Appendix report

1) **Statement of collaboration**

In order to attain an experiment based on simulation for Beerlicious, our team collaborated with a few other teams. The whole ideology behind the working of the project made us collaborate teams. Please find the respective student names below.

Group 1 :
Vikranth Nayakanti - s200086
Varun Biradar - s200235

Group 2 :
Himank Ambashta - s200102
Sana Ilyas - s192815

2) **Performance management**

In order to analyze the operational performance of the system, it is prominent to investigate both the requirements and the supply of the project. KPIs need to be developed to identify the behavior of the whole process. Referring to the S.M.A.R.T. -technique from Lectures, we came up with the following KPIs interested with respect to the project;

1. Average Utilization of resources :
    a. Fermenter.
    b. Fast & Slow Cooler.
    c. Filter.
    d. Cleaning processor.
    e. Packaging (Small/Large bottles & Cans).
2. Cumulative process time
    a. Process until Filtering (Fermenting, Cooling, Mixing, Filtering)
    b. Packaging process (Bottling, Capsuling, labeling, Boxing)
3. Total moving time (Input batch)

- The utilization of the resources is important to measure and analyze consumption under varying conditions depending upon growth & decline in demand for the product.

However, the average utilization of the resources could be calculated based on the applied experiment of a particular resource by each batch entitled as Agent/entity in the project.

- The cumulative process time until the Filtering & Packaging process could be potential KPIs which were identified to calculate the total elapsed time taken by each individual process from end-to-end including; Fermenting, Cooling, Mixing, Filtering & Packaging (Bottling, Capsuling, labeling, Boxing).

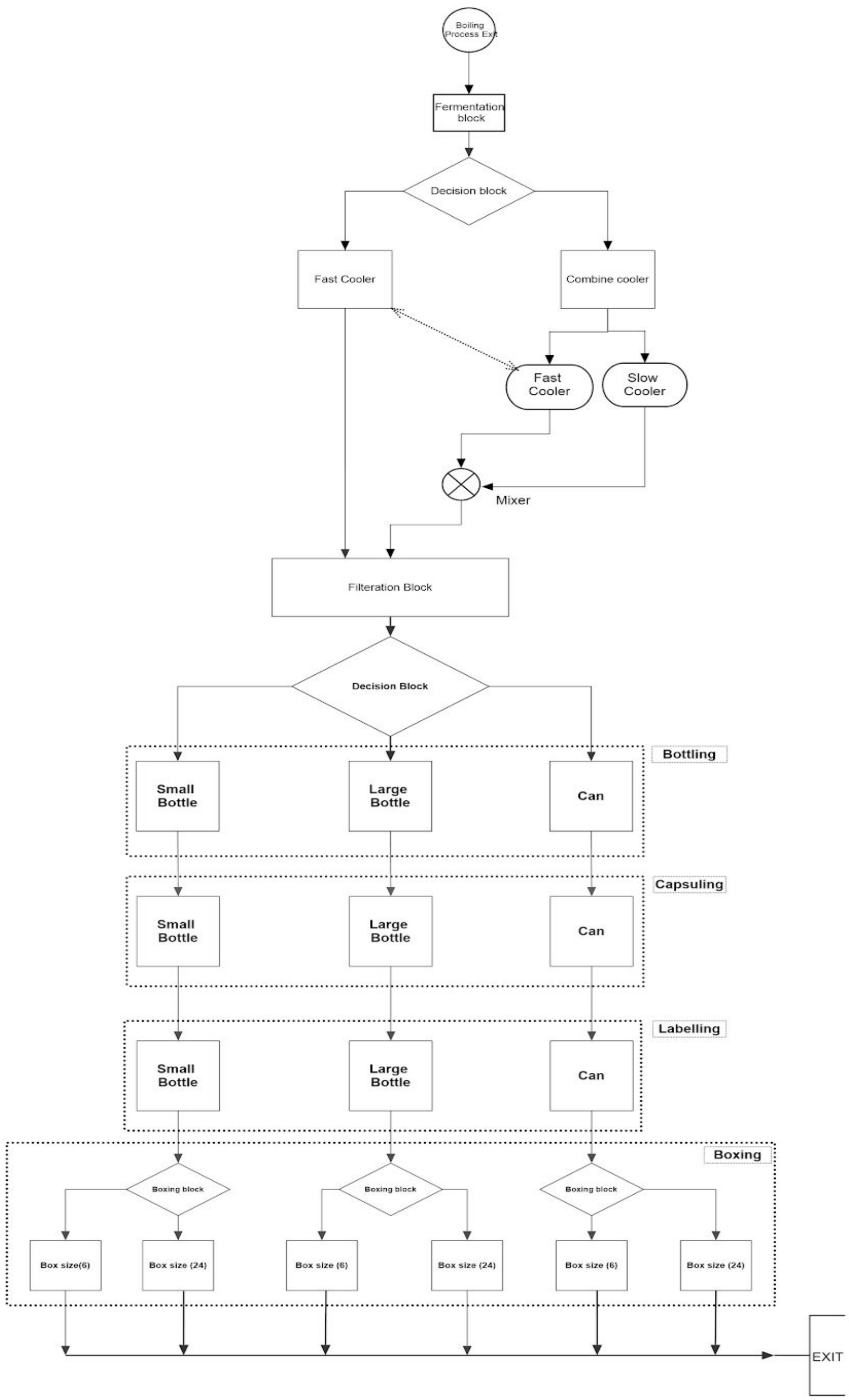
- Total moving time could be another potential KPI needed to be evaluated in order to examine and conclude a hypothesis based on moving time, an entity/batch is required to move throughout the resource blocks from the exit of the Boiling section until it reaches Pallet.

- However, all of the suggested KPIs could be identified to be Specific, Measurable, Achievable, Relevant, and Time-bound in nature.

Fig : SMART - Technique
[Source : https://www.smartinsights.com/goal-setting-evaluation/goals-kpis/define-smart-marketing-objectives/]

