END3032 – SYSTEMS SIMULATION

Laboratory Practice #9

The Cotton Spinning Looms Problem

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Problem Definition*

- A room has 10 cotton spinning looms.
- Once the looms are set up, they run automatically.
- The setup time is exponentially distributed, with mean 10 minutes.
- The machines run for an average of 40 minutes, also exponentially distributed.
- Loom operators are paid $10 an hour, and looms not running incur a cost of $40 an hour.
- Make a simulation model and answer the following questions.
  a) How many loom operators should be employed to minimize the total cost of the loom room?
  b) If the objective becomes "on the average, no loom should wait more than 1 minute for an operator" how many people should be employed?
  c) How many operators should be employed to ensure that, on average, at least 7.5 looms are running at all times?

Hint: Model by an M/M/c/10/10 queue with (λ=1/40, μ=1/10, N=K=10) and design scenarios for different number of operators (c=1, c=2, etc.).

*Banks, J., Carson II, J.S., Nelson, B.L., Nicol, D.M. (2005). Discrete-event system simulation. Pearson Prentice Hall.

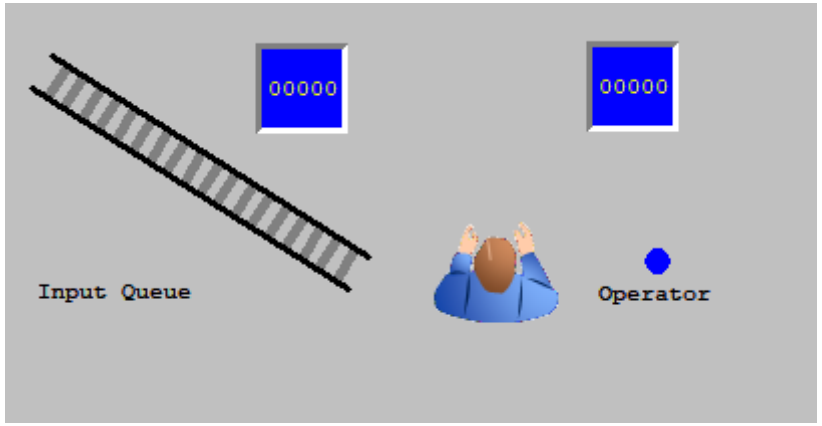
Implementation on ProModel

- Define the locations

Locations

Icon	Name	Cap.	Units	DTs...	Stats	Rules...
	Input_Queue	10	1	None	Time Series	Oldest, FIFO
	Operator	Op	1	None	Time Series	Oldest

! We will define a macro parameter for the capacity of the Operator, later.



Implementation on ProModel

- Define the entities

Entities

Icon	Name	Speed (fpm)	Stats
	Loom	150L	Time Series

- Set entity arrivals

Arrivals

Entity...	Location...	Qty Each...	First Time...	Occurrences	Frequency
Loom	Input_Queue	10	0	1	0

Implementation on ProModel

- Define attributes in order to track some time parameters for each entity

Attributes

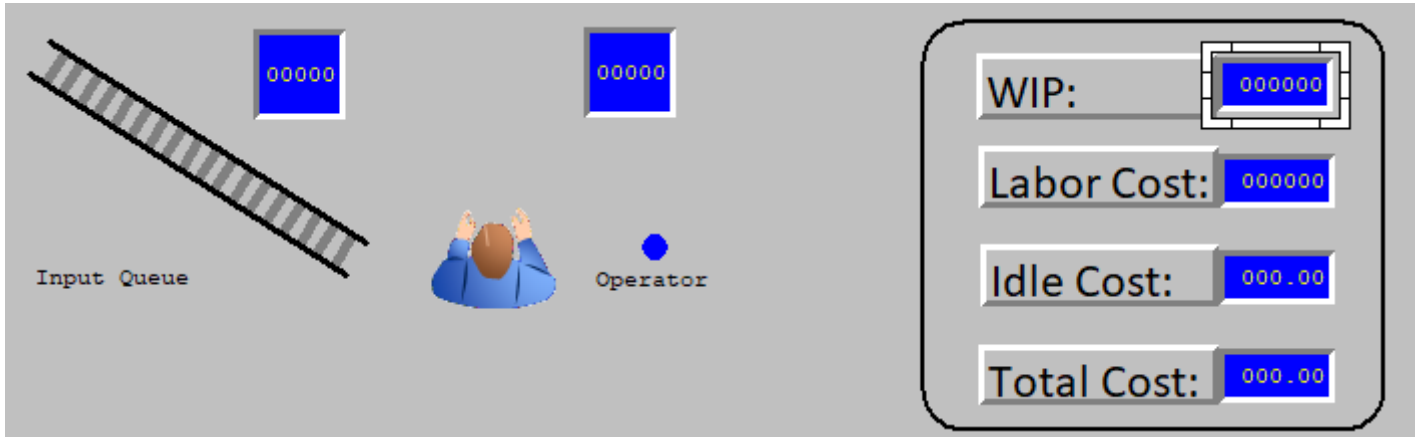
ID	Type	Classification
Entry_Time	Real	Ent
Exit_Time	Real	Ent
Lead_Time	Real	Ent

