# Manufacturing System Analysis Experiment

Variability

# 1. Experiment Overview

- Title

**Understanding of variability basic concept**

- Objective
  - Understand the effects of the process time variability (availability & setup) on jobs
  - Observe the changes in variability from different parameter values using ARENA simulation

# 2. Theoretical Background

- Coefficient of Variation (CV)
  - $c_0 = \frac{\sigma_0}{t_0}\,(t_0\colon base\ process\ mean\ time)$

- Availability
  - $A = \frac{m_f}{m_f+m_r}\ (m_f\ \colon mean\ time\ between\ failures, m_f\ \colon mean\ time\ to\ repair)$

# 2. Theoretical Background

- Variability from breakdown
  - $t_e = \frac{t_0}{A} \quad (t_e : mean\ process\ time\ of\ a\ job)$
  - $\sigma_e^2 = \frac{\sigma_0^2}{A^2} + \frac{(m_r^2+\sigma_0^2)(1-A)t_0}{Am_r},\ c_r = \frac{\sigma_r}{m_r}$
  - $c_e^2 = c_0^2 + \frac{(1+c_r^2)A(1-A)m_r}{t_0}$

➢ Decreasing MTTF (Mean Time To Failure) and MTTR (Mean Time To Repair) reduces the variability

# 2. Theoretical Background

- Variability from setup
  - $t_e = t_0 + \frac{t_s}{N_s}$ $(t_s : average\ setup\ time,\ N_s : average\ number\ of\ parts\ between\ setups)$
  - $\sigma_e^2 = \sigma_0^2 + \frac{\sigma_s^2}{N_s} + \frac{N_s - 1}{N_0^2} t_0^2$
  - $c_e^2 = \frac{\sigma_e^2}{t_e^2}$

➢ Decreasing setup time and cycle time reduces the variability

# 3. Experiment Design

1. Yonsei Electronics plant manager is trying to buy a new machine to replace the old machine. Each machine has the same conditions except for the few minor differences shown in the table below. Do a experiment to decide which machine is more effective.

- Variability from breakdown

|  | MTTF | MTTR |  | Process time (Constant) |
|---|---|---|---|---|
| Hare X19 | 774 minutes | 248 minutes | $Cr = 0$ | $t_0 = 15\ minutes$ |
| Tortoise 2000 | 114 minutes | 38 minutes |  |  |

- Calculate $t_e$ (effective mean process time), $\sigma_e^2$ (effective variance process time), $c_e^2$ (effective squared coefficient), and $r_e$ (effective capacity) with given equations, and calculate which machine has bigger variability.

- Based on the calculation, compare the WIP and TH and explain which machine is better.

# 3. Experiment Design

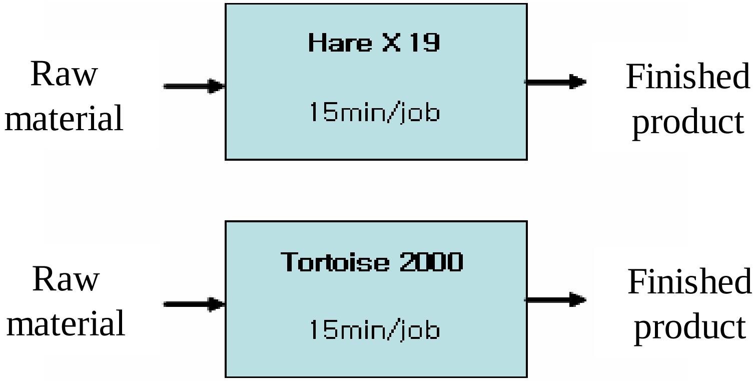
2. Under same situation, machine replacement for different production line has a machine with longer process time and no setup time, and other machine with shorter process time and setup time. Calculate the variability using the equations given like the first problem, and compare the results.

| | Process time (NORM) | | Setup |
|---|---|---|---|
| Machine 1 | $t_0$ = 1.2 hours | $\sigma = 0.25$ | - |
| Machine 2 | $t_0$ = 1.0 hours | $\sigma = 0.125$ | $N_s = 10, t_s = 2\ hours, \sigma = 0.125$ |

# 4. Experiment Procedure

## Experiment 1. Variability from breakdown

- **Step 1-1. Simulation summary**
    - Simulation consists of two systems with one machine
    - Each system has same arrival interval and processing time
    - Each system has different MTTF and MTTR
    - Statistics on WIP and TH of two systems with same availability, but different MTTR and MTTF
    - Simulation runs for one week (7 days x 24 hr/day) and is repeated 30 times