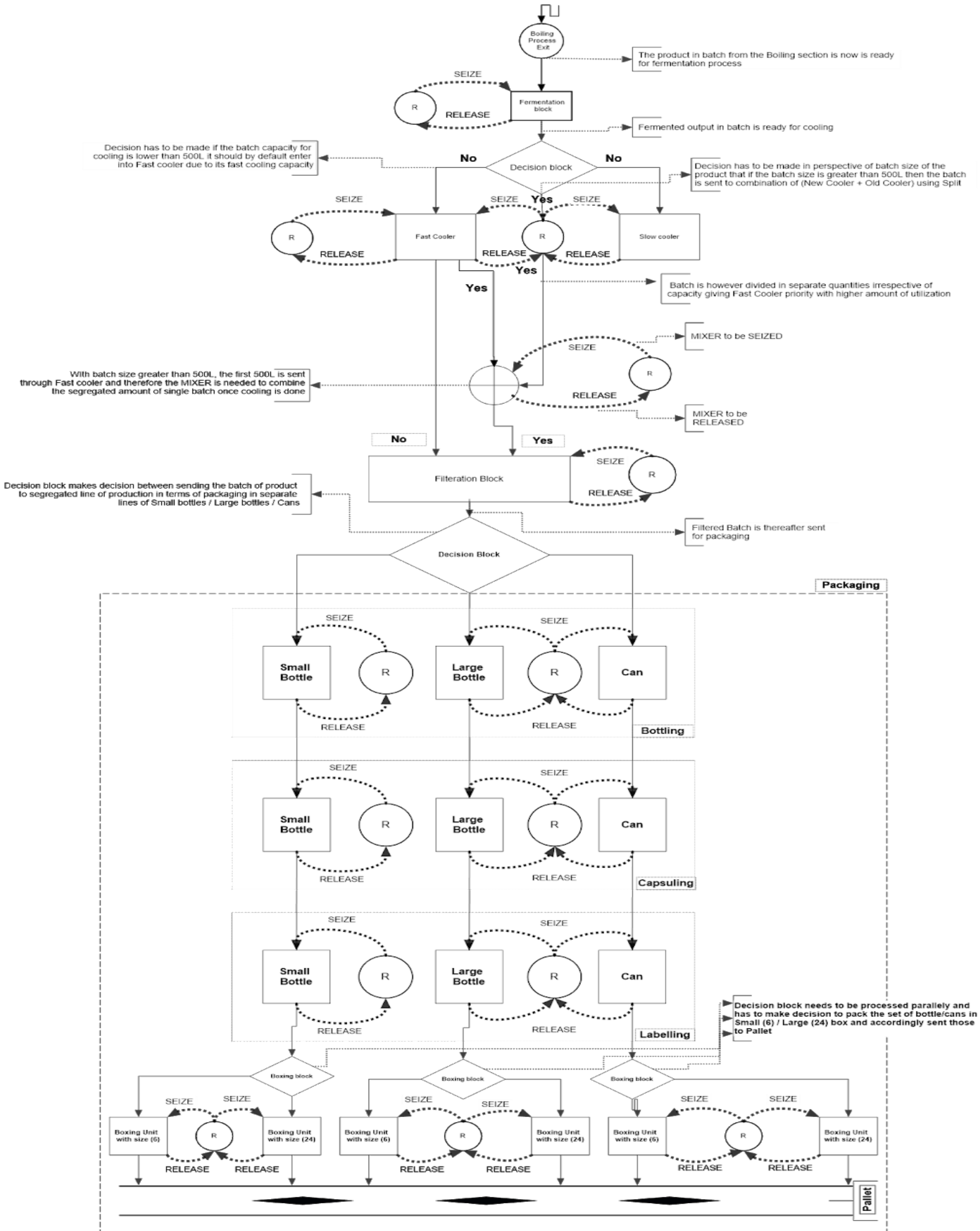
3) Conceptual modeling

a. **Flow chart**:



Note: **For a better visibility, please zoom into each section of the diagram, or please find a copy of the same diagram under the Project folder section.**

b. Activity diagram:



Note: For better visibility please zoom into each section of the diagram or please find a copy of the same diagram under the Project folder section.

4) Assumptions

Assumptions are made in order to presume the overall requirements to construct the potential outcome of the project. The assumptions are taken throughout building the project as could be manipulated based on the desired optimum output. These assumptions help us construct the actual representation of the case study & project model. The particular hypothesis could be shared once the assumptions are supported with legitimate evaluations based on supervision. However, in order to build the project model we had to come up with some genuine assumptions as followed;

- The agent/entity is assumed to be an individual batch of beer throughout the project.
- A batch of beer would be moving from a different set of resource blocks making Agent moving dynamically from point to point & resource to be static.
- The source is considered to be an outcome from the boiling unit and can be queued to the fermentation block.
- Each resource/process block is considered a service block when compared to activity diagrams with our model. Each service/delay block is respectively seized & released by an individual resource based on their performance with respect to the agent.
- When the agent travels through the fermentation process onto the cooling block few things have to be assumed to make further decisions based on the quantity of input batch.
    - It is assumed that if the *quantity of an input batch is less than or equal to 500 lit.*, the decision block sends the batch of beer to the fast cooler for cooling as the fast cooler has higher efficiency than the slow cooler. In either case, when the input quantity of beer is greater than 500 lit., a batch of beer is sent to the combined processor including the same fast cooler & slow cooler.
    - The typical calculation for *quantity greater than 500 lit*. can be explained using an example (If *agent.quantity is 800 lit.*, the decision block sends 500 lit. to fast cooler & remaining (800-500) i.e. 300 lit., to slow cooler, and then the combination is sent to the mixer once the batch of beer is done with cooling.
- A mixer is connected to the combined processing block where the outlet from the fast & slow cooler is supposed to get mixed when the quantity of input batch is greater than 500 lit. (However, the fast cooler is capable of processing faster than slow cooler which makes us assume that once fast cooler is done cooling its acquainted batch awaits for the slow cooler to finish its processing & then is combined in mixer)
- Virtually, it could be imagined to have 2 separate processing for cooling depending upon the size of the input batch. Filtration block has input from 2 such processes;
    1. Quantity <= 500 lit. (Fast Cooler)
    2. Quantity > 500 lit. (Combination of Slow cooler & *same* Fast cooler)

[Note: No separate Fast cooler is required for processing the batch as the regular fast cooler can be used in parallel to slow cooler in order to distribute the load/processing of any of the single cooler]

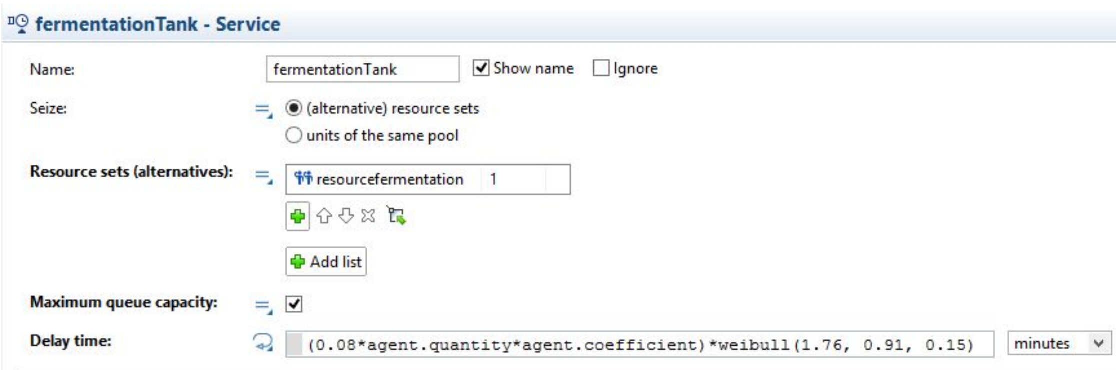
- Cleaning is presumed to be done every time, as the change in the type of an input batch is recorded. This type of batch/beer is, however, classified in type (A/B/C/D), and therefore, while running the simulation from start, the cleaner is activated to clean the individual resource blocks until the packaging process. For the very first input of the day according to the work schedule, the cleaning process would be running regardless of the change in the type of beer.
- After the filtration process, the equivalent quantity of batch is given as an input to the packaging process without changing the type of Agent/entity in the project. The appropriate formulation is used in order to evaluate the delay time for each individual block from the packaging process for assuming a bottle or can be bottled/ capsuled/ labeled or boxed.
- The boxes from the boxing unit are supposed to travel to the pallet and therefore, the pallet is assumed to be an output sink block.
- Periodic cleaning and repairing are considered to be under downtime/maintenance and are therefore assigned to each resource pool in the model. This assignment of downtime in terms of periodic cleaning & repairing may constitute voluntarily periodic cleaning & repairing of all the resource/service blocks stated in the project.
- For output analysis and extended production runs the input work schedule was stressed to find outcomes based on the existing setup of the module. However, the gradual growth of 5% in demand per year (until 2025) is assumed to evaluate the system dynamics then.

