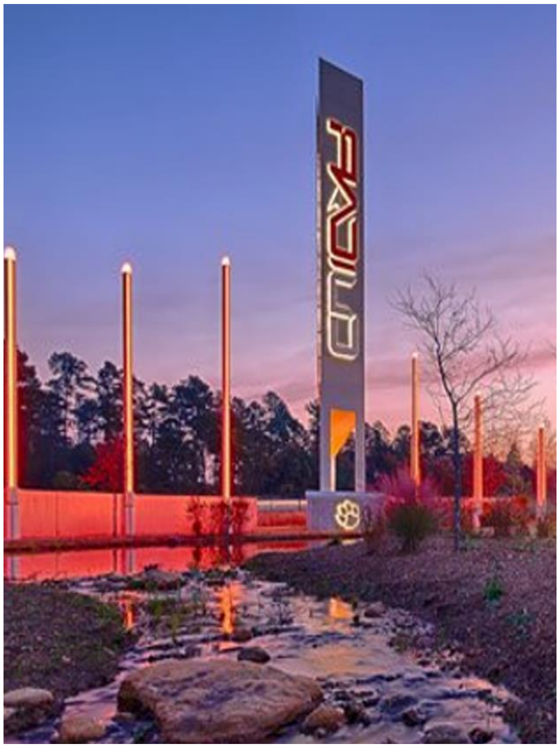

AUE 8330 AUTOMOTIVE MANUFACTURING SYSTEMS

PLANT SIMULATION LAYOUT DESIGN

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Contents

1. EXECUTIVE SUMMARY

1. A succinct and complete statement of the problem.

We don't have a layout for the production floor of bell housing for the new transmission. We are responsible for setting up the production floor for manufacturing a bell housing for the new six-speed, eight-speed, and nine-speed transmissions that we designed for a major automotive OEM while optimizing the process cost and satisfying the demand of 70000 parts/year.

2. What are you trying to do?

We came up with several plans for the process and created various layouts for the plant floor. We tested all the layouts to determine the best performing layout. We started with the simple layout of case1, where neither equipment breakdown nor breaks of personnel nor variability of cycle times are considered. Then we moved on to case 2 where we included maintenance, resources, and variability in the model. In case 3, we aimed at attaining minimum investment cost while maintaining fixed minimum building and equipment setup by optimizing the plant.

3. What are you not trying to do?

We did not include starvation cost to simplify the model; however, we made sure that the production line never starves in any case. We used plant sim only to create a layout and balance the production line. Calculations for takt time and costs involved are not done using Plant sim. Also, we are not monitoring the quality of the parts produced.

4. What are your measure(s) of success?

We termed the model that is most economical while meeting the demand as 'Final optimized layout.' Therefore, our measures of success are least cost and meeting the demand. Also, maximizing the working time by reducing the wait time of machines to fully utilize of the available resources is another measure of success.

5. What tools did you use?

We used the following tools in plant sim software for the production line design.

- Material Flow
- Information Flow
- Resources
- User Interface
- Mobile Units

We used the following tools for results discussion:

- Detailed Statistics Reports from the drain
- Charts to analyze resource utilization

• Bottleneck Analyzers to check bottleneck formation

• We used Microsoft Excel for takt time calculation and cost analysis.

6. What did you find out, and how well did you think you did?

We were able to gain a thorough understanding of the various parameters involved in the process control by simulating actual working conditions and analyzing the manufacturing process in plant sim. Failure rate and resource distribution are not considered in the theoretical line balancing model. In plant sim, we could see the arrangement of different equipment, floor space utilization, resource utilization, availability of machines, arrangement of equipment for material handling, and the plant's productivity. While designing the plant for each of the three cases, we considered the most minute details mentioned earlier. By simulating the actual working environment, we also investigated the impact of all parameters on plant output, resource usage, and cost analysis.

2. MODELING APPROACH.

For the simulation, how did you approach the layout? How did you build the model (what machine elements, what material handling elements, how to account for variability in your cycle times, what were your models of breakdowns and repair times? How did you account for resources?). Explain what is included, or if you didn't include something how that might affect the reality of the result.

Case 1:

a. Machine Tools

Considering the cost and space occupied by the machine (without considering the failure rate), we have selected the following machines.

Assumptions:

1. As the case is ideal, conveyors and workers are not considered.
2. Shift calendar is not assigned considering the ideal case.