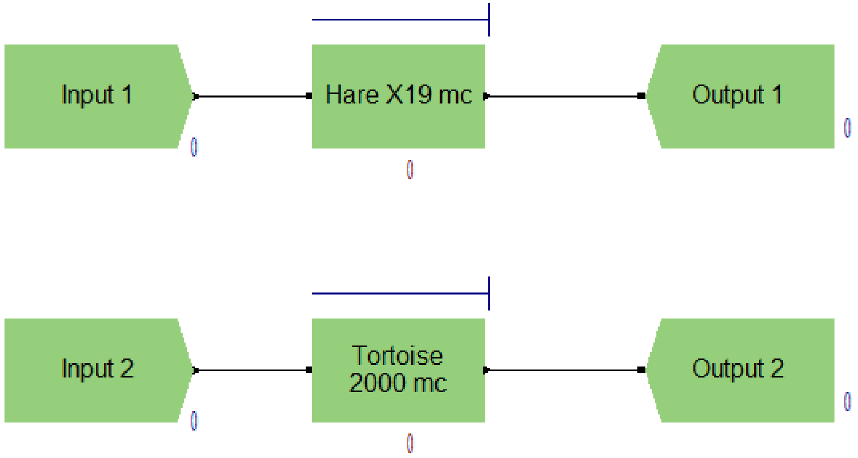


<Picture 1> Production system

# 4. Experiment Procedure

## Experiment 1. Variability from breakdown

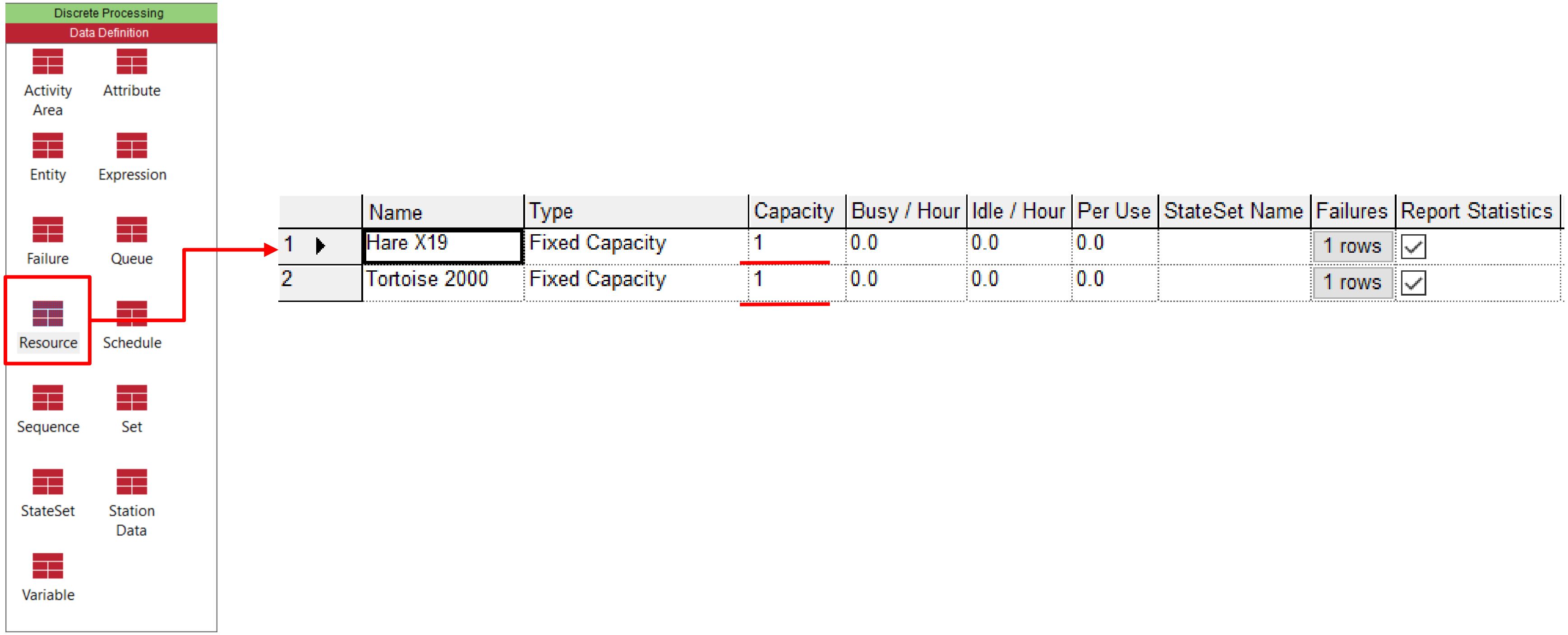
- **Step 1-2. Creating the model**
  - Basic simulation model is as the picture shown below
  - Modules used: 1 Create, 1 Process, 1 Dispose for each system



# 4. Experiment Procedure

## Experiment 1. Variability from breakdown

- **Step 1-2. Creating the model (cont.)**
  - Add resources (M/C) for each system



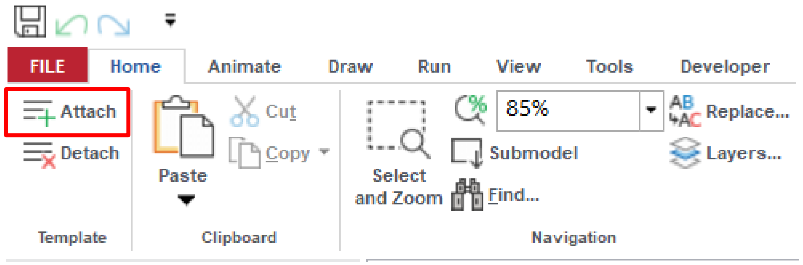
| | Name | Type | Capacity | Busy / Hour | Idle / Hour | Per Use | StateSet Name | Failures | Report Statistics |
|---|---|---|---|---|---|---|---|---|---|
| 1 ▶ | Hare X19 | Fixed Capacity | 1 | 0.0 | 0.0 | 0.0 | | 1 rows | ☑ |
| 2 | Tortoise 2000 | Fixed Capacity | 1 | 0.0 | 0.0 | 0.0 | | 1 rows | ☑ |

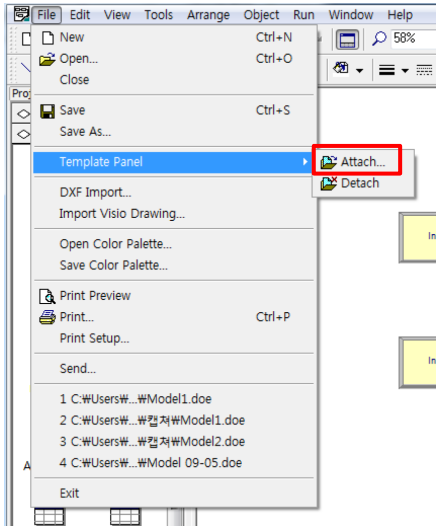
# 4. Experiment Procedure

## Experiment 1. Variability from breakdown

- **Step 1-2. Creating the model (cont.)**
  - Each resource has different Break time
  - Use Failure module from Advanced process

    - File → Template Panel → Attach, open ‘Advanced process’



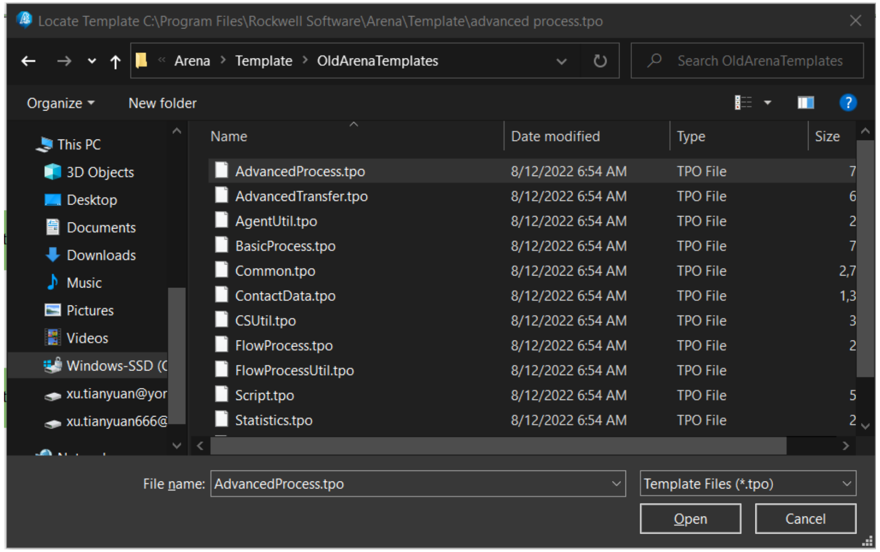


# 4. Experiment Procedure

## Experiment 1. Variability from breakdown

- **Step 1-2. Creating the model (cont.)**
  - Each resource has different Break time
  - Use Failure module from Advanced process (cont.)