5) **Input modeling**

This section will showcase the randomness and hypothesis of the inputs. To identify the production improvement within a given facility, we have used certain and stochastic inputs. We have also changed the quantity of the single batch by 5% successively for five years to predict the time for expanding the current production line. Furthermore, the coefficients column has been added in the batch arrival data file for future calculations. The resources and the corresponding calculations that are taken into consideration while performing the simulation of the 'Beer Production' are described below;

Fermentation:

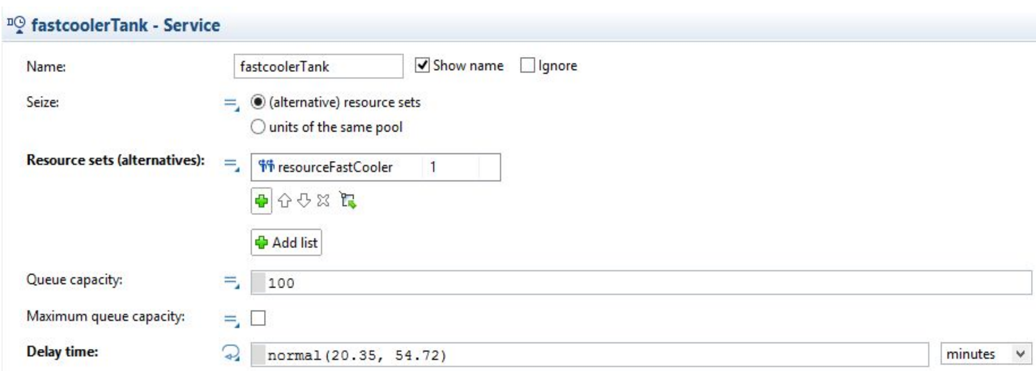
In this resource, to calculate the delay time we evaluated the data distribution with the help of the data fitting process on the available data fitter and got ‘Weibull’ distribution with least error value.



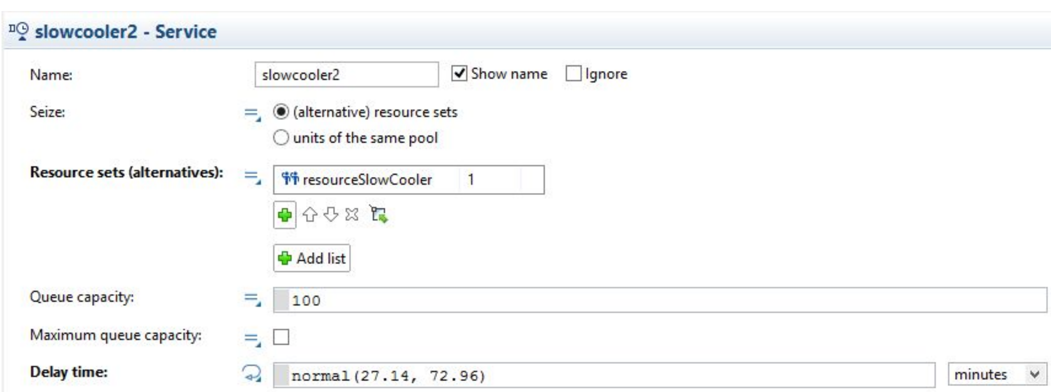
Coolers-

After observing the first instance, the existing multiplier was combined with the distorted difference of +-5% and multiplied for the whole records under work schedule giving us distributed numerical values which then were fitted to the data fitter resulting into a distinctive normal distribution for both coolers.

1. Fast Cooler

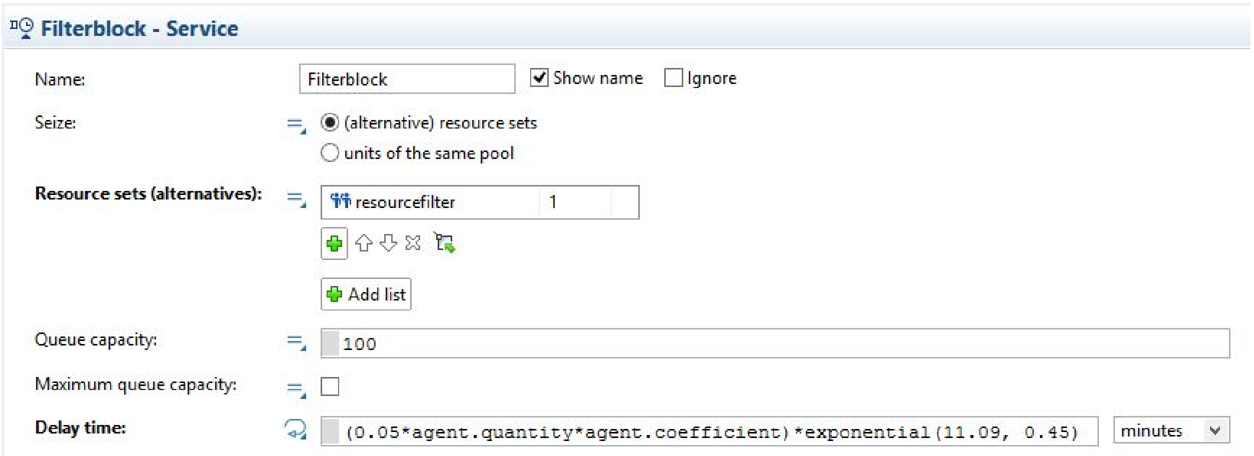


2. Slow Cooler



Filter-

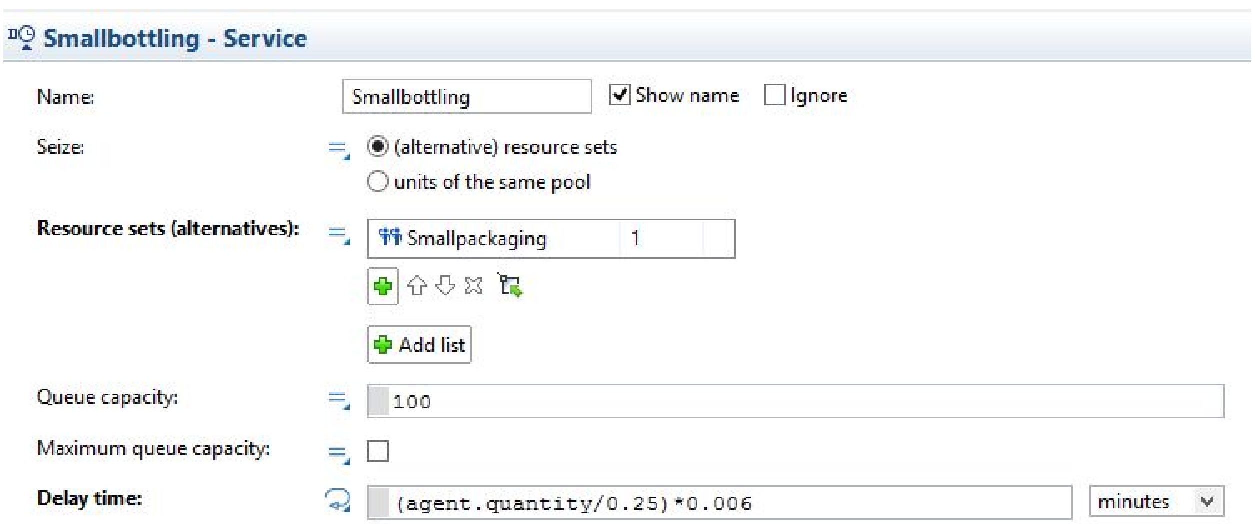
In the filtering process, exponential distribution is calculated from the data fitter, which is used to observe the occurrences of the batch at respective resource units..



