IE 551: Project 3

JOB SHOP DESIGN

Date: 04/07/2020
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Subject: Find the optimal number of machines within allocated budget of 40 million required to process 2 different job types to achieve low run-cycle time and waiting job types in line.

OBJECTIVE:
To determine the optimal number of machines required to process 2 different job types in order to lower the run-cycle time and number of units waiting in line using queuing tools, queuing theory and Arena's Process Analyzer; considering the allocated budget of 40 million USD.

EXECUTIVE SUMMARY:
Considering the budget, in order to lower the run-cycle time of job types and reduce the number of job types waiting in assembly line, we recommend having **6 Casting units, 1 Lathe, 3 Planers, 3 Drill Press and 7 Shaper machines**. The average total time for job type I is 2.5746 hours and for job type II is 5.1882 hours with an acceptable error tolerance of 36 seconds. **The total setup cost is 38.5 million USD.**

SOFTWARE USED:
To simulate the shop-floor design environment, we used Arena Modeling Software. To compare different scenarios, we used Arena's Process Analyzer. Initial approximation for machine requirements was done using queuing tools.

EXPERIMENTAL DESIGN AND ANALYSIS:
We use queuing tools to obtain an initial approximation of the number of machines required to process our job types. We are simulating a 3-shift job shop design that **runs continuously**, making it a non-terminating simulation.

1. **Model Logic**
   - **Sequences spreadsheet** is used to input the machine sequences which are provided as an attribute to the entities in the assign modules.
   - **Resources spreadsheet** is used to input our resources (Number of machines)
   - Arena's Basic process modules are used to model the entity creation, job type decision, assign attributes, record required statistics and finally dispose the entities.
   - The route modules have a route time of 5 mins (travel time) except for the initial routes where no travel time is accounted.
   - Arena animations are used to animate resources, entities and path (route)

2. **Determining the warm-up period and replication length:**
   - We set the arrival rate to 1 per time interval, thus the replication length corresponds to the number of entities.
   - To get a rough estimate of the warm-up time required for the setup, we plot the cumulative average total time of entity in the system as a function of time and note for changes in the trend as our simulation runs.
   - Mean plot analyzer tool is used to obtain the actual estimates of our warm-up period. We assign an attribute named 'Time in' for both the job type entities and record the average total time spent by each entity in the system over all replications.
   - We use the **statistics spreadsheet** to extract the total time spent by each job type in the system.
   - Mean plot analyzer plots the entity number (X-axis) and the average total time spent in system over all replications (Y-axis) and provides a good visual aid to identify the deletion point.
   - In this setup, we observe the trend of 'Time in' plot for job type II since it has a longer processing time. The point where we observe the trend to be stable is set to be the deletion point. For this setup, deletion

point (T_0) is around 146 hours. This means that the setup needs around 146 job types to be processed first to obtain steady state. This warm-up period is not accounted for in the simulation results.

- The replication length (R) for our model is calculated as:
  $R = T_0 + 10^* T_0 \sim$ **1500 hours**
- Number of replications used in our model: 10; as we increase the number of replications, we reduce the confidence interval width
- In this case, for 10 replications, we have an acceptable halfwidth (0.01 hours = 36 seconds in the wait times).
- **Our simulation model takes moderate time to run and thus we choose multiple replications (instead of 1 long run) given we do not have time constraint.**

3. Input modelling

We have the expected time for each process and the variation in it. We assume a normal distribution for service times with given mean time and variance for each.

Using the same common random number (CRN) stream allows us to compare scenarios on same level.

The route

Below table summarizes the process and the service time distribution:

Process	**Best-fit distribution**
Incoming calls arrival rate	Constant (Expression) 1 per 13 mins, CRN stream used: 5
Casting unit machine	NORM(60, 9, 5)
Lathe machine	NORM(20, 3, 5)
Planer machine	NORM(35, 5.25, 5)
Drill Press machine	NORM(50, 7.5, 5)
Shaper machine	NORM(125, 18.75, 5)

4. Validation

- The initial model validation is done by consulting an expert and our general understanding of a job shop.
- The output metrics of interest here are the 'Average total time' for both entities and the waiting times at each of the processes.
- From the category overview report, we see that the halfwidth for these output metrices is **acceptable (0.01 hours = 36 seconds**)