Implementation on ProModel

- Define variables and put icons on the layout

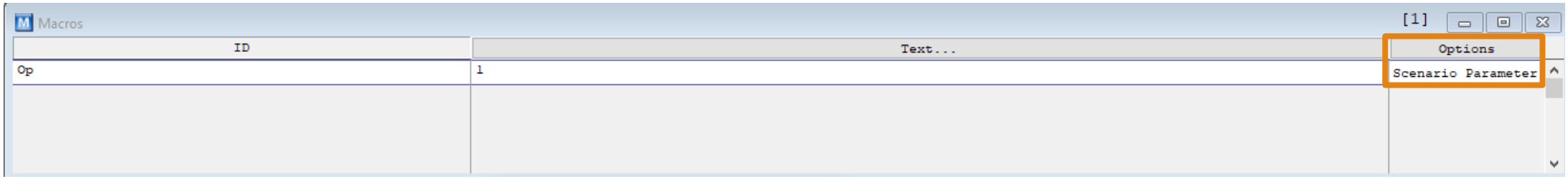
Variables (global)

Icon	ID	Type	Initial value
Yes	WIP	Integer	0
No	Total_Idle_Time	Real	0
Yes	Labor_Cost	Integer	0
Yes	Idle_Cost	Real	0
Yes	Total_Cost	Real	0

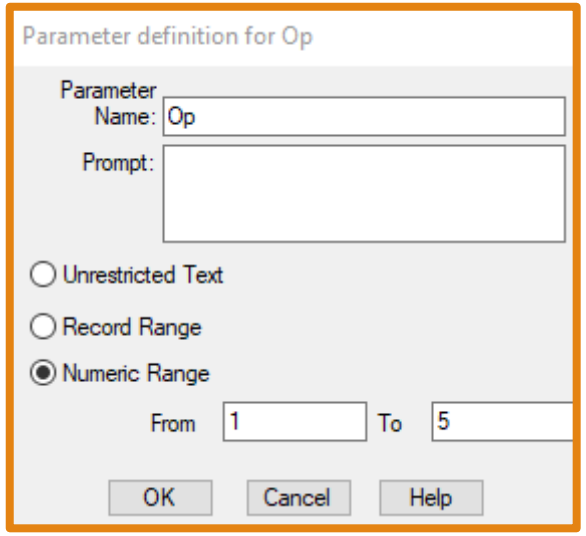


Implementation on ProModel

- Define macro parameters
  - Select the <Scenario Parameter> option from the <Options> menu