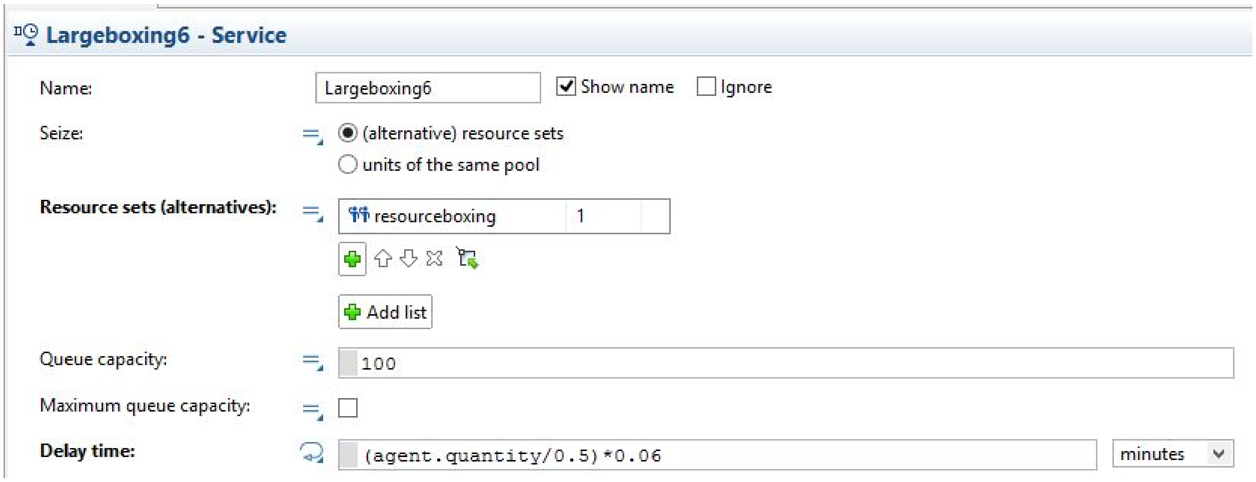
Packaging-

With the consideration, boxing to be part of the packaging process where the three types of the (Small, Large, and Can) are running in parallel, the entity (Batch) is assumed to be an individual batch of beer throughout the simulation. The batch is further filled in the different capacities of the bottles, henceforth, with a given capacity of each container, the delay time is then calculated. And a similar method is adapted for the distribution of the boxes. However, the input overview is shown below for separate machines.

Small Bottling unit:

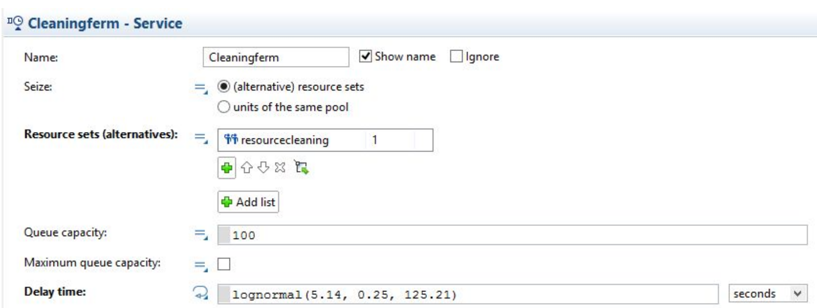


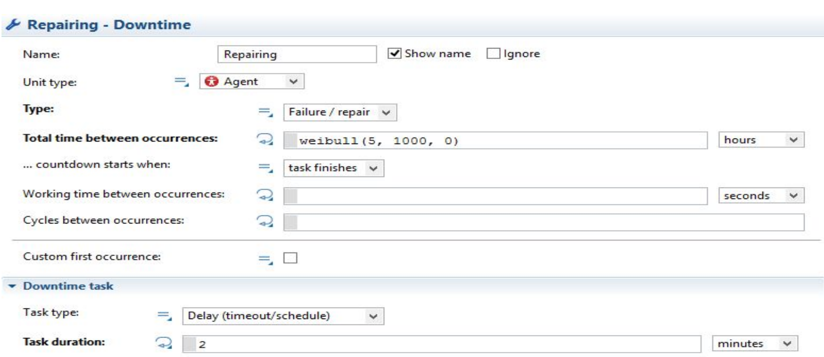
Large bottles to be boxed into an unit with box of size 6:



Cleaning and Repairing

Cleaning of the machines is done every time when the *beer batch* is changed and hence **Lognormal** is used in delay time to construct various distributions for replications. However, *periodic* cleaning will be done after every *shift* where each shift will last for 8 hours in a day. While the repairing is carried out using **"Weibull"** data distribution as a downtime in maintenance/repair .





6) **Verification / validation**

There are numerous techniques used to perform the verification & validation of simulation models. Some of them might be implemented depending upon the nature of the simulation project as followed;

- Tracing the intermediate results and comparing them with observed outcomes.
- Checking the simulation model output using various input combinations.
- Comparing final simulation results with analytic results based on production runs.

1. Verification:

- The simulation model has an input schedule of discrete inputs throughout the 24 hour day span depending upon the type of beer in the batch and quantity of batch.
- The logical error had occurred while creating the model in the case of application of fast/slow cooler. The supply at some of the instances boosted more than 500 lit. in a single batch, however, any of the cooler could not manage to occupy more than 400 lit. / 500lit. respectively. It was considerable to use a combination of fast & slow cooler by splitting the utilization, as capacity of coolers & quantity of agent could be considered as prominent problem solvers while concluding the scenario.
- Input data of 35 records was fed to the simulation module in order to evaluate the practical utilization of various resource/service units, time taken by the resources/service blocks to process and time taken by the agent to move from the source until sink.
- In order to verify the model, debugging has to be done to locate minimal bugs. Distinct experiments were run generating random seed and multiple replications.
- The model represented the accurate outcome for each basic run with the unified amount of resources and therefore, the data was manipulated and stressed to verify the scenario after increase in demand. However, with an increase in capacity of demand, it could be concluded that the same setup would not be optimal to pursue in the upcoming successive years.
- The severe bottlenecks were recorded in the units such as Fermentation block, Fast cooler, Filtering & packaging (boxing) block. (Charts explaining the situation is showcased under section 7 & 8)
- In order to overcome this real-time scenario of higher demand in future years, some production runs are done with an increase in quantity of resource/service units to satisfy the requirements per demand.
- This sensitivity analysis on the data gave us a brief idea about bottlenecks and distinct production runs helped in evaluating & tracking those bottleneck issues.

2. Validation:

- Validation was done on the basis of evaluation of KPIs assumed and listed in order to solve bottleneck situations. After evaluating the KPIs from distinct experimental production runs, ideal measurements were calculated and were compared with the data from previous runs.
- Furthermore, the calculations based on KPIs were identified and compared with that of collaborated groups and made sure, even exceptions are handled.
- Based on simulations and values extracted from experiments and their higher increase in demand, it could be possibly suggested for Beerlicious to develop the model with respect to accommodate new resource units or increase the capacity of existing units.
- From the below highlighted data in excel, it can be seen that the subtle increase in demand of beer is noticed from **Green** - **yellow** to **Red** in terms of 5% gradual growth.
- It is very well suggested based on validations that management may start on an action plan for expansion of desired resource units by 2024 as it may take upto 1 year setting up the infrastructure making them ready for the situation of severe bottleneck in the year 2025. However, the suggestion based on expansion, is regardless of the effective cost behind the installation of the new setup.

