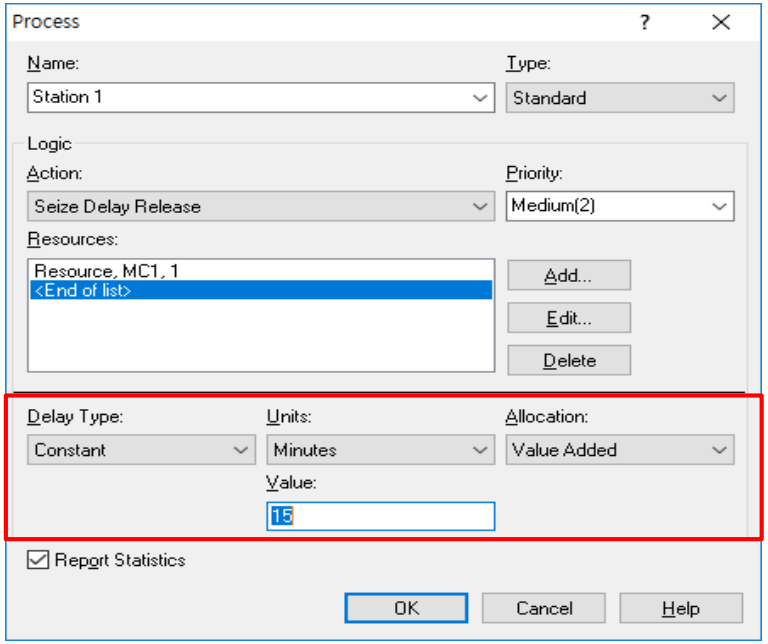
- After setting up the Action for Logic, then click 'Add' to set up the resource
- Allocate a Resource (previously set in Resource Basic Process) to the Process, set quantity as 1 since one entity occupies one machine



4. Experimental Procedure

■ Step 1-3. Process module (cont')

- Set the information about the delay after allocating the resource
- Delay shows how long Resource occupies the entity (=processing time of the resource or machine)
- For example, in case of Station 1, processing time of Machine 1 is 15 min/job, so set it as constant, 15 and change for other stations using the same method



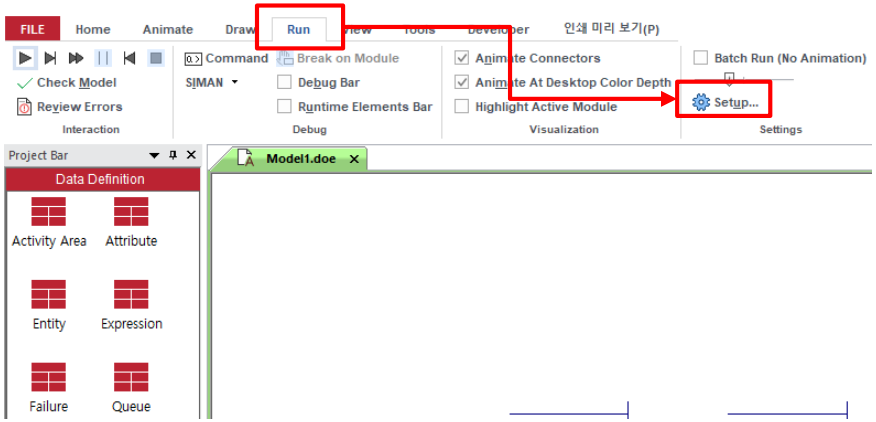
※ Processing time → reference Table 1 from Slide 5