    - File → Template Panel → Attach, open 'Advanced process'



Locate Template C:\Program Files\Rockwell Software\Arena\Template\advanced process.tpo

« Arena > Template > OldArenaTemplates

| Name | Date modified | Type | Size |
|---|---|---|---|
| AdvancedProcess.tpo | 8/12/2022 6:54 AM | TPO File | 7 |
| AdvancedTransfer.tpo | 8/12/2022 6:54 AM | TPO File | 6 |
| AgentUtil.tpo | 8/12/2022 6:54 AM | TPO File | 2 |
| BasicProcess.tpo | 8/12/2022 6:54 AM | TPO File | 7 |
| Common.tpo | 8/12/2022 6:54 AM | TPO File | 2,7 |
| ContactData.tpo | 8/12/2022 6:54 AM | TPO File | 1,3 |
| CSUtil.tpo | 8/12/2022 6:54 AM | TPO File | 3 |
| FlowProcess.tpo | 8/12/2022 6:54 AM | TPO File | 2 |
| FlowProcessUtil.tpo | 8/12/2022 6:54 AM | TPO File | |
| Script.tpo | 8/12/2022 6:54 AM | TPO File | 5 |
| Statistics.tpo | 8/12/2022 6:54 AM | TPO File | 2 |

File name: AdvancedProcess.tpo

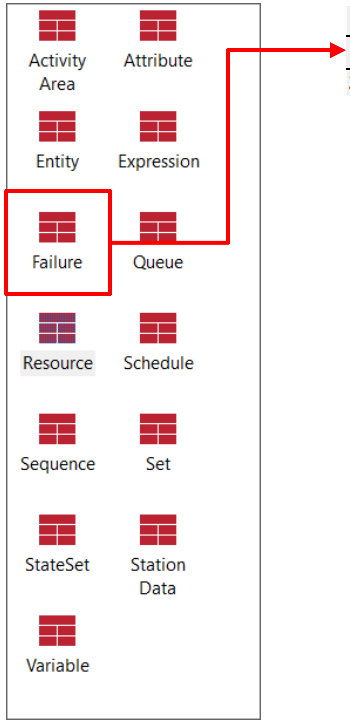
Template Files (*.tpo)

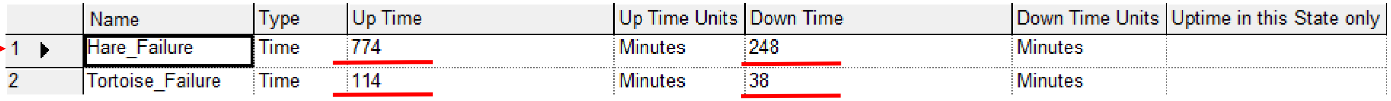
# 4. Experiment Procedure

## Experiment 1. Variability from breakdown

### ■ Step 1-2. Creating the model (cont.)

- Set MTTR and MTTF for each machine using Failure module





| | Name | Type | Up Time | Up Time Units | Down Time | Down Time Units | Uptime in this State only |
|---|---|---|---|---|---|---|---|
| 1 ▶ | Hare_Failure | Time | 774 | Minutes | 248 | Minutes | |
| 2 | Tortoise_Failure | Time | 114 | Minutes | 38 | Minutes | |

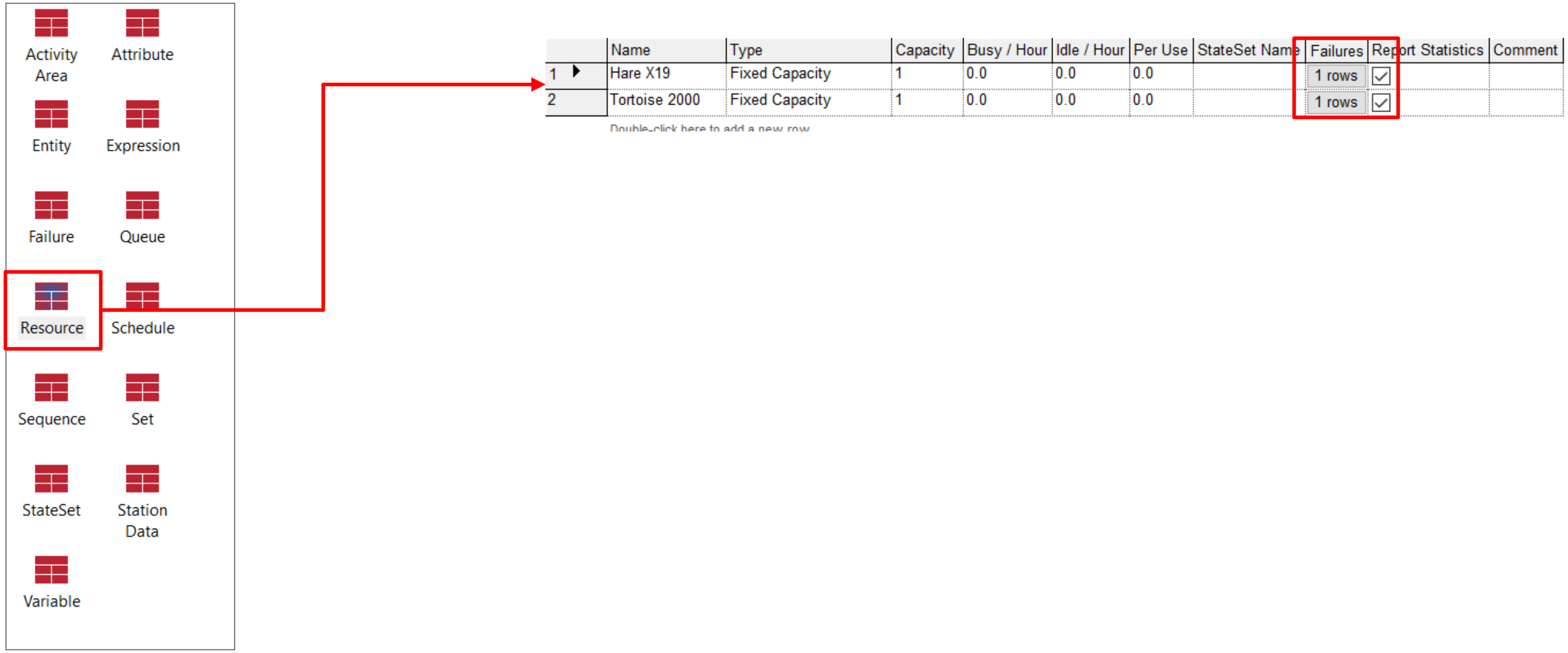
| | MTTF | MTTR |
|---|---|---|
| **Hare X19** | 774 minutes | 248 minutes |
| **Tortoise 2000** | 114 minutes | 38 minutes |