1							Increase in batch quantity per year				
2	BatchBeer	Arrival	Type	Packaging	Box Size	Quantity (2020)	2021	2022	2023	2024	2025
3	1	6/15/2020 0:00	C	Small Bottle	6	300	315	330.75	347.2875	364.651875	382
4	2	6/15/2020 0:30	C	Big Bottle	24	800	840	882	926.1	972.405	1021.02525
5	3	6/15/2020 1:30	C	Small Bottle	6	200	210	220.5	231.525	243.10125	255.2563125
6	4	6/15/2020 2:00	B	Can	6	800	840	882	926.1	972.405	1021.02525
7	5	6/15/2020 3:00	A	Can	24	700	735	771.75	810.3375	850.854375	893.3970938
8	6	6/15/2020 4:00	D	Can	6	400	420	441	463.05	486.2025	510.512625
9	7	6/15/2020 4:40	C	Small Bottle	6	400	420	441	463.05	486.2025	510.512625
10	8	6/15/2020 5:20	A	Small Bottle	24	600	630	661.5	694.575	729.30375	765.7689375
11	9	6/15/2020 6:15	A	Big Bottle	24	200	210	220.5	231.525	243.10125	255.2563125
12	10	6/15/2020 6:45	A	Can	24	700	735	771.75	810.3375	850.854375	893.3970938

7) Scenarios / experimental study

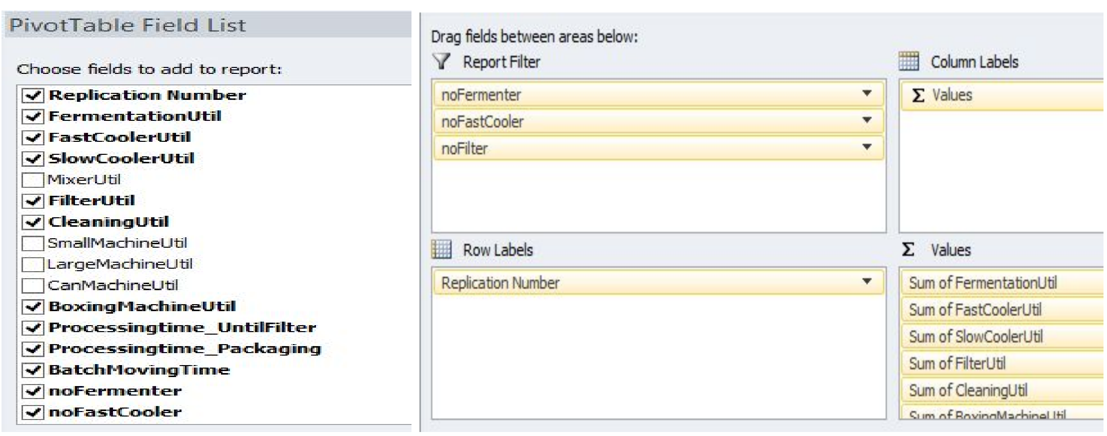
The experimental study is done based on the application of simulation to perform in current and future state. The simulation model remains unchanged for the sake of experiment but the sensitivity analysis is carried out on the same model using different planned and unplanned scenarios. However, the respective simulation study revolves around the implementation of experiments based on differences in commercial demand of certain types of beer. It is assumed for the respective study that the demand is seen to gradually increase in coming years with the rate of 5%. For this instance, parameter variation experiments were taken into account in order to generate the steady state average values. The experiment study section here reviews the data from the respective practiced experiments and showcases different trends when the demand is marginally high.

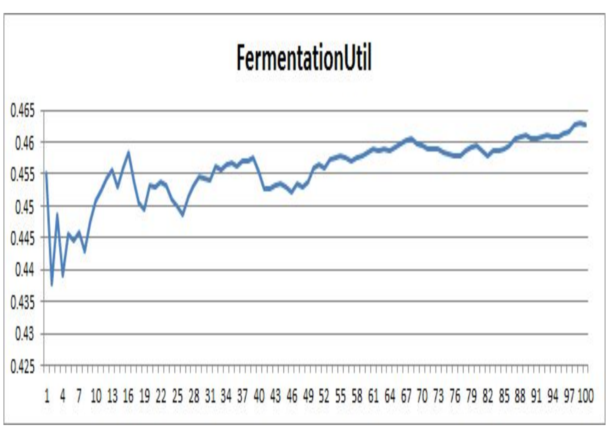
In order to get started, the data is manipulated in the form of a Pivot table as shown below. The filters have to be set depending upon the variation in resources, the user has to vary the later values in order to evaluate the change in elapsed time or cumulative utilization.

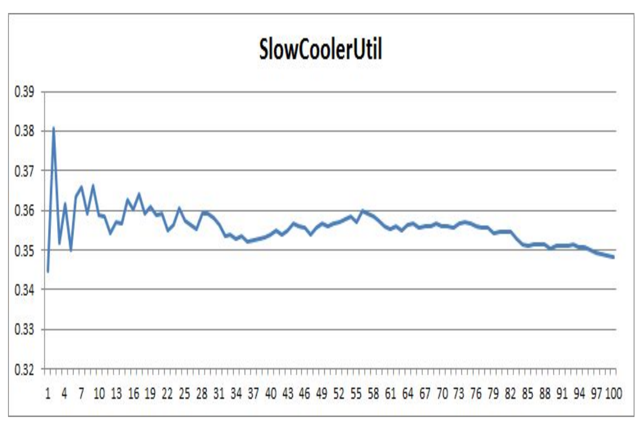
noFermenter	1
noFastCooler	1
noFilter	1

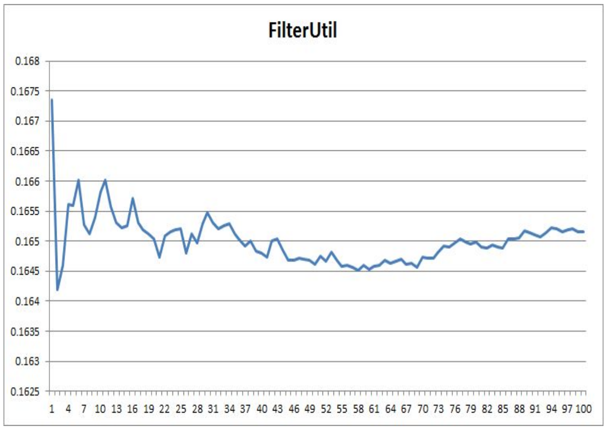
Row Labels	Sum of FermentationUtil	Sum of FastCoolerUtil	Sum of SlowCoolerUtil	Sum of FilterUtil
2	0.455255688	0.571763322	0.34454436	0.167344606
7	0.420228072	0.587562069	0.417029828	0.161036058
11	0.470058503	0.499716811	0.294179036	0.165424038
18	0.411093518	0.563897742	0.390646414	0.16862183

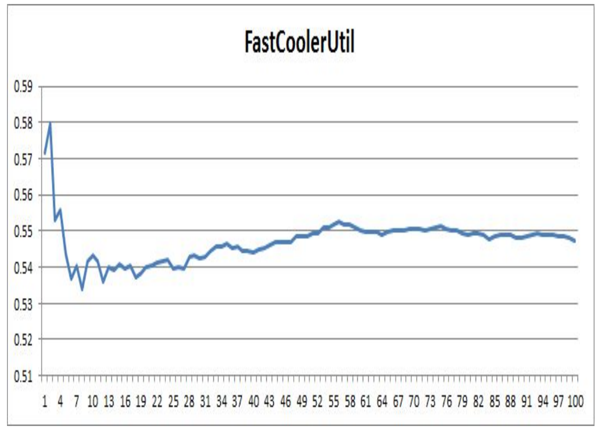
After stating the filters, the row labels & value has to be set to generate the required columns based on the value, user has chosen as shown below. The below values are then moved to another sheet to calculate the successive average of the utilization/resource or time. Once the data is updated with average values, simple plotting can be done based on the preference of the resources, the utilization or the elapsed time is calculated. Below are some of the charts, displaying the utilization of the resources and the process time depending upon those resources to run the whole set of replications.