Process	Machine Name	Area occupied (sq.m)	Price
Process A	Okuma M3453	5.6	188,000
Process B	Okuma M3453	5.6	188,000
Process C	Okuma T453	9.2	85,000
Process D	Okuma M3453	5.6	188,000

Methods used:

```
if @.origin=.MUs.six_speed
    ProcessB1.procTime:=z_triangle(1,380,350,430)
elseif @.origin=.MUs.eight_speed
    ProcessB1.procTime:=z_triangle(1,417,397,457)
elseif @.origin=.MUs.nine_speed
    ProcessB1.procTime:=z_triangle(1,480,455,530)
end
```

```
if @.origin=.MUs.six_speed
    ProcessD.procTime:=z_triangle(1,33,30,38)
elseif @.origin=.MUs.eight_speed
    ProcessD.procTime:=z_triangle(1,36,34,41)
elseif @.origin=.MUs.nine_speed
    ProcessD.procTime:=z_triangle(1,42,40,48)
end
```

```
if @.origin=.MUs.six_speed
    ProcessC.procTime:=z_triangle(1,51,48,56)
elseif @.origin=.MUs.eight_speed
    ProcessC.procTime:=z_triangle(1,59,57,64)
elseif @.origin=.MUs.nine_speed
    ProcessC.procTime:=z_triangle(1,66,64,72)
end
```

```
if @.origin=.MUs.six_speed
    ProcessA3A4.procTime:=z_triangle(1,677,647,727)
elseif @.origin=.MUs.eight_speed
    ProcessA3A4.procTime:=z_triangle(1,750,725,810)
elseif @.origin=.MUs.nine_speed
    ProcessA3A4.procTime:=z_triangle(1,848,823,898)
end
```

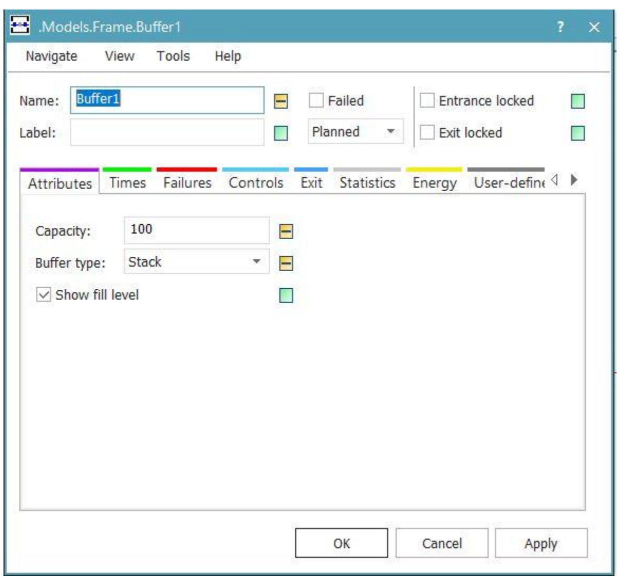
```
if @.origin=.MUs.six_speed
    ProcessB.procTime:=z_triangle(1,380,350,430)
elseif @.origin=.MUs.eight_speed
    ProcessB.procTime:=z_triangle(1,417,397,457)
elseif @.origin=.MUs.nine_speed
    ProcessB.procTime:=z_triangle(1,480,455,530)
end
```

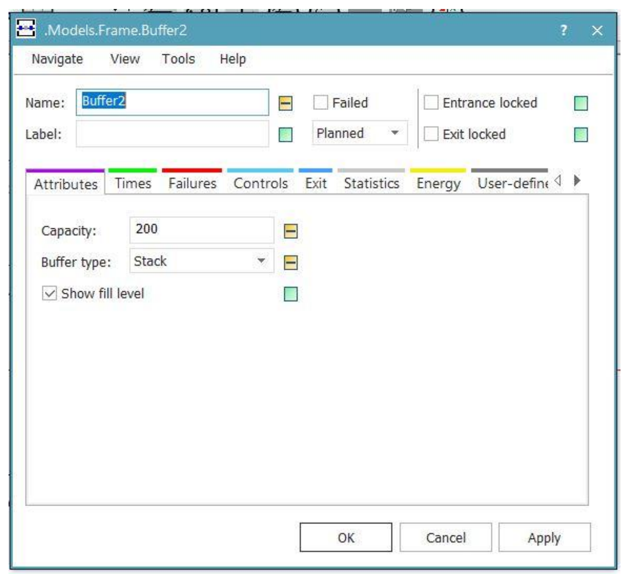
```
if @.origin=.MUs.six_speed
    ProcessA1A2.procTime:=z_triangle(1,677,647,727)
elseif @.origin=.MUs.eight_speed
    ProcessA1A2.procTime:=z_triangle(1,750,725,810)
elseif @.origin=.MUs.nine_speed
    ProcessA1A2.procTime:=z_triangle(1,848,823,898)
end
```

```
Assembly5.procTime:=z_triangle(1,90,70,110)
```