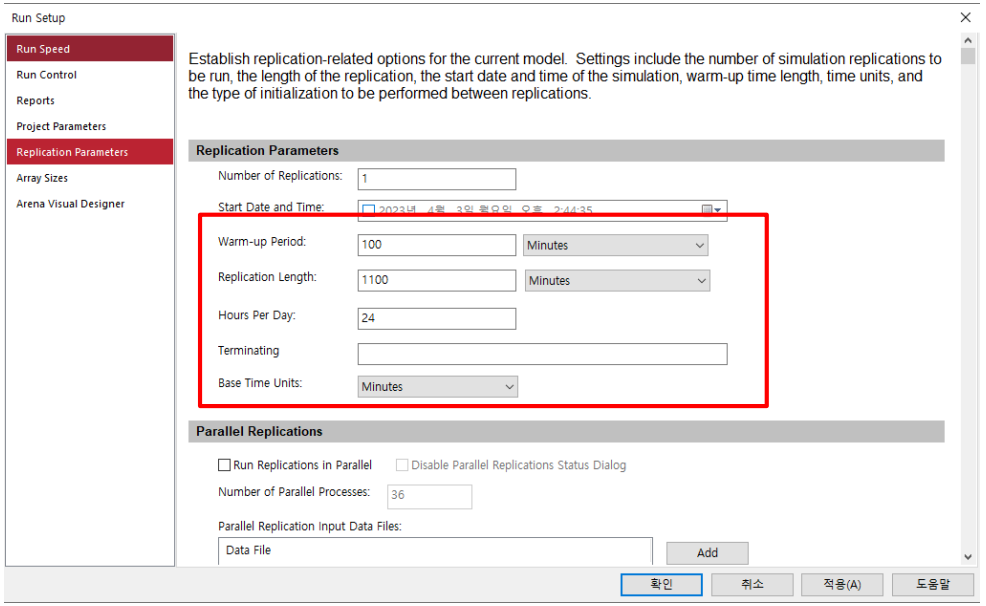
	Workstation 1	Workstation 2	Workstation 3	Workstation 4
# of machine (resource capacity)	5	12	1	4
Processing time	15 min/job	30 min/job	3 min/job	10 min/job

4. Experimental Procedure

■ Step 1-4. Run Setup

- Set the total experiment length as 1100 minutes with 100 minutes of warm-up period for system stabilization and 1000 minutes of actual experiment length (Run Tab → Setup → Replication parameters)
- Bottleneck of the current manufacturing system is station 3, and for the future experiment purpose, we will change the Input rate in Create module and verify the Little's law (included in lab report)