# 4. Experiment Procedure

## Experiment 1. Variability from breakdown

### ■ Step 1-2. Creating the model (cont.)

- Add failure to each resource



| | Name | Type | Capacity | Busy / Hour | Idle / Hour | Per Use | StateSet Name | Failures | Report Statistics | Comment |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 ▶ | Hare X19 | Fixed Capacity | 1 | 0.0 | 0.0 | 0.0 | | 1 rows | ☑ | |
| 2 | Tortoise 2000 | Fixed Capacity | 1 | 0.0 | 0.0 | 0.0 | | 1 rows | ☑ | |

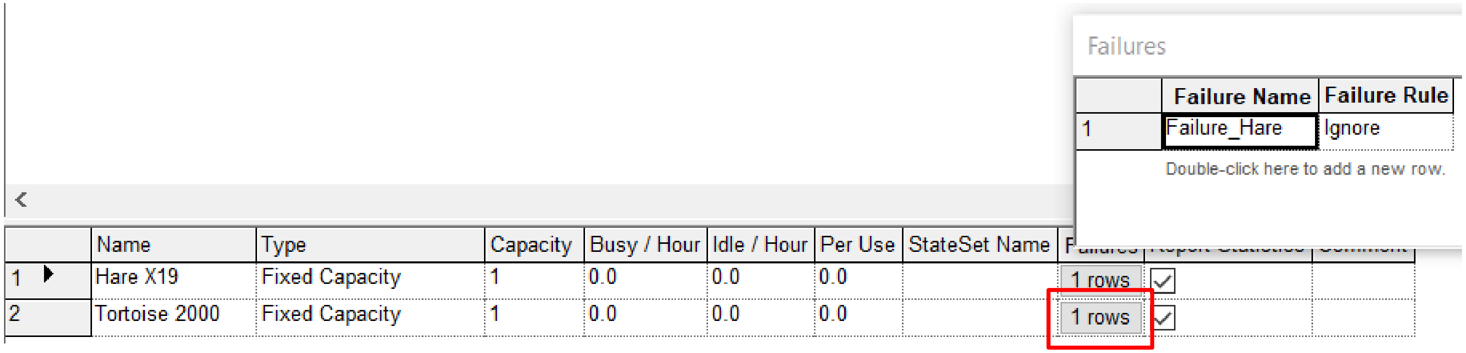
Double-click here to add a new row.

# 4. Experiment Procedure

## Experiment 1. Variability from breakdown

### ■ Step 1-2. Creating the model (cont.)

- Select failure name (already made) for each resource
- Set Failure Rule as Ignore



Failures

| | Failure Name | Failure Rule |
|---|---|---|
| 1 | Failure_Hare | Ignore |

Double-click here to add a new row.

| | Name | Type | Capacity | Busy / Hour | Idle / Hour | Per Use | StateSet Name | Failures | Report Statistics | Comment |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Hare X19 | Fixed Capacity | 1 | 0.0 | 0.0 | 0.0 | | 1 rows | ☑ | |
| 2 | Tortoise 2000 | Fixed Capacity | 1 | 0.0 | 0.0 | 0.0 | | 1 rows | ☑ | |

# 4. Experiment Procedure

## Experiment 1. Variability from breakdown

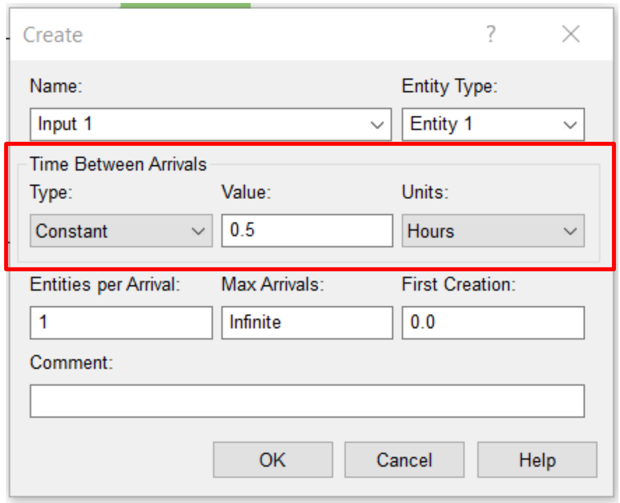
### ■ Step 1-2. Creating the model (cont.)

- Create raw material entities

  - Different entities for each system

  - Each entity will have a statistics in Arena Report

- Time between Arrivals = 0.5 hours



Name: Input 1

Entity Type: Entity 1

Time Between Arrivals

Type: Constant

Value: 0.5

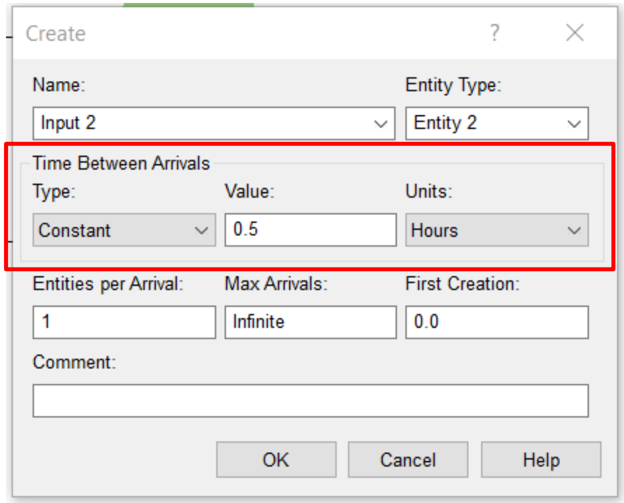
Units: Hours

Entities per Arrival: 1

Max Arrivals: Infinite

First Creation: 0.0

Comment:



Name: Input 2

Entity Type: Entity 2

Time Between Arrivals

Type: Constant

Value: 0.5

Units: Hours

Entities per Arrival: 1

Max Arrivals: Infinite

First Creation: 0.0

Comment:

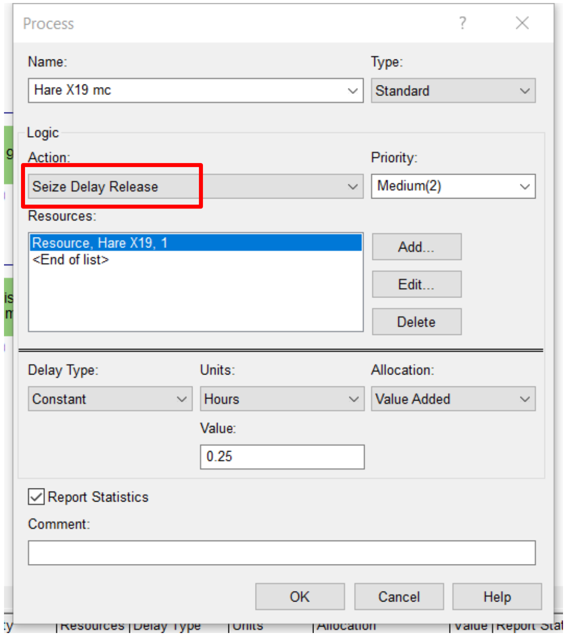
# 4. Experiment Procedure

## Experiment 1. Variability from breakdown

### ■ Step 1-2. Creating the model (cont.)

- Set action as ‘Seize Delay Release’