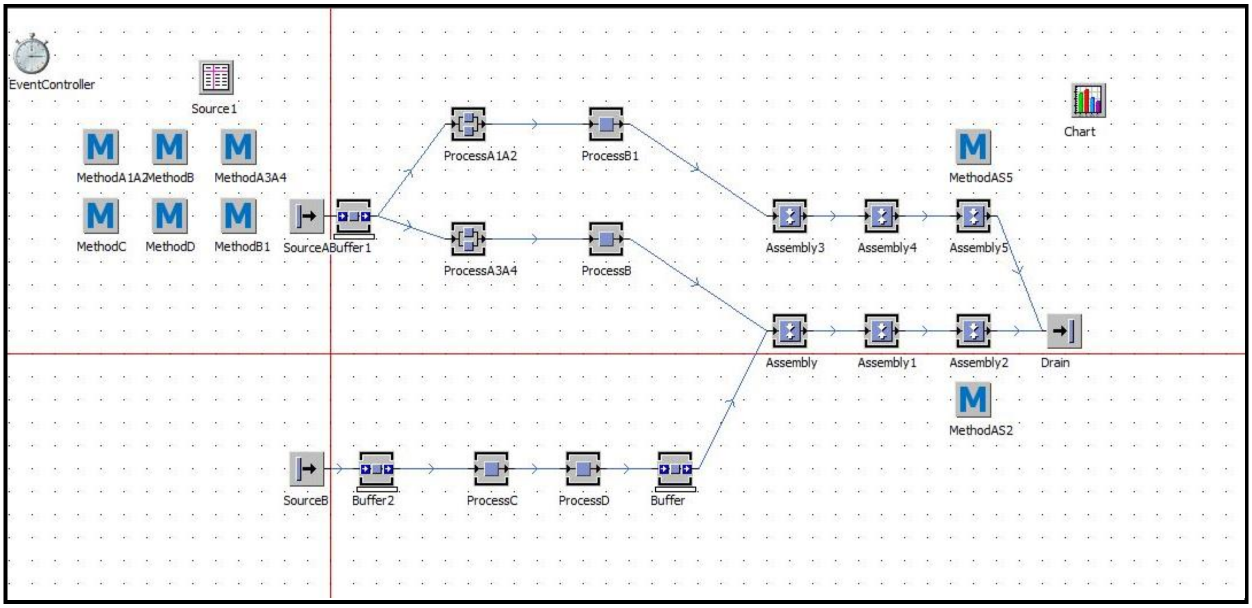
```
Assembly2.procTime:=z_triangle(1,90,70,110)
```

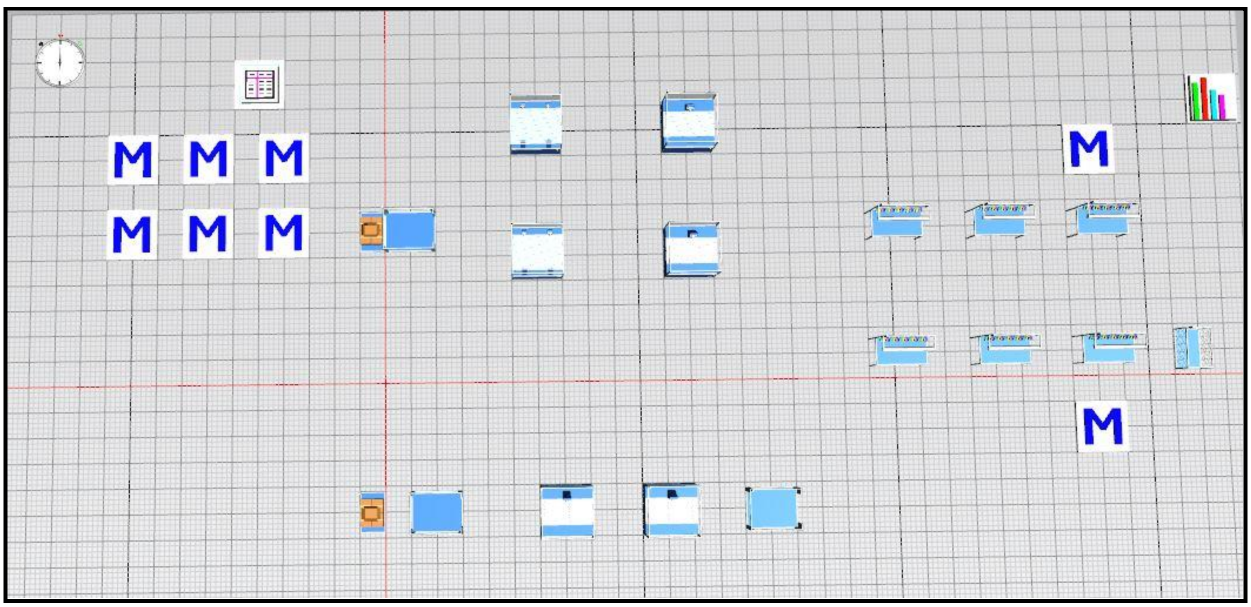
Buffers:





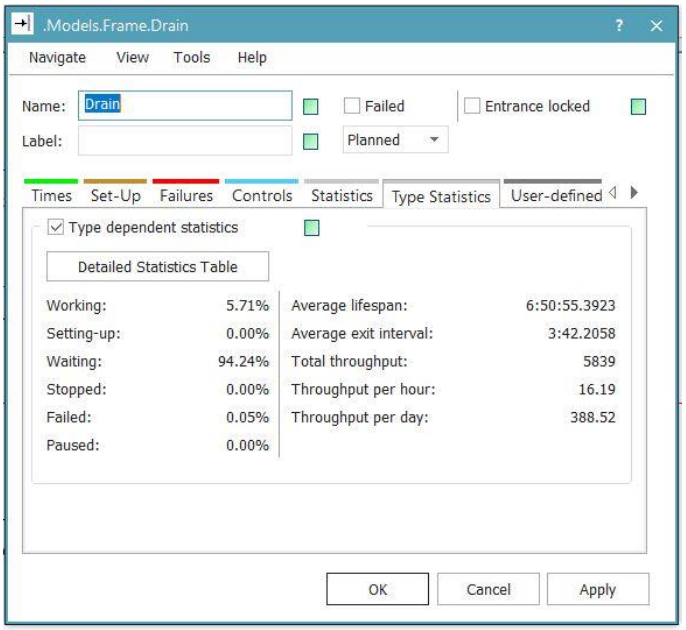
b. Plant Layout:





c. Hourly Production:

For the created plant layout, the hourly production came out to be 16 parts which concludes the daily production as 388 parts.



d. Number of machine tools required:

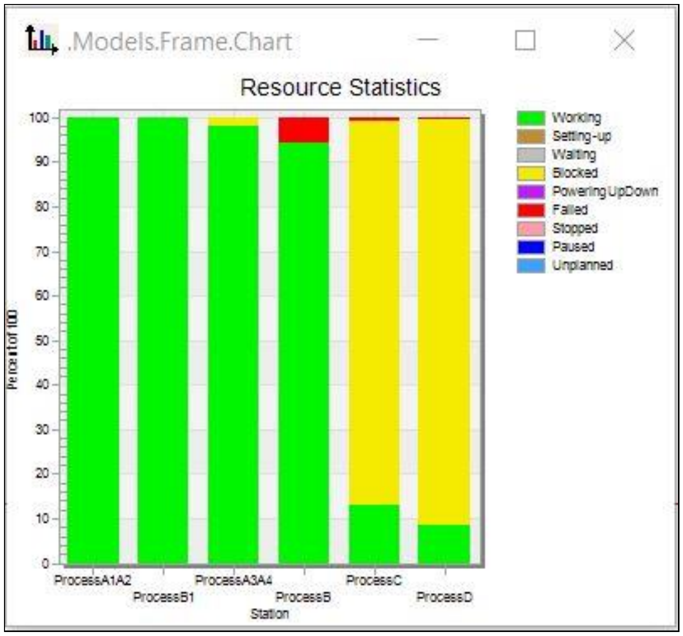
Considering the throughput and yearly production rate, we considered using the following number of machine tools.

Process A	4 stations
Process B	2 stations
Process C	1 station
Process D	1 station
Assembly	6 stations
Buffers	3

The above machine tools are considered to obtain the desired output within the minimum amount of days/time.

e. Resource utilization chart:

Based on the machine tools considered and required output, we have obtained the resource utilization chart.



Case 2:

a. Machine tools

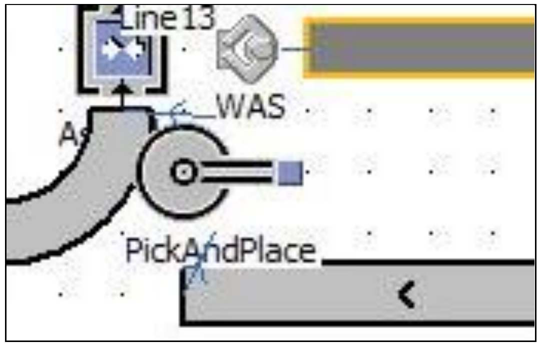
Having considering all the inputs like cost, space occupied, reliability, mean time to repair, and desired output, the following machine tools are taken.

Assumptions:

1. Failures are not considered for the belt conveyors.
2. Assemblies are 100% efficient.

Process	Machine	Area (sq.m)	Cost ($)
Process A	Emcon Mill E850	6.5	193,000
Process B	Emcon Mill E850	6.5	193,000
Process C	Okuma T453	9.2	85,000
Process D	Emcon Mill E850	6.5	193,000
Pick and place robot	ABB IRB 1600	4	19,504.30

We used material handling elements like ABB IRB 1600 to pick and place the parts and used 2 of them which costs $19,504.30 per each and occupies a space of 4 sq.m. each. Conveyor belts are also used to distribute the parts.