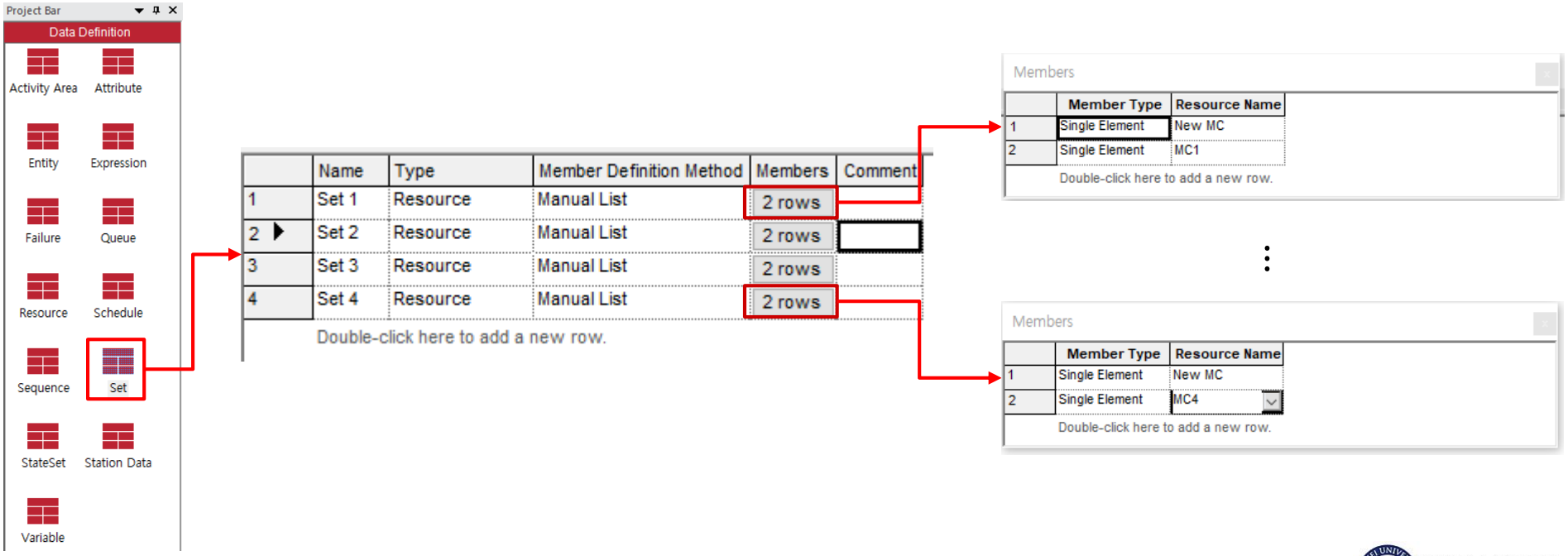




4. Experimental Procedure (2: additional machine case)

■ Step 2-1. Basic settings for the additional machine case

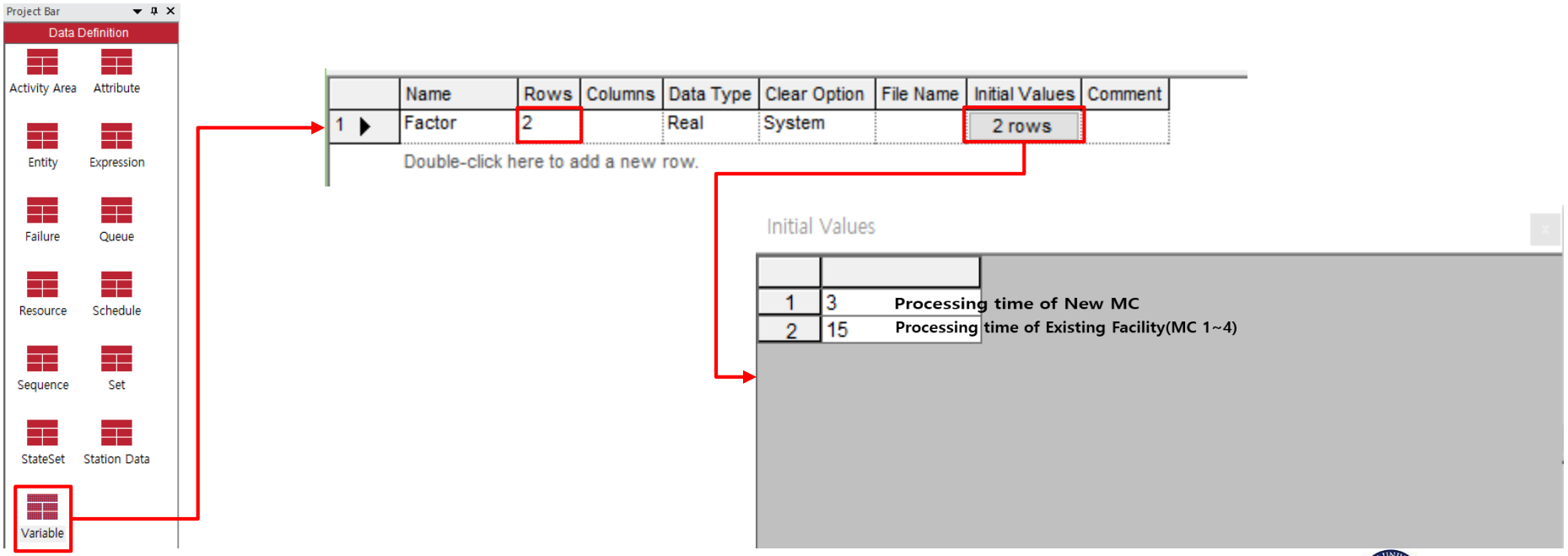
- Define each set by combining the existing equipment and new equipment (New MC). (Set: a set of resources available to each process module)
- Add the existing machine and the new machine as members to the set for each process.
- Click the Set icon in the Basic Process Panel, and Double-click the Settings for each module UI area to add a set.