  = Station seize, process, and return the resource



Process

Name: Hare X19 mc

Type: Standard

Logic

Action: Seize Delay Release

Priority: Medium(2)

Resources:

Resource, Hare X19, 1
<End of list>

Delay Type: Constant

Units: Hours

Allocation: Value Added

Value: 0.25

☑ Report Statistics

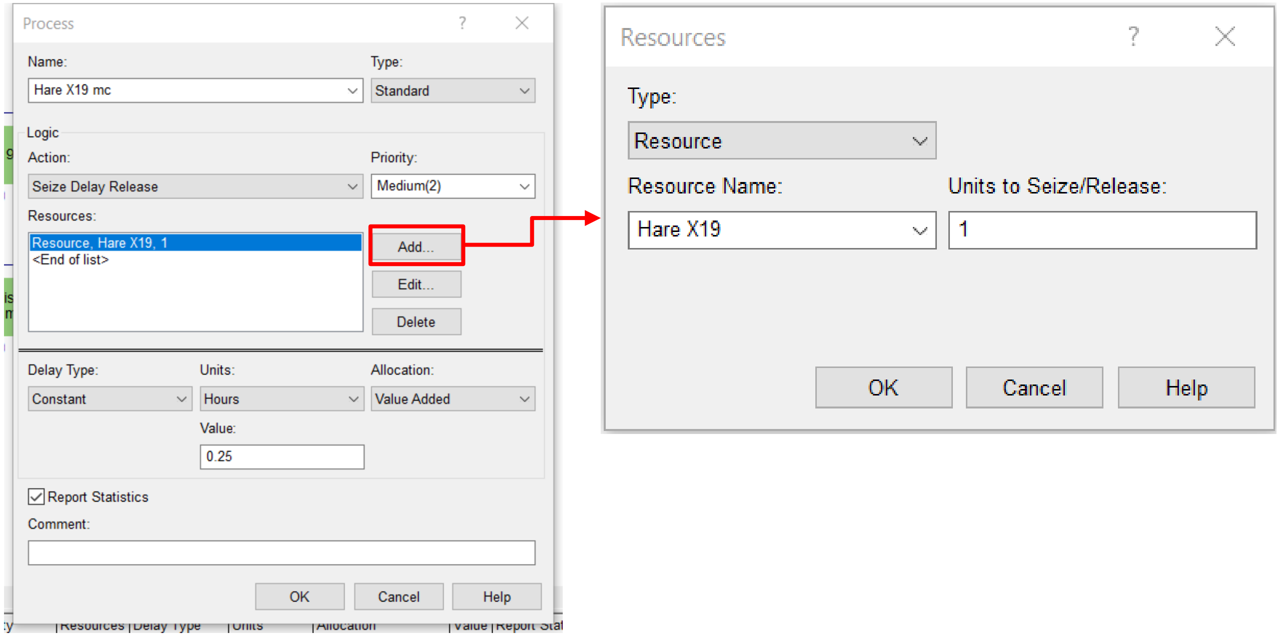
Comment:

# 4. Experiment Procedure

## Experiment 1. Variability from breakdown

### ■ Step 1-2. Creating the model (cont.)

- Use Add button to assign resources
- Quantity is the number of resource



Process

Name: Hare X19 mc

Type: Standard

Logic

Action: Seize Delay Release

Priority: Medium(2)

Resources:

Resource, Hare X19, 1
<End of list>

Delay Type: Constant

Units: Hours

Allocation: Value Added

Value: 0.25

☑ Report Statistics

Comment:

Resources

Type: Resource

Resource Name: Hare X19

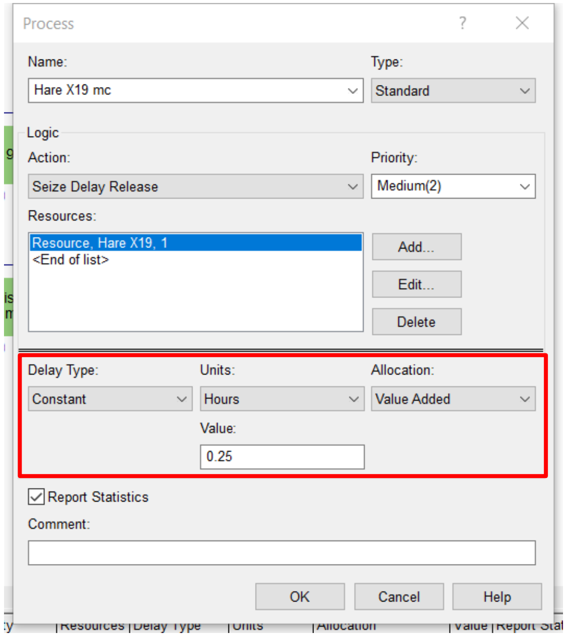
Units to Seize/Release: 1

# 4. Experiment Procedure

## Experiment 1. Variability from breakdown

### ■ Step 1-2. Creating the model (cont.)

- Delay Type decides how long a station seizes the resources (actual production time)
- Processing time for both system = 15 minutes



Process

Name: Hare X19 mc

Type: Standard

Logic

Action: Seize Delay Release

Priority: Medium(2)

Resources:

Resource, Hare X19, 1
<End of list>

Delay Type: Constant

Units: Hours

Allocation: Value Added

Value: 0.25

☑ Report Statistics

Comment:

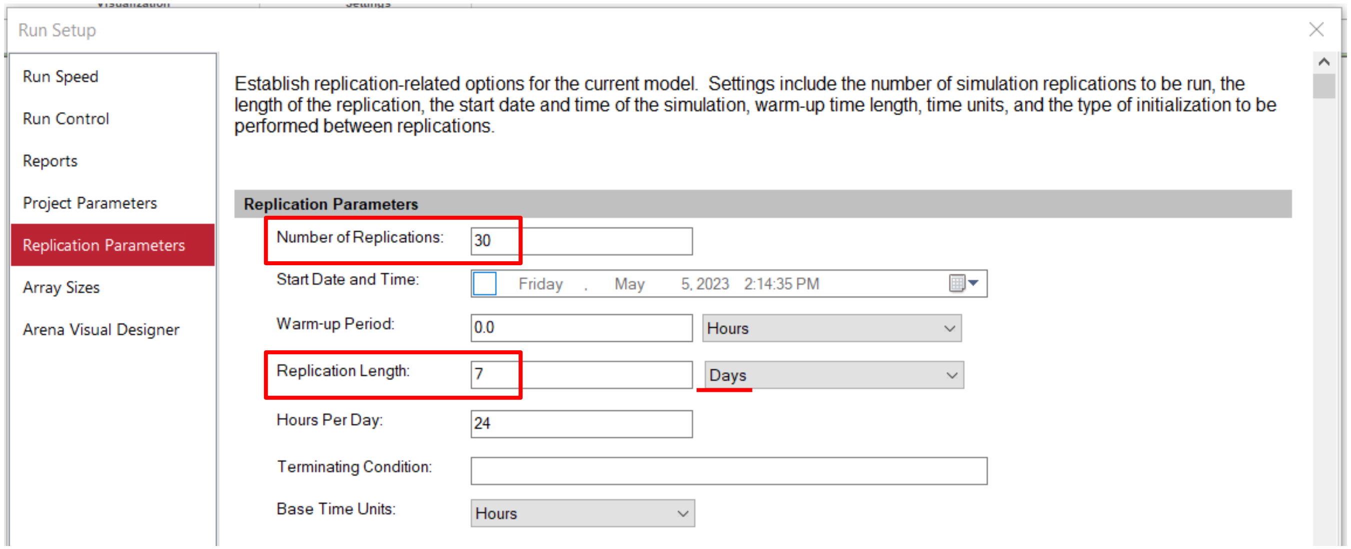
# 4. Experiment Procedure

## Experiment 1. Variability from breakdown

- **Step 2. Compare the performance of two machines**

1) Run setup (Run → Setup)

- Set up the repetitive experiment
- Replication length = 1 week (7 days), Number of replications = 30



Establish replication-related options for the current model. Settings include the number of simulation replications to be run, the length of the replication, the start date and time of the simulation, warm-up time length, time units, and the type of initialization to be performed between replications.

**Replication Parameters**

| | | |
|---|---|---|
| Number of Replications: | 30 | |
| Start Date and Time: | □ Friday , May 5, 2023 2:14:35 PM | |
| Warm-up Period: | 0.0 | Hours |
| Replication Length: | 7 | Days |
| Hours Per Day: | 24 | |
| Terminating Condition: | | |
| Base Time Units: | Hours | |

# 4. Experiment Procedure

## Experiment 1. Variability from breakdown

■ **Step 2. Compare the performance of two machines**

2) Analysis of result report

- To analyze the variability of two machines,

  - Use [$Waiting\ time \approx V \times U \times t_e$]

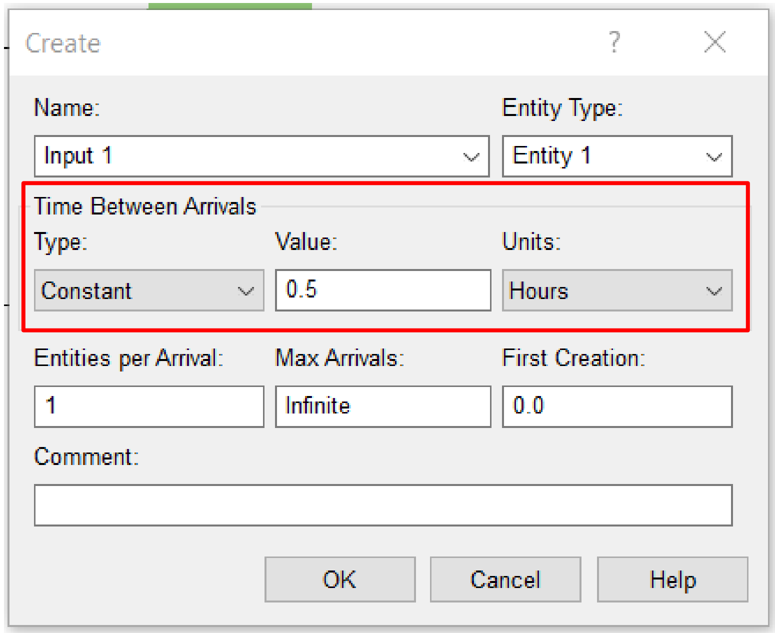
  - V = variability, U = utilization ($u/(1-u)$), $t_e$ = production time

# 4. Experiment Procedure

## Experiment 1. Variability from breakdown

### ■ Step 3. Change time intervals & analyze the performance

- Compare the performance of each system by changing time interval from Create module



Create

Name: Input 1

Entity Type: Entity 1

Time Between Arrivals

Type: Constant

Value: 0.5

Units: Hours

Entities per Arrival: 1

Max Arrivals: Infinite

First Creation: 0.0

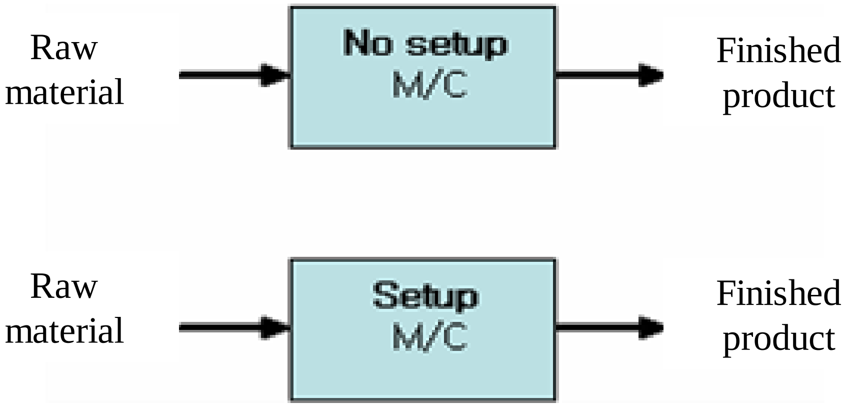
Comment:

# 4. Experiment Procedure

## Experiment 2. Variability from setup

■ **Step 1-1. Simulation summary**

- Simulation consists of a system with setup and a system without setup
- Analyzing variability of each system with one M/C
- Simulation runs for one week (7 days x 24 hr/day) and is repeated 30 times