Methods:

```
if @.origin=.MUs.six_speed
    ProcessD.procTime:=z_triangle(1,33,30,38)
elseif @.origin=.MUs.eight_speed
    ProcessD.procTime:=z_triangle(1,36,34,41)
elseif @.origin=.MUs.nine_speed
    ProcessD.procTime:=z_triangle(1,42,40,48)
end
```

```
if @.origin=.MUs.six_speed
    ProcessC.procTime:=z_triangle(1,51,48,56)
elseif @.origin=.MUs.eight_speed
    ProcessC.procTime:=z_triangle(1,59,57,64)
elseif @.origin=.MUs.nine_speed
    ProcessC.procTime:=z_triangle(1,66,64,72)
end
```

```
if @.origin=.MUs.six_speed
    ProcessB2.procTime:=z_triangle(1,380,350,430)
elseif @.origin=.MUs.eight_speed
    ProcessB2.procTime:=z_triangle(1,417,397,457)
elseif @.origin=.MUs.nine_speed
    ProcessB2.procTime:=z_triangle(1,480,455,530)
end
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```
if @.origin=.MUs.six_speed
    ProcessB1.procTime:=z_triangle(1,380,350,430)
elseif @.origin=.MUs.eight_speed
    ProcessB1.procTime:=z_triangle(1,417,397,457)
elseif @.origin=.MUs.nine_speed
    ProcessB1.procTime:=z_triangle(1,480,455,530)
end
```

```
if @.origin=.MUs.six_speed
    ProcessA3A4.procTime:=z_triangle(1,677,647,727)
elseif @.origin=.MUs.eight_speed
    ProcessA3A4.procTime:=z_triangle(1,750,725,810)
elseif @.origin=.MUs.nine_speed
    ProcessA3A4.procTime:=z_triangle(1,848,823,898)
end
```

```
if @.origin=.MUs.six_speed
    ProcessA1A2.procTime:=z_triangle(1,677,647,727)
elseif @.origin=.MUs.eight_speed
    ProcessA1A2.procTime:=z_triangle(1,750,725,810)
elseif @.origin=.MUs.nine_speed
    ProcessA1A2.procTime:=z_triangle(1,848,823,898)
end
```

```
Assembly4.procTime:=z_triangle(1,90,70,110)
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```