5. Comparing scenarios (Using Arena's Process Analyzer tool)

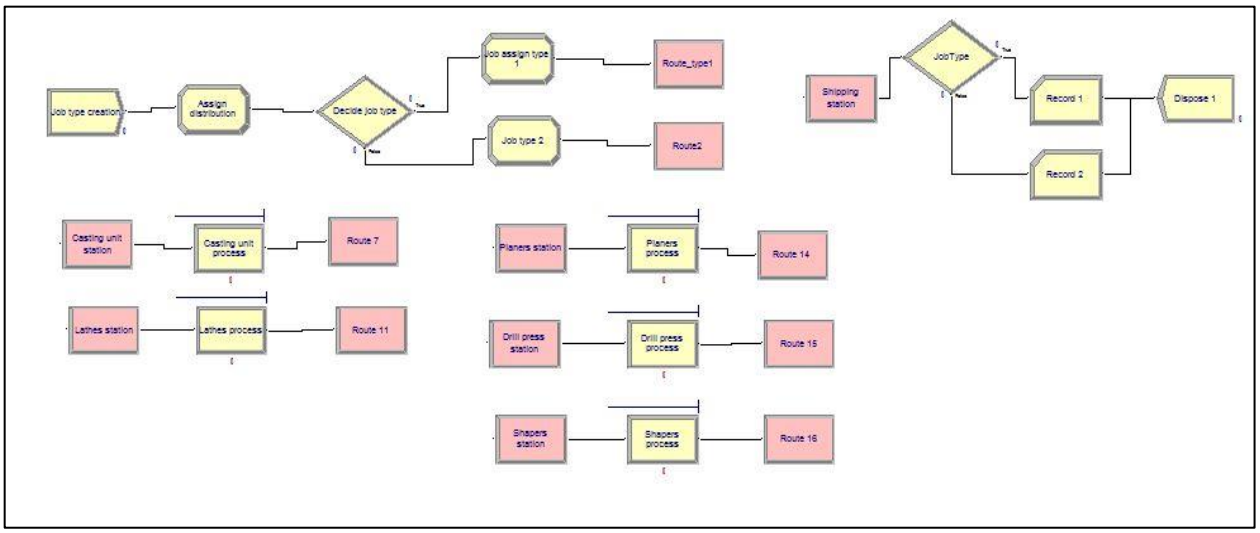
- The controls are number of machines used (Capacity) and the responses observed are the 'Average total time' for each entity in system and the average waiting time at each machine. (Considering our objective)
- We use our best understanding to determine the scenarios to consider with budget as a constraint.
- The best scenarios are displayed by PAN and further formal statistical comparison of scenario results is done using a Box-Whisker plot.
- The best scenario identified is displayed in red on the plot. The box indicates our 95% CI and the whiskers indicate minimum and maximum times.
- We choose 'Smaller is better' since our objective is to lower the run-cycle time and tolerance is the practical significance value we determine.