  - Click on the <Options> menu and define a numeric range for the parameter

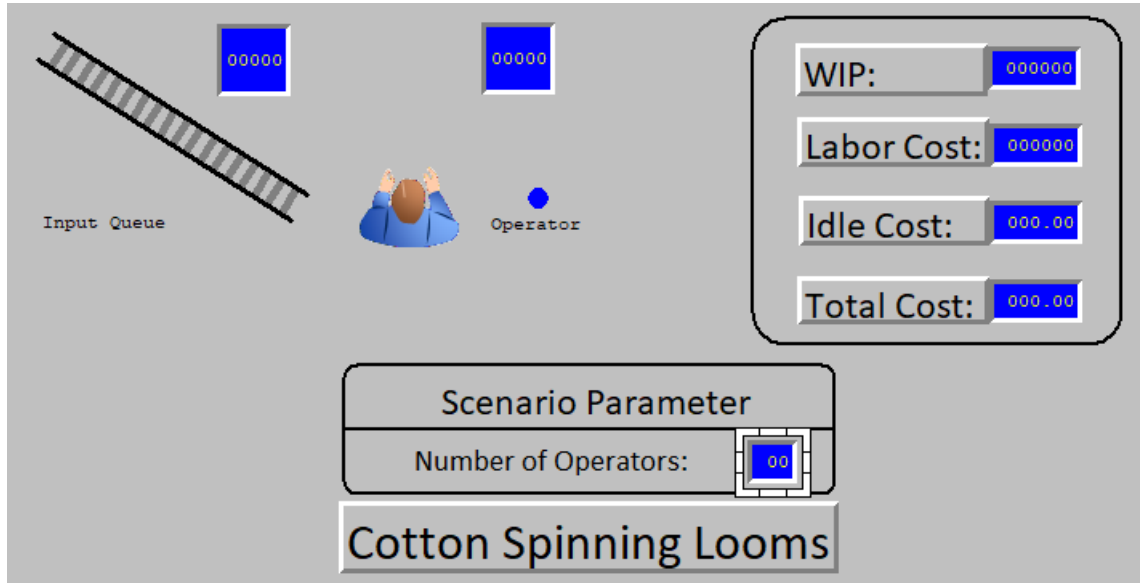


Implementation on ProModel

- Define an additional variable in order to track number of operators in each scenario

Variables (global)

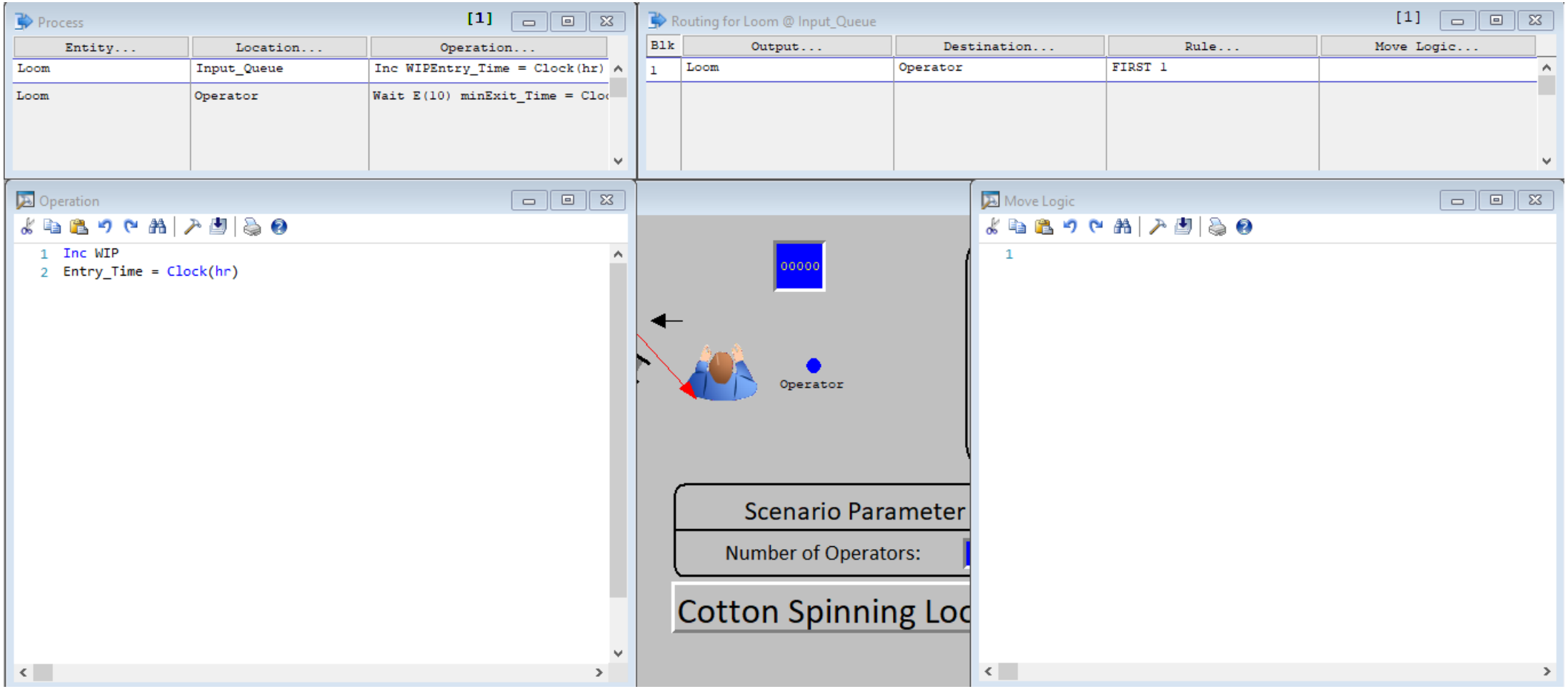
Icon	ID	Type	Initial value	Stats
Yes	WIP	Integer	0	Time Series, Time
No	Total_Idle_Time	Real	0	Time Series, Time
Yes	Labor_Cost	Integer	0	Time Series, Time
Yes	Idle_Cost	Real	0	Time Series, Time
Yes	Total_Cost	Real	0	Time Series, Time
Yes	Number_of_Operators	Integer	Op	Time Series, Time