Assembly5.procTime:=z_triangle(1,90,70,110)
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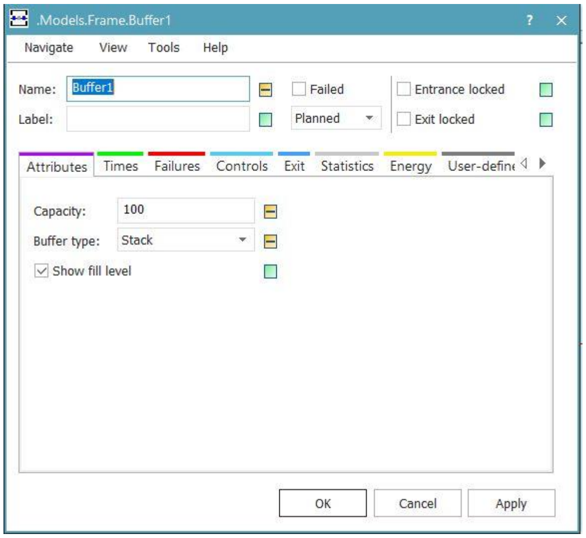
Buffers:


.Models.Frame.Buffer1
Navigate View Tools Help
Name: Buffer1
Failed
Entrance locked
Label:
Planned
Exit locked
Attributes Times Failures Controls Exit Statistics Energy User-define
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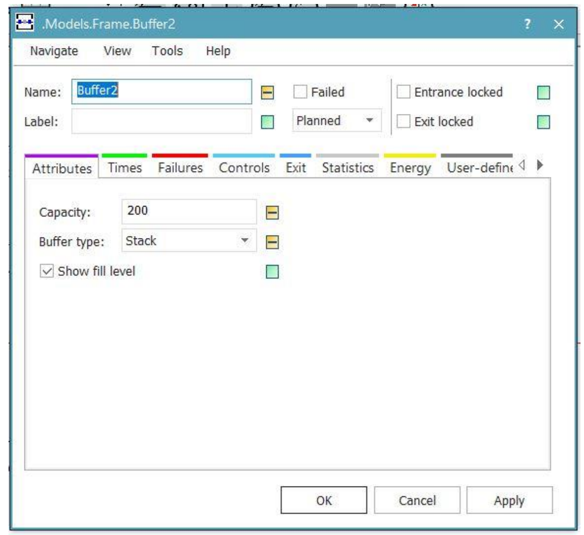
Show fill level
OK Cancel Apply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Navigate View Tools Help
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Entrance locked
Label:
Planned
Exit locked
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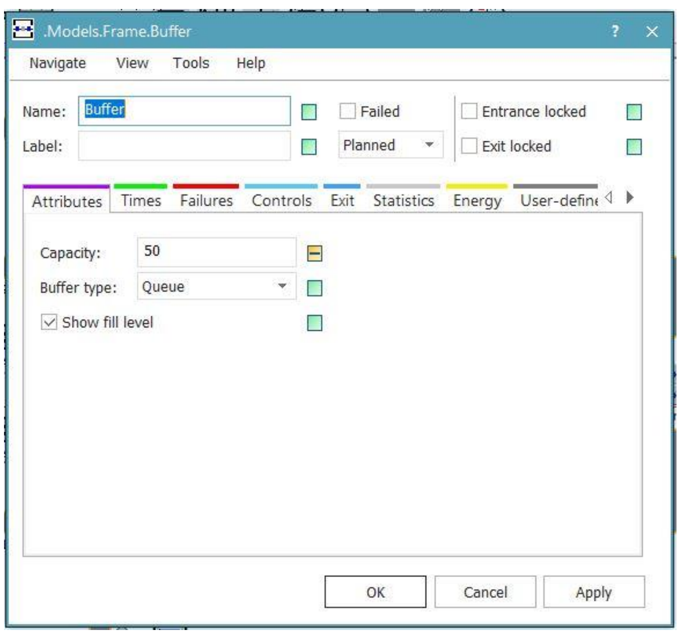
OK Cancel Apply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Name: Buffer
Failed
Entrance locked
Label:
Planned
Exit locked