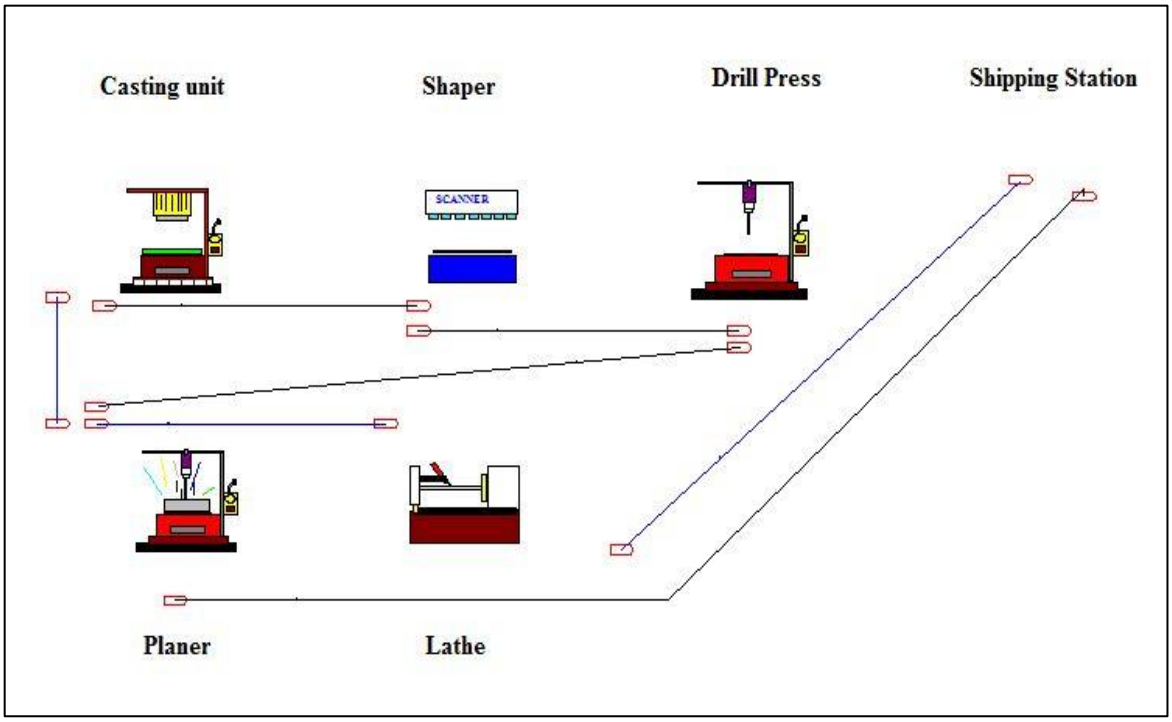
SHORTCOMINGS

- Further analysis can be done to improve the deletion point
- Service time distributions can be determined using historical data

APPENDIX

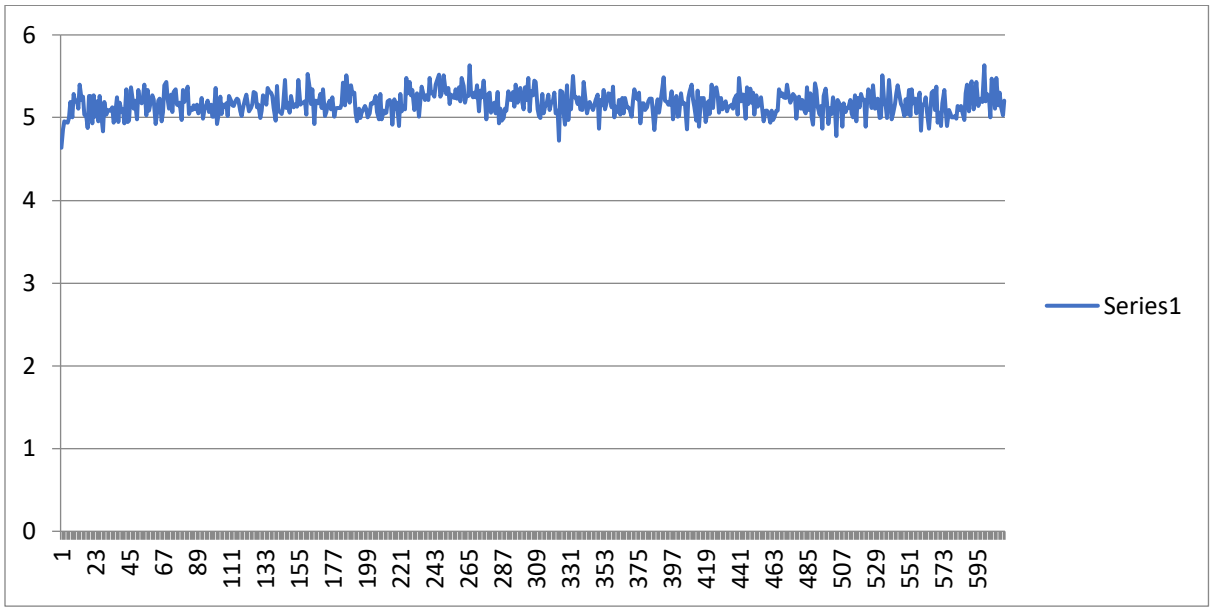
Proposed system:





MEAN PLOTS:

Type 1:



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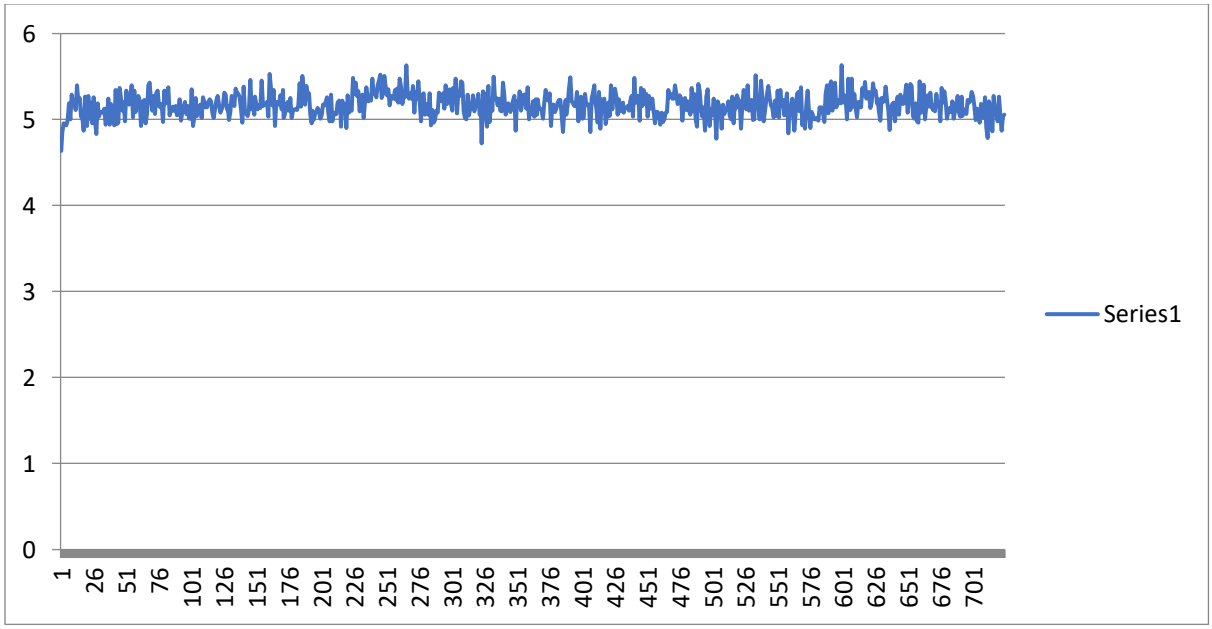
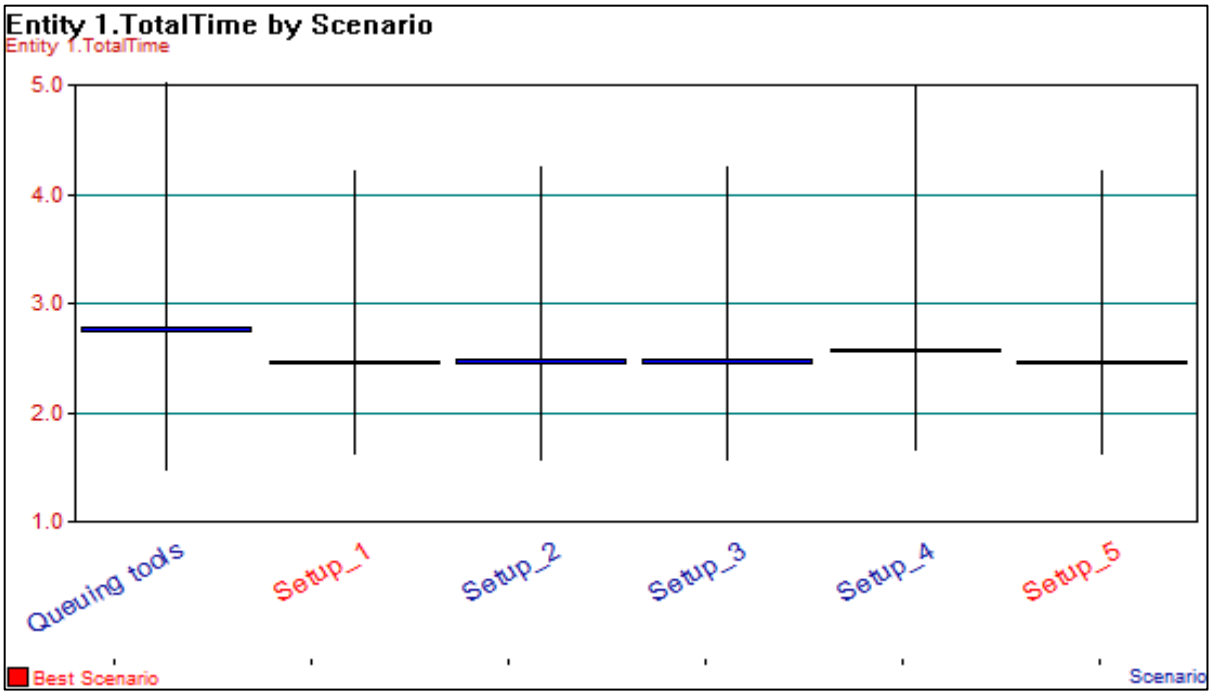
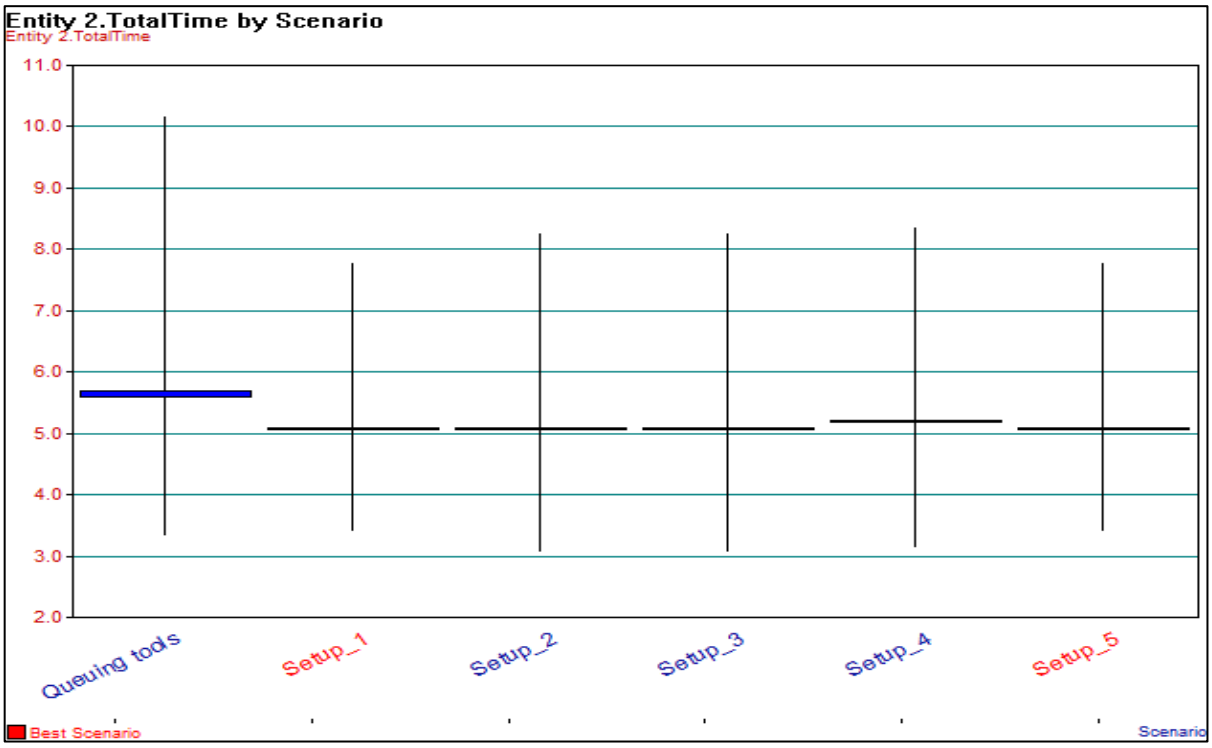