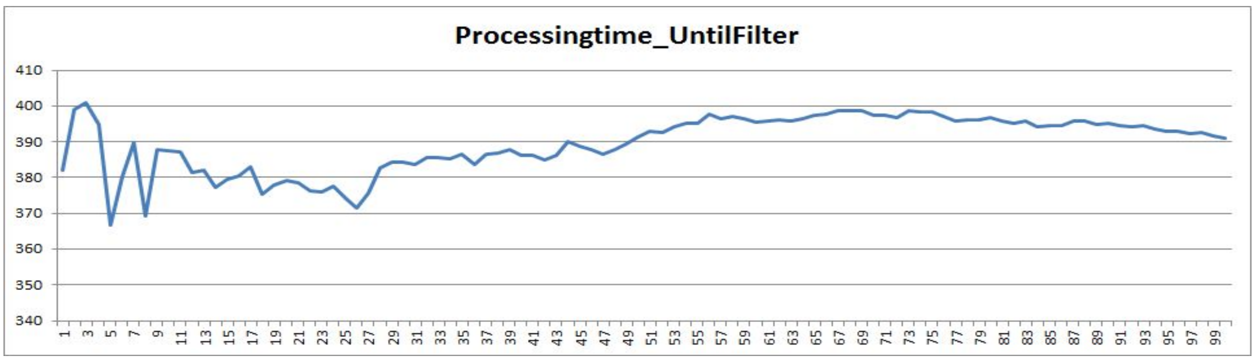


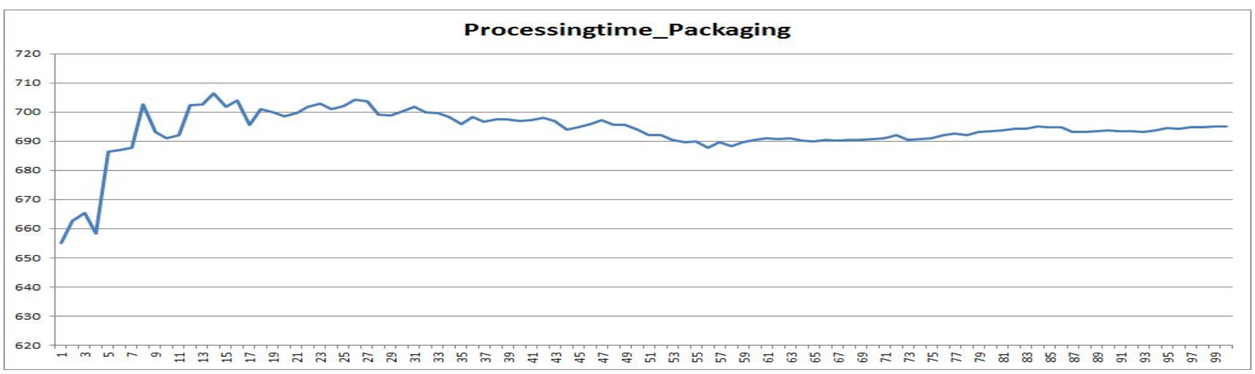


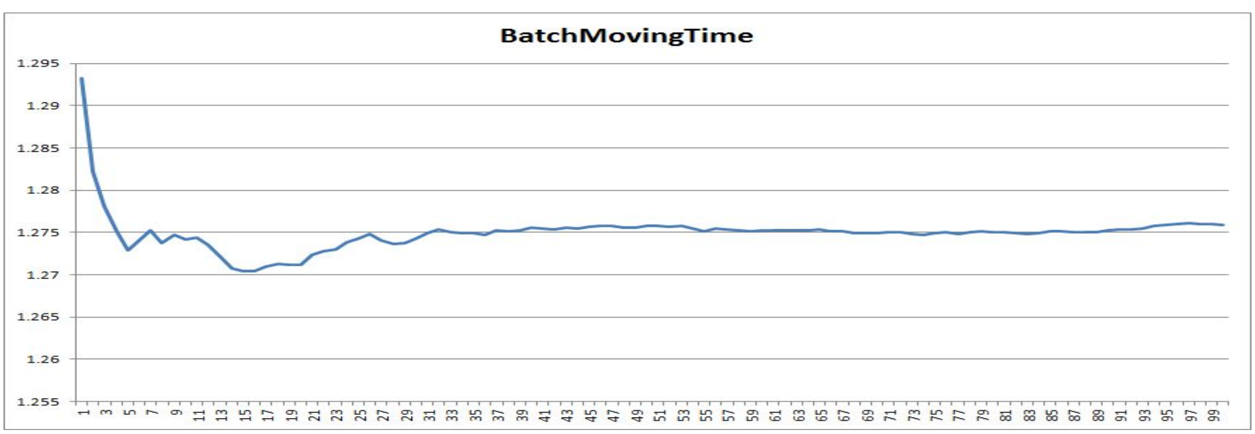



FilterUtil
0.168
0.1675
0.167
0.1665
0.166
0.1655
0.165
0.1645
0.164
0.1635
0.163
0.1625


FastCoolerUtil
0.59
0.58
0.57
0.56
0.55
0.54
0.53
0.52
0.51


Processingtime_UntilFilter
410
400
390
380
370
360
350
340


Processingtime_Packaging
720
710
700
690
680
670
660
650
640
630
620


BatchMovingTime
1.295
1.29
1.285
1.28
1.275
1.27
1.265
1.26
1.255

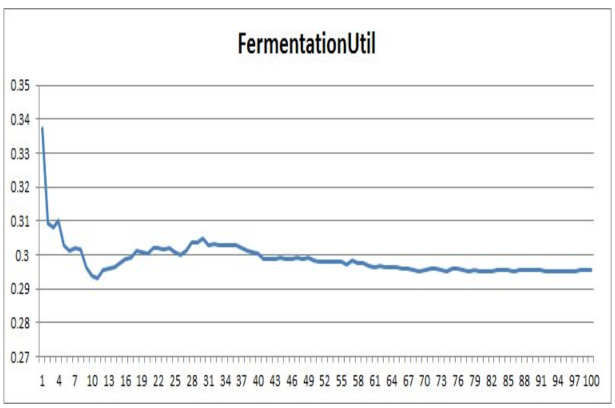
The above charts were drawn and plotted with respect to the current scenario of the market demand.