Raw material

Finished product

Raw material

Finished product

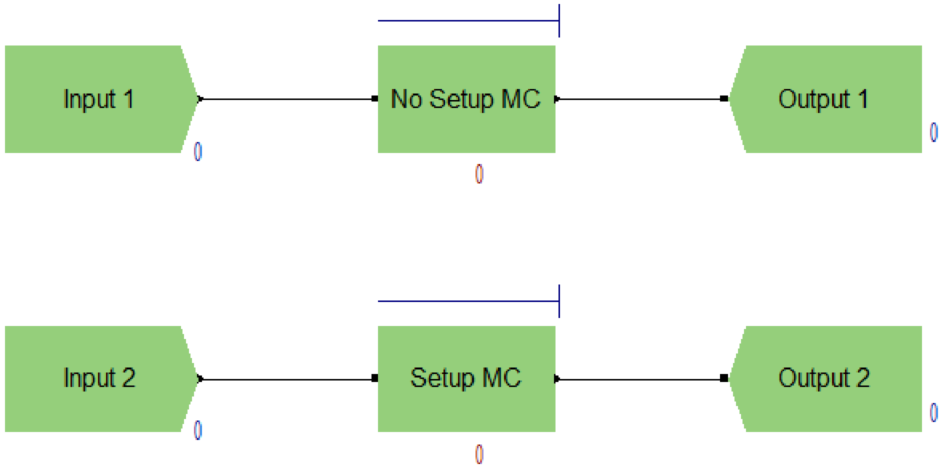
<Picture 2> Production system (2)

# 4. Experiment Procedure

## Experiment 2. Variability from setup

### ■ Step 1-2. Creating the model

- Basic simulation model is as the picture below
- Modules: 1 Create, 1 Process, 1 Dispose for each system

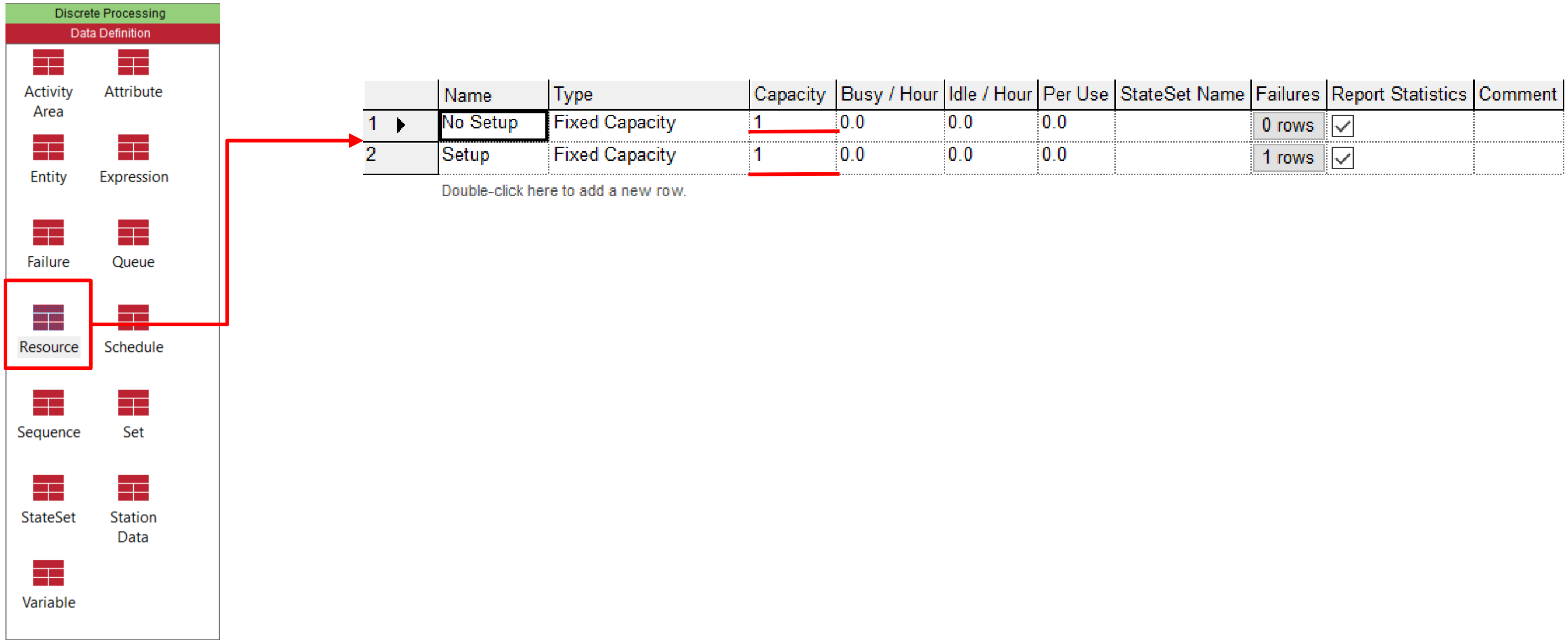


# 4. Experiment Procedure

## Experiment 2. Variability from setup

### ■ Step 1-2. Creating the model (cont.)

- Add resources (M/C) for each system



| | Name | Type | Capacity | Busy / Hour | Idle / Hour | Per Use | StateSet Name | Failures | Report Statistics | Comment |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 ▶ | No Setup | Fixed Capacity | 1 | 0.0 | 0.0 | 0.0 | | 0 rows | ☑ | |
| 2 | Setup | Fixed Capacity | 1 | 0.0 | 0.0 | 0.0 | | 1 rows | ☑ | |

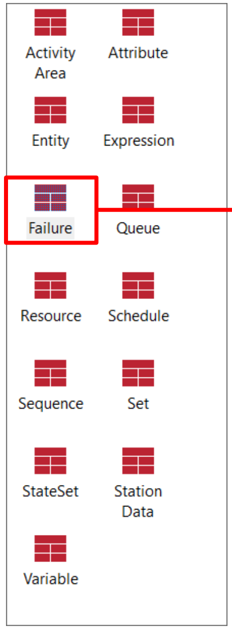
Double-click here to add a new row.

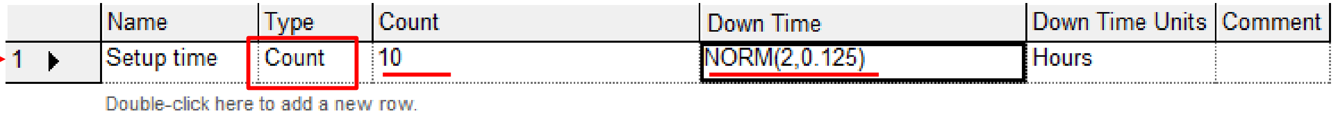
# 4. Experiment Procedure

## Experiment 2. Variability from setup

### ■ Step 1-2. Creating the model (cont.)

- Add setup time using Failure module
- Set Type as count (Resource works on the number of counts and becomes down = machine is idle for setup)





| | Name | Type | Count | Down Time | Down Time Units | Comment |
|---|---|---|---|---|---|---|
| 1 | Setup time | Count | 10 | NORM(2,0.125) | Hours | |

Double-click here to add a new row.