! Value of the variable is equal to the value of the macro parameter for the corresponding scenario.

Implementation on ProModel

- Processing: Input Queue →Operator



Implementation on ProModel

- Processing: Operator → Input Queue

Process [2]

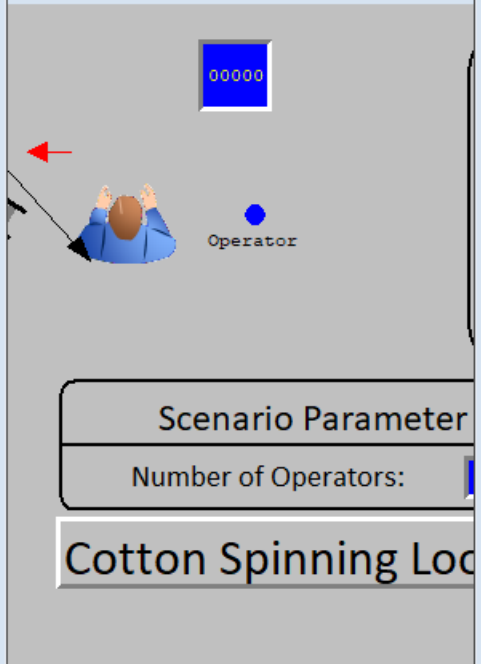
Entity...	Location...	Operation...
Loom	Input_Queue	Inc WIPEntry_Time = Clock(hr)
Loom	Operator	Wait E(10) minExit_Time = Clo

Routing for Loom @ Operator [1]

Blk	Output...	Destination...	Rule...	Move Logic...
1	Loom	Input_Queue	FIRST 1	Move For E(40) min

Operation

```
1  Wait E(10) min
2
3  Exit_Time = Clock(hr)
4  Lead_Time = Exit_Time - Entry_Time
5  Inc Total_Idle_Time, Lead_Time
6  Labor_Cost = 10 * Op
7  Idle_Cost = 40 * Total_Idle_Time / Clock(hr)
8  Total_Cost = Labor_Cost + Idle_Cost
9
10 Dec WIP
```