4. Experimental Procedure (2: additional machine case)

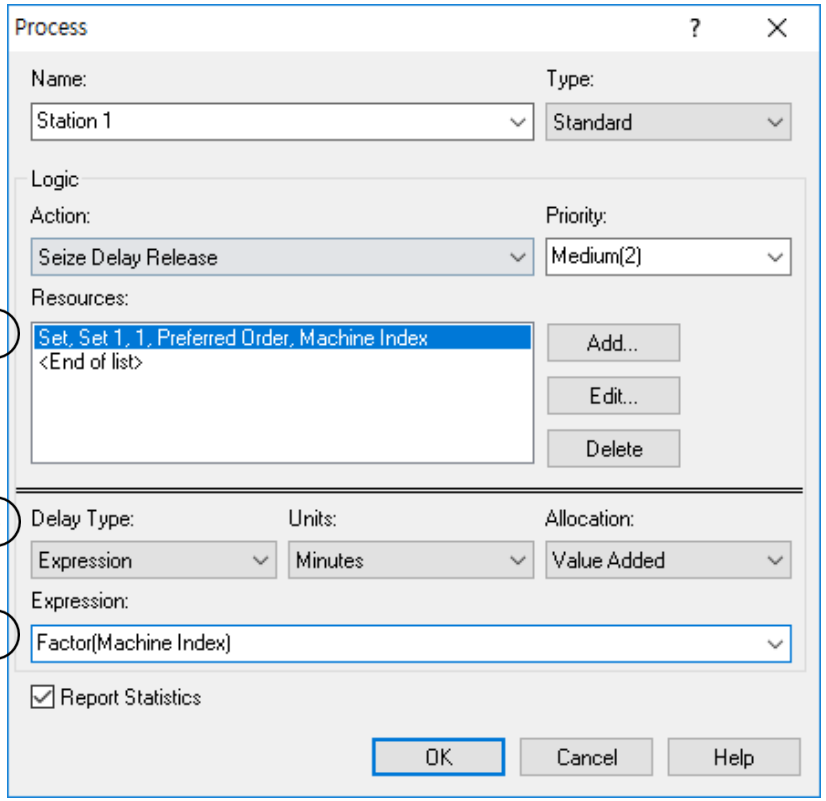
■ Step 2-2. Variable settings

- Change the processing time depending on whether it is the existing machine or the new machine.
- Define the variable to apply the delay time of each process module.
- Click the Variable icon in Basic Process Panel, and double-click the Settings for each module UI area to define the variable. (Variable Name: **Factor)**
- Set the variable 4 different times for each set to determine which place to add the new workstation

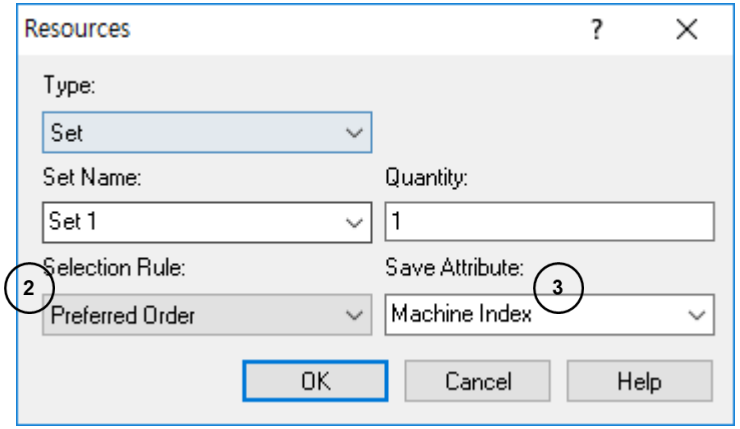


4. Experimental Procedure (2: additional machine case)

- **Step 2-3. Set up the addition of New MC for all four workstations**
  - Conduct a total of four experiments with four different settings (repeat the step 2-2 and step 2-3) to analyze the effect of the location where the new machine should be added. (figure below is for Workstation 1)



①	**Double-click process module→ Edit → Type : choose Set → Set name : choose Set 1**
②	**Selection Rule : Change to Preferred Order**
③	**Save Attribute : Type "Machine Index"**
④	**Delay Type : Constant → Change to Expression**
⑤	**Expression : Type "Factor(Machine Index)"**



4. Experimental Procedure (2: additional machine case)

■ Step Additional explanation for step 2-3

- Preferred Order: selecting the first (=lowest-numbered) available resource in the set
  → If the order for set members in Step 2-1 were set in order of New MC and MC1, then NEW MC is selected first and proceed with the process.
- Let's go back to Step 2-1 and see if we wrote down New MC first when defining set members for each set
  → Since New MC has better performance (processing time) than all of the existing machines, it should always be given the priority in every set.
- Save Attribute: save the number of selected members in the Set to the machine index
- Expression: stored value will enter to input value for "Factor(Machine Index)"
  → Corresponding value to machine index from the Initial value matrix for Factor in Step 2-2 operate as Delay time.