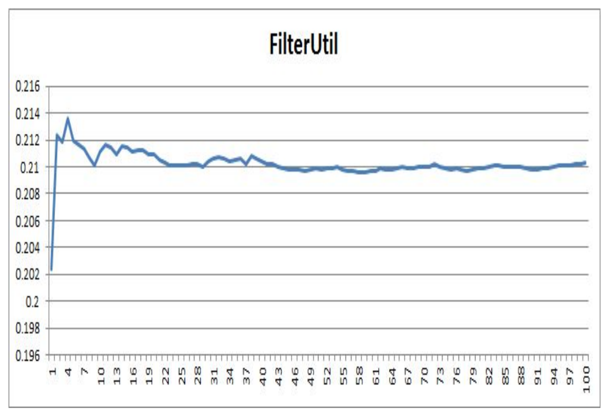
Below analysis involves the inclusion of the recommended resource units for the future state to handle the remarkable growth in demand. In order to attain this future state of the model, the experiment is run again with 100 replications to showcase the important features with increase in the quantity of desired resources and stressing the data by increasing the demand by 5% recurring growth to attain the outcome of the state as of in 2025 for the simulation model.
Pivot table is now updated for resources to be taken as 2 as shown below;

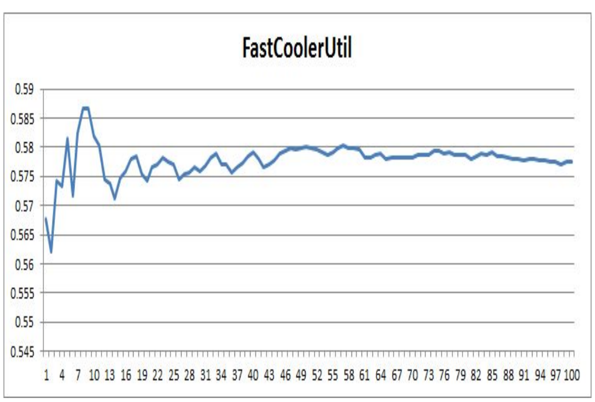
noFermenter	2	
noFastCooler	2	
noFilter	2	
Row Labels	**Sum of FermentationUtil**	**Sum of FastC**
410	0.337337676	0.4
415	0.281417837	0.4

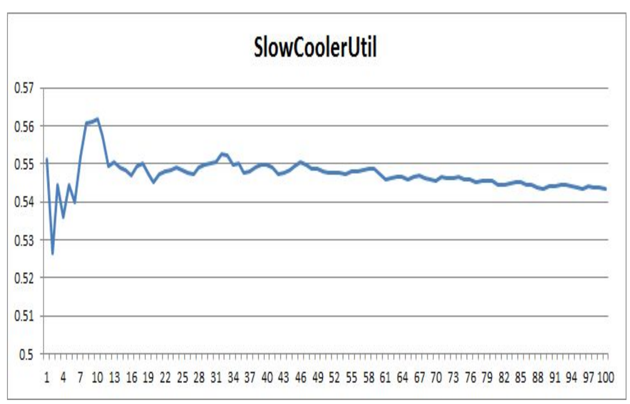
Keeping the other values such as filters, rows, etc to be the same, the data is extracted & averaged successively to find the steady state average values of the desired resources and to verify the utilization of the resources to the ones from the previous runs.

The charts are shown below for respective resources and therefore, data can be compared for the new run with respect to the old production run.

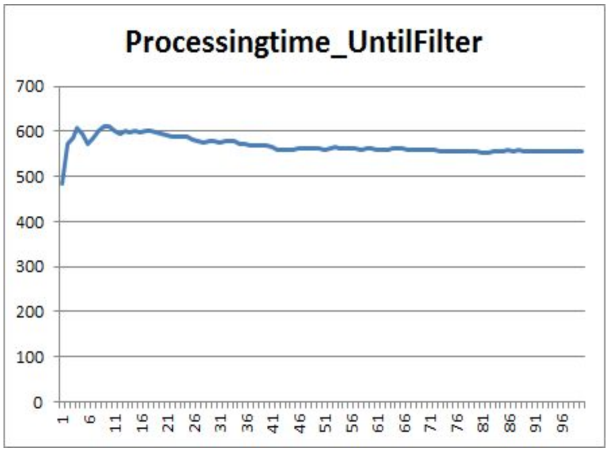


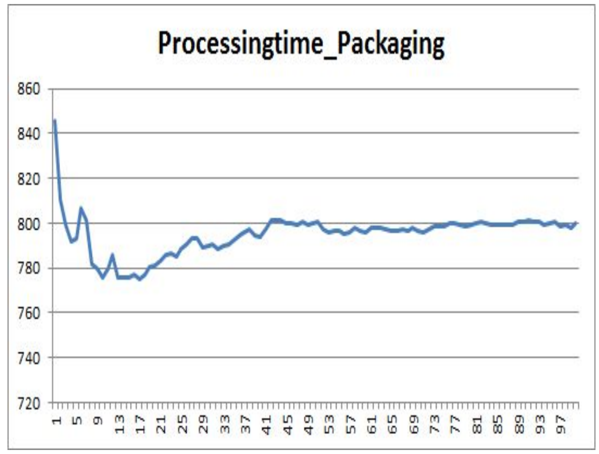


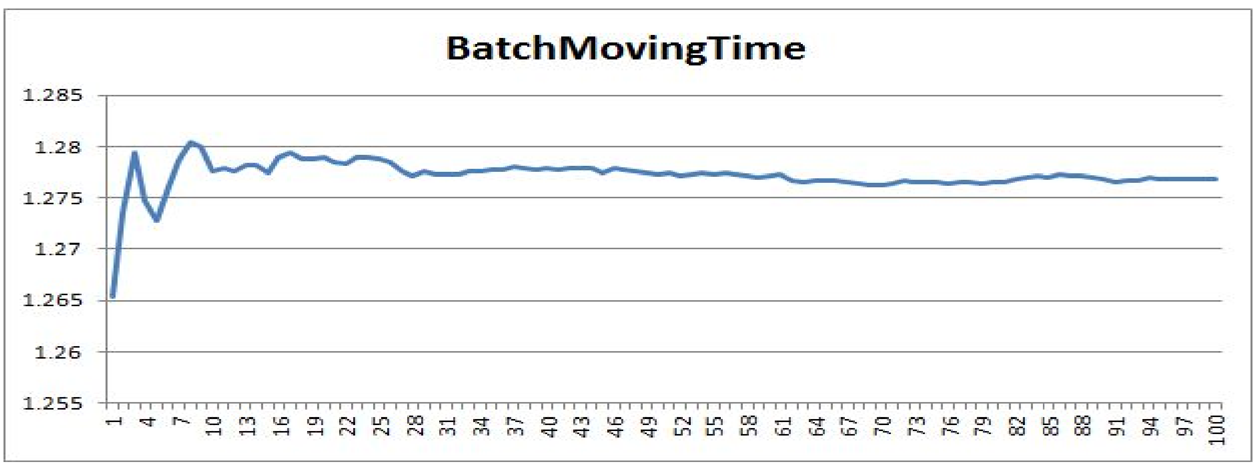




However, when the charts from these respective runs is compared to the earlier, there is a certain decline in utilization of resources and therefore, the processing time can be seen reduced when compared to early state. Hence, it would be recommended to use 2 units of fermenter, 2 fast coolers (maybe replace the old cooler with a fast one) and implementation of another filter (per requirement) per discussed in the report. However, it is to be considered that the experiments are done based on an analogy and are regardless of the finance behind the installation of new resources, maintenance charges and the marginal revenue it will generate by increasing the supply in the nearer future.







8) Output analysis

Below are the output charts based on our simulation runs of the project model, the model output charts represents the overall/individual performance of the resources (utilization, elapsed time evaluation, segregated/cumulative moving time)

Starting from top, the utilization of each resource block until the filtering process is displayed in fig. (Resource Utilization Until Filtering), resource utilization of individual processes such as (Small bottle, Large bottle & Can) is shown under fig. (Resource Utilization Packaging) including the cumulative processes of bottling, capsuling & labeling. Utilization of boxing is shown below in fig (Boxing).