Move Logic

```
1  Move For E(40) min
```

Implementation on ProModel

- Define scenarios

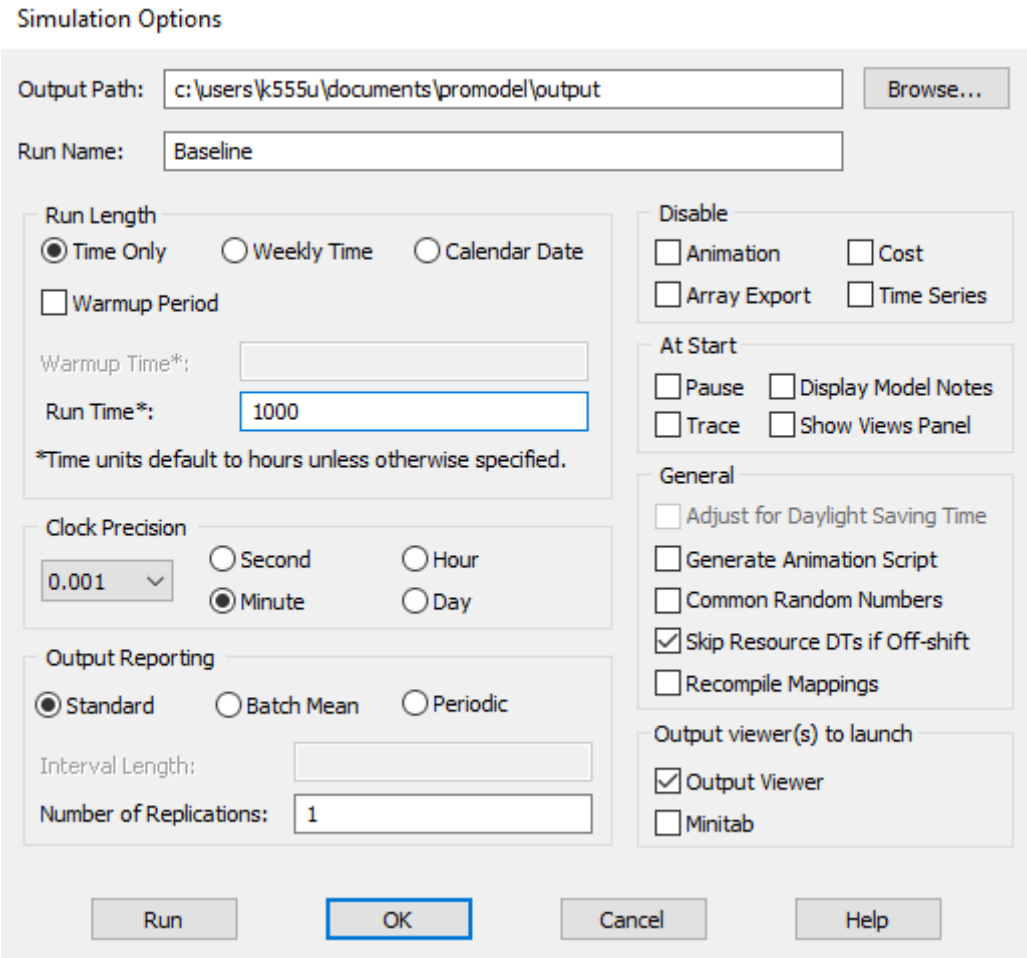
Scenario Manager

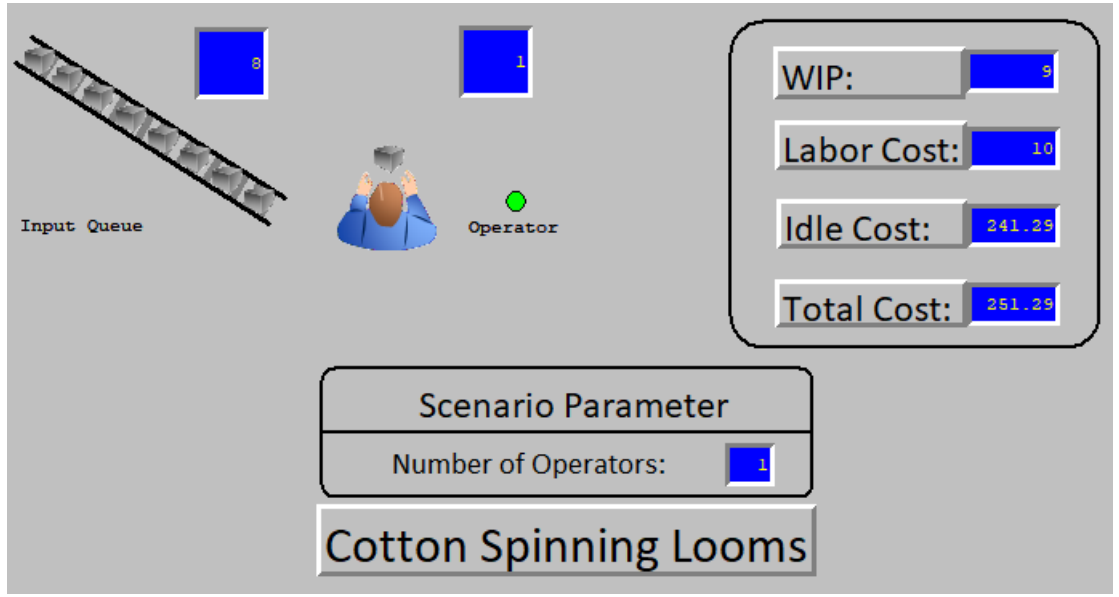
#	Parameters	Baseline	Scenario1	Scenario2	Scenario3	Scenario4	Scenario5
	Simulate Scenario?	☑	☑	☑	☑	☑	☑
	Last Simulation Run						
*	Op	1	1	2	3	4	5

Run Scenarios | OK | Cancel

Implementation on ProModel

- Run the simulation for 1000 hours and get the results





Implementation on ProModel

a) Three operators should be employed to minimize the total cost of the loom room.

Variable Summary Table ×

Variable Summary							
Scenario	Name	Total Changes	Average Time Per Change (Min)	Minimum Value	Maximum Value	Current Value	Average Value
Scenario1	Total Cost	6.044,00	9,93	0,00	272,88	249,00	248,46
Scenario2	Total Cost	10.360,00	5,79	0,00	274,15	146,62	147,82
Scenario3	Total Cost	11.704,00	5,13	0,00	279,59	122,68	122,28
Scenario4	Total Cost	12.042,00	4,98	0,00	287,00	124,73	124,77
Scenario5	Total Cost	12.024,00	4,99	0,00	297,57	131,37	132,84

Implementation on ProModel

b) Four operators should be employed to ensure that, on the average, no loom should wait more than 1 minute for an operator.

Location Summary Table

Location Summary