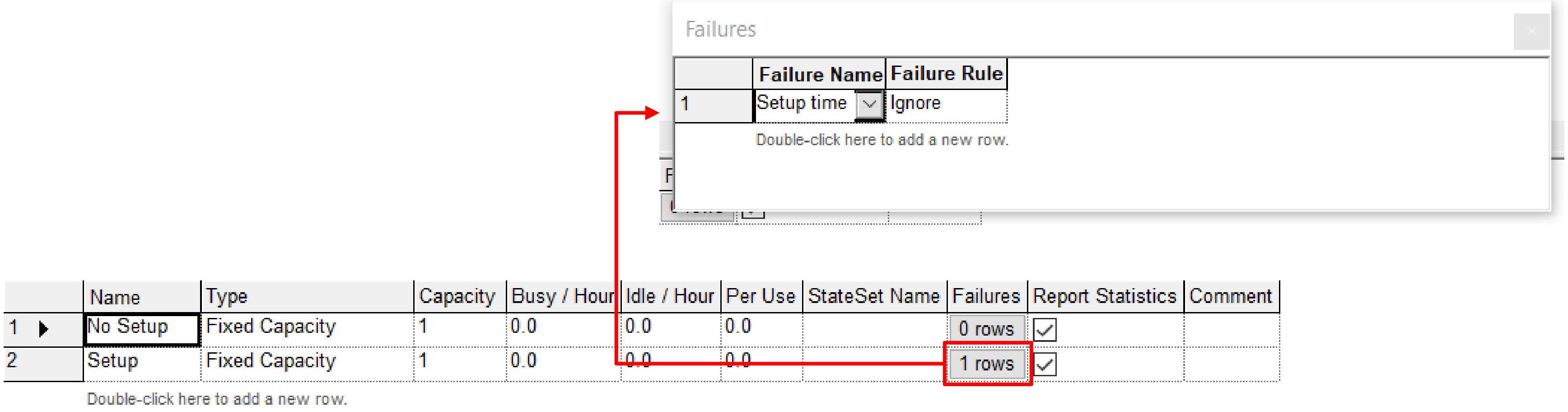
| | Setup |
|---|---|
| **Machine 1** | - |
| **Machine 2** | $N_s = 10, t_s = 2\ hours, \sigma = 0.125$ |

# 4. Experiment Procedure

## Experiment 2. Variability from setup

### ■ Step 1-2. Creating the model (cont.)

- Add failure to each resource
- Select failure name (already made) for each resource
- Set Failure Rule as Ignore



| | Failure Name | Failure Rule |
|---|---|---|
| 1 | Setup time | Ignore |

Double-click here to add a new row.

| | Name | Type | Capacity | Busy / Hour | Idle / Hour | Per Use | StateSet Name | Failures | Report Statistics | Comment |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | No Setup | Fixed Capacity | 1 | 0.0 | 0.0 | 0.0 | | 0 rows | ☑ | |
| 2 | Setup | Fixed Capacity | 1 | 0.0 | 0.0 | 0.0 | | 1 rows | ☑ | |

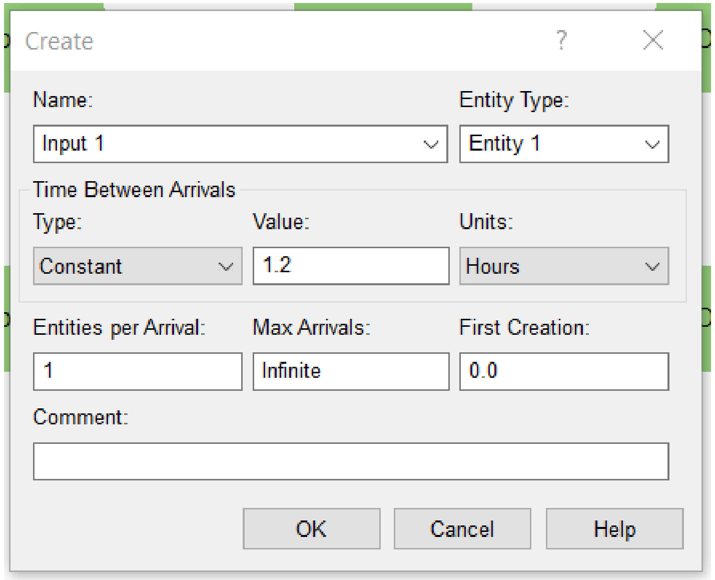
Double-click here to add a new row.

# 4. Experiment Procedure

## Experiment 2. Variability from setup

### ■ Step 1-2. Creating the model (cont.)

- Create raw material entities (different entities for each system)
- Time between Arrivals = 1.2 hours
- Set up Process modules same as experiment 1



Create

Name: Input 1

Entity Type: Entity 1

Time Between Arrivals

Type: Constant

Value: 1.2

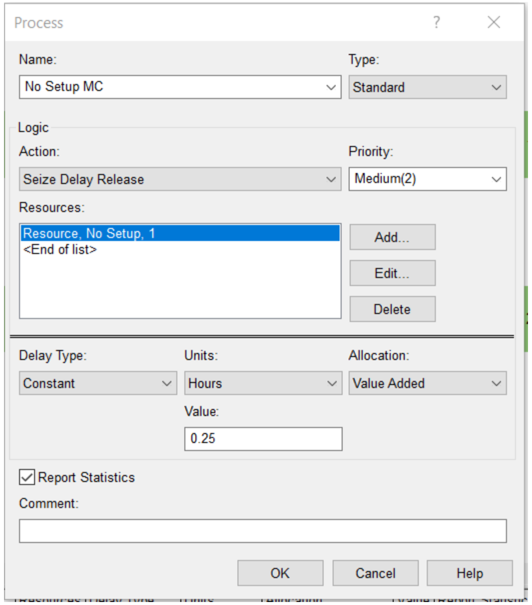
Units: Hours

Entities per Arrival: 1

Max Arrivals: Infinite

First Creation: 0.0

Comment:



Process

Name: No Setup MC

Type: Standard

Logic

Action: Seize Delay Release

Priority: Medium(2)

Resources:
Resource, No Setup, 1
<End of list>

Delay Type: Constant

Units: Hours

Allocation: Value Added

Value: 0.25

☑ Report Statistics

Comment:

# 4. Experiment Procedure

## Experiment 2. Variability from setup

- ■ **Step 2. Compare the performance of two machines**

1) Run setup (Run → Setup)

- Set up the repetitive experiment
- Replication length = 1 week (7 days), Number of replications = 30

# 4. Experiment Procedure

## Experiment 2. Variability from setup

■ **Step 2. Compare the performance of two machines**

1) Analysis of result report

- To analyze the variability of two machines,

- Use $Waiting\ time \approx V \times U \times t_e$

- V = variability, U = utilization ($u/(1-u)$), $t_e$ = production time

# 4. Experiment Procedure

## Experiment 2. Variability from setup

- **Step 3. Change time intervals & analyze the performance**
  - Like experiment 1, compare the performance of each system by changing time interval from Create module

- **Step 4. Change Setup & analyze the performance**
  - Change set up frequency ($N_s$) and time ($t_s$)
  - Analyze the performance

# *Q & A*