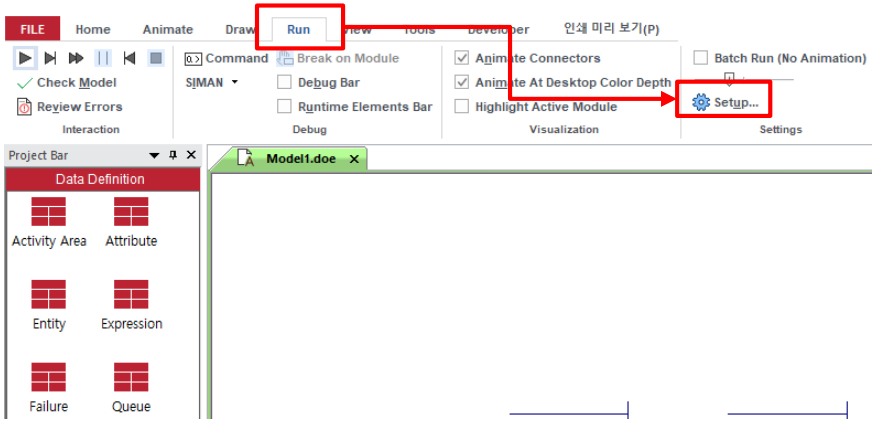
Machine Index	Factor(Machine Index)	Output
1	Factor(1)	3
2	Factor(2)	15

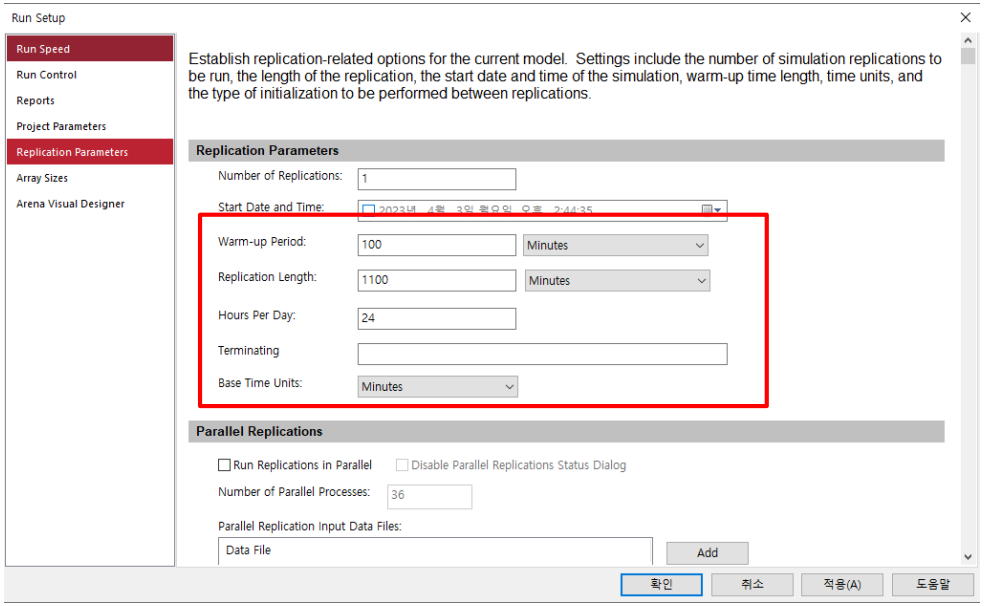
※ Example of experiment 1 (Set 1)

4. Experimental Procedure (2: additional machine case)

■ Step 2-4. Run Setup (same as Step 1-4)

- Set Warm-up time as 100 minutes, actual experiment time as 1000 minutes, total experiment time as 1100 minutes for system stabilization. (Run Tab → Setup → Replication parameters)
- For future experiments, verify the Little's Law while changing the Input rate in the Create Module.





Q & A