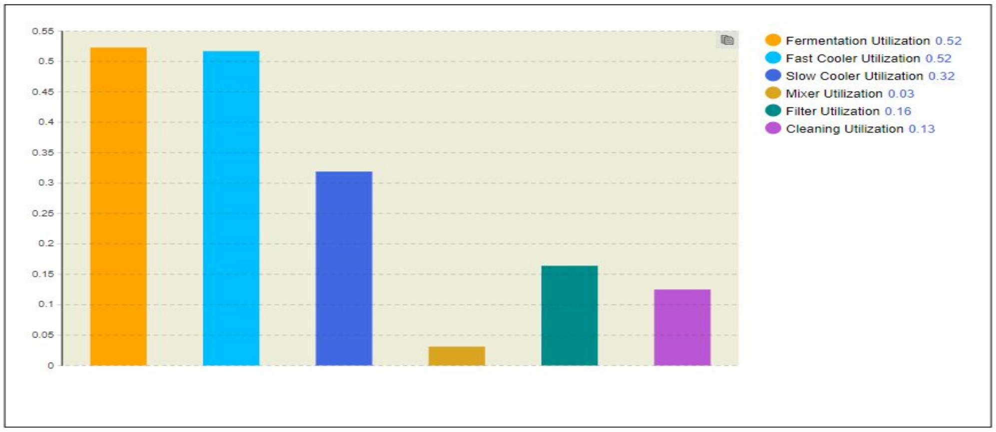
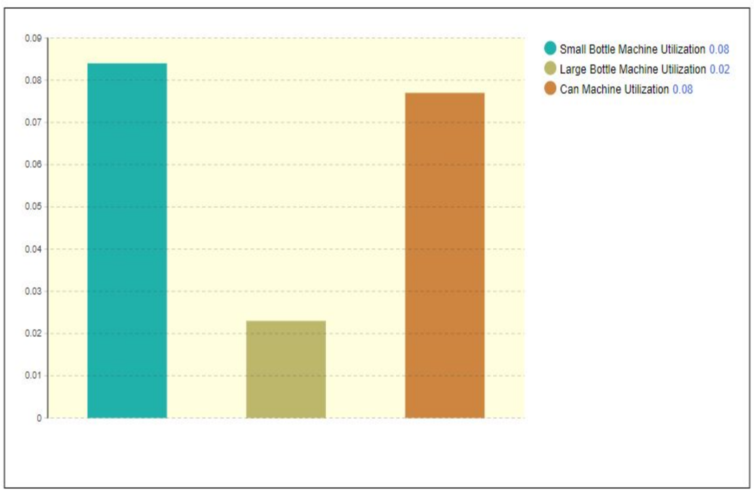


Fig. Resource Utilization Until Filtering



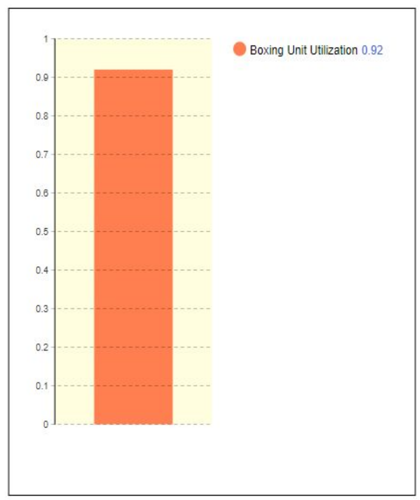


Fig. Resource Utilization Packaging & Boxing

In order to attain our main goal, it is essential to validate the bottlenecks within the system, hence we illustrated the overall time taken by each process (*fig: Process Time of a Resource*) and the total moving time taken by the batch (*fig: Batch Moving Time in individual resource*) moving from boiler unit to packaging unit. (*fig: Packaging & Boxing Process Time*) is used to visualize the time distribution in the packaging section considering it to be cumulative (Bottling, Capsuling & Labeling). The respective figure defines the individual packaging time required by (Small bottle/Large Bottle/Can) to process through (Bottling, Capsuling & Labeling).

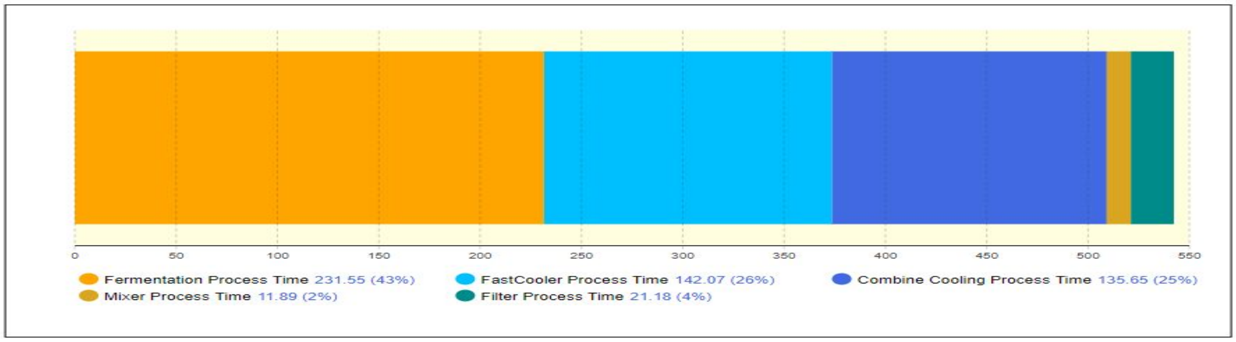
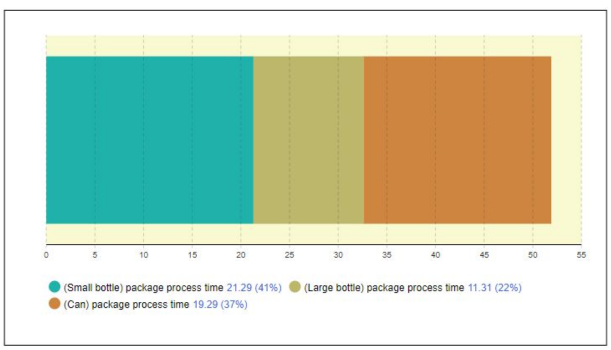


Fig. Process Time of a Resource

Fig. Batch Moving Time in individual resource



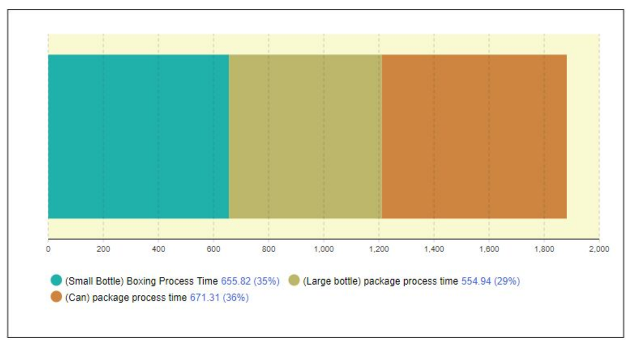
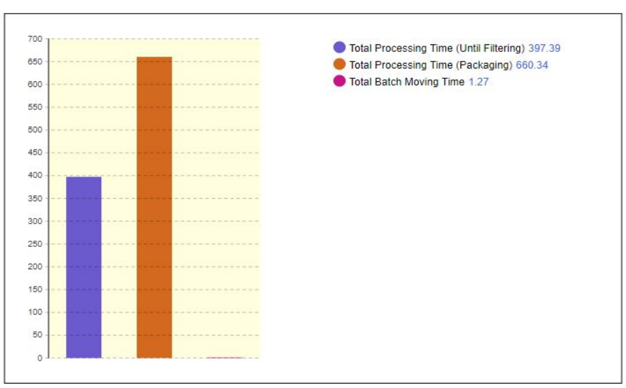


Fig. Packaging & Boxing Process Time



We can observe that the packaging takes more time to process the batch in the production as the demand of the **small bottle** and **Can** are higher. However, we recognize in the output analysis that the fermentation and Cooler utilize more time to process a single batch, which concludes the bottlenecks.

Fig. System Dynamic Time