Scenario	Name	Scheduled Time (Hr)	Capacity	Total Entries	Average Time Per Entry (Min)	Average Contents	Maximum Contents	Current Contents	% Utilization
Scenario1	Input Queue	1.000,00	10,00	6.049,00	49,42	4,98	10,00	4,00	49,82
Scenario2	Input Queue	1.000,00	10,00	10.361,00	8,42	1,45	10,00	0,00	14,53
Scenario3	Input Queue	1.000,00	10,00	11.706,00	1,88	0,37	10,00	0,00	3,67
Scenario4	Input Queue	1.000,00	10,00	12.042,00	0,51	0,10	10,00	0,00	1,03
Scenario5	Input Queue	1.000,00	10,00	12.028,00	0,22	0,04	10,00	0,00	0,45

Implementation on ProModel

c) Three operators should be employed to ensure that, on the average, at least 7.5 looms are running at all times?

Variable Summary Table

Variable Summary							
Scenario	Name	Total Changes	Average Time Per Change (Min)	Minimum Value	Maximum Value	Current Value	Average Value
Scenario1	WIP	12.093,00	4,96	0,00	10,00	5,00	5,98
Scenario2	WIP	20.721,00	2,90	0,00	10,00	1,00	3,17
Scenario3	WIP	23.410,00	2,56	0,00	10,00	2,00	2,32
Scenario4	WIP	24.084,00	2,49	0,00	10,00	0,00	2,12
Scenario5	WIP	24.052,00	2,49	0,00	10,00	4,00	2,04

Scenario	Capacity - WIP
Scenario1	10 - 5.98 = 4.02
Scenario2	10 - 3.17 = 6.83
Scenario3	10 - 2.32 = 7.68
Scenario4	10 - 2.12 = 7.88
Scenario5	10 - 2.04 = 7.96

Thanks!...

Questions?

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