Best scenarios:
Type1:



Type 2:



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Process Analyzer

1. Scenarios

	Scenario Properties			
	S	Name	Program File	Reps
1		Queuing tools	15 : Project_2_team3.p	10
2		Setup_1	15 : Project_2_team3.p	10
3		Setup_2	15 : Project_2_team3.p	10
4		Setup_3	15 : Project_2_team3.p	10
5		Setup_4	15 : Project_2_team3.p	10
6		Setup_5	15 : Project_2_team3.p	10

2. Controls

Controls				
Machine CU	Machine DP	Machine Lathes	Machine Planers	Machine Shapers
5.0000	3.0000	1.0000	3.0000	6.0000
6.0000	3.0000	1.0000	3.0000	7.0000
7.0000	3.0000	1.0000	3.0000	7.0000
7.0000	3.0000	1.0000	4.0000	6.0000
5.0000	4.0000	1.0000	3.0000	7.0000
6.0000	3.0000	1.0000	3.0000	8.0000

3. Response

Responses						
Entity 1.TotalTime	Entity 2.TotalTime	Casting unit process.Qu	Drill press process.Qu	Lathes process.Qu	Planers process.Qu	Shapers process.Qu
2.761	5.637	0.055	0.052	0.141	0.242	0.329
2.462	5.077	0.001	0.074	0.178	0.029	0.060
2.468	5.078	0.000	0.072	0.186	0.029	0.063
2.468	5.078	0.000	0.072	0.186	0.029	0.063
2.575	5.188	0.055	0.071	0.185	0.028	0.062
2.462	5.077	0.001	0.074	0.178	0.029	0.060