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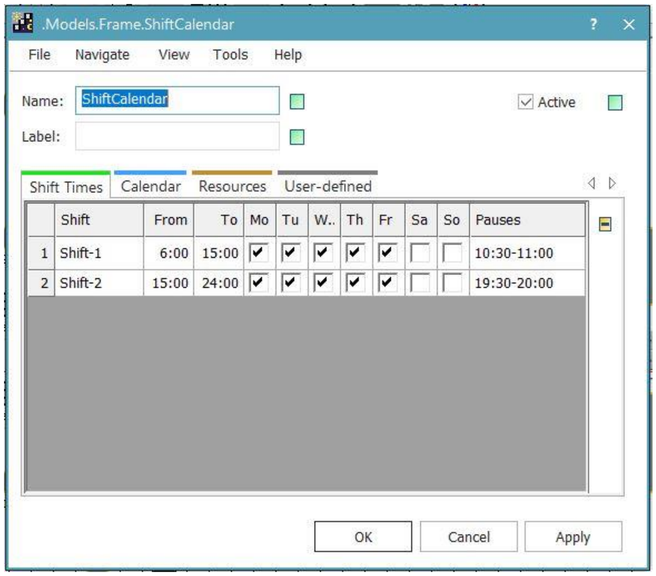
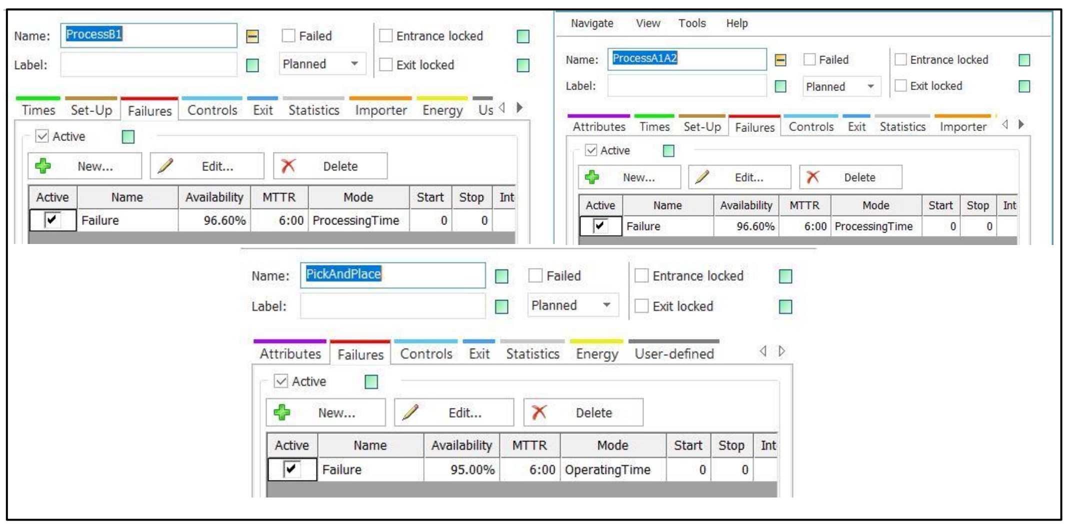
Capacity: 50
Buffer type: Queue
Show fill level
OK Cancel Apply

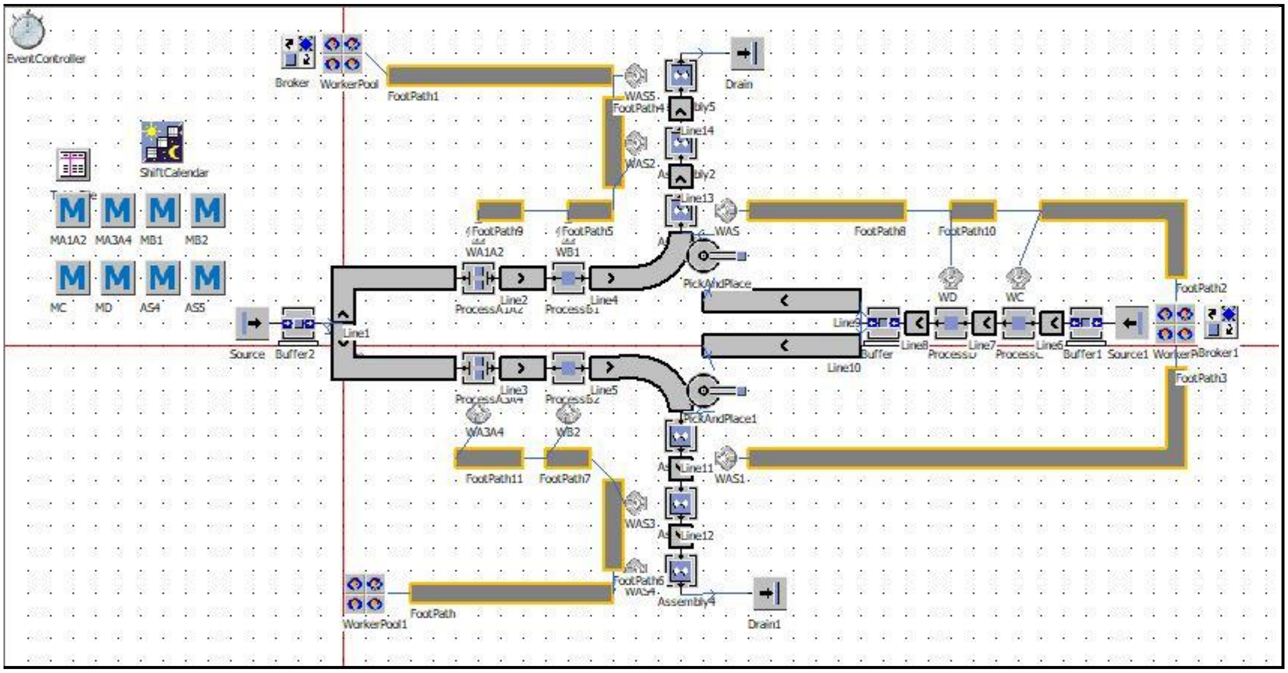
Shift Calendar:

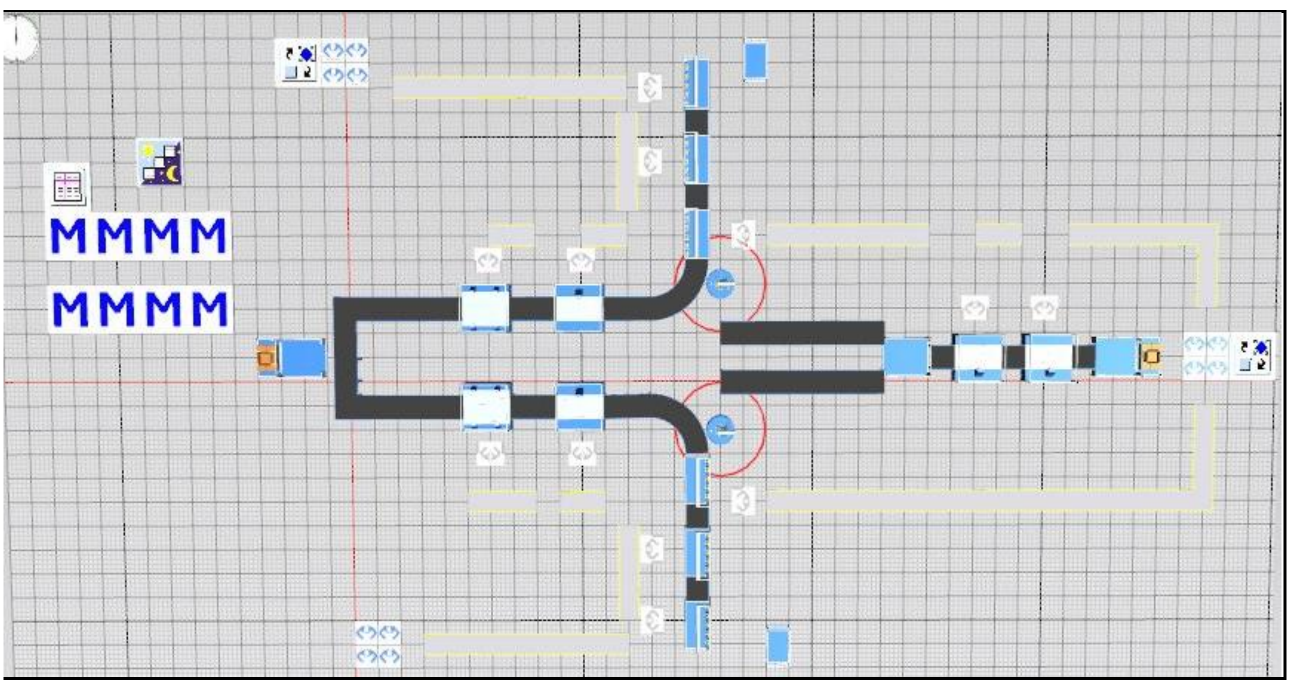


Breakdowns and repair times:



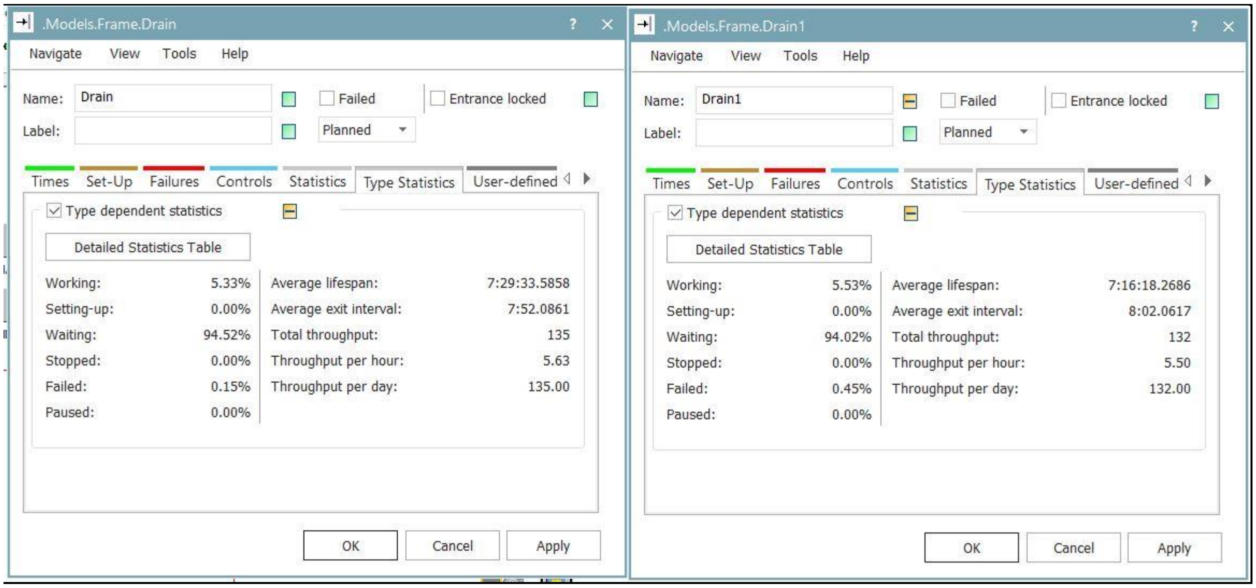
b. Plant Layout:





c. Hourly production:

We put two drains in order to obtain better results and better layout.

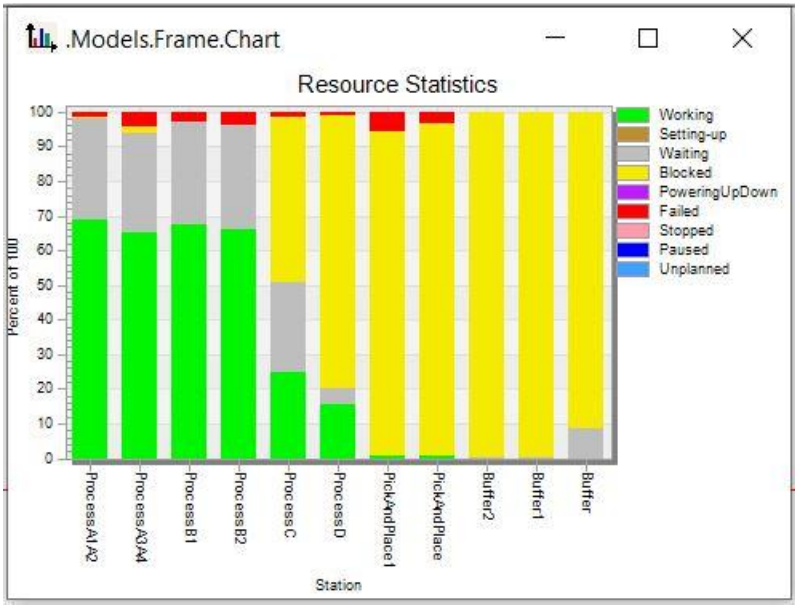


The number of parts produced came out to be 11 parts per hour and 267 parts per day.

d. Number of machines required:

Process A	4 stations
Process B	2 stations
Process C	1 station
Process D	1 station
Assembly	6 stations
Buffers	3
Pick and Place robots	2

e. Resource utilization chart:



__**Case 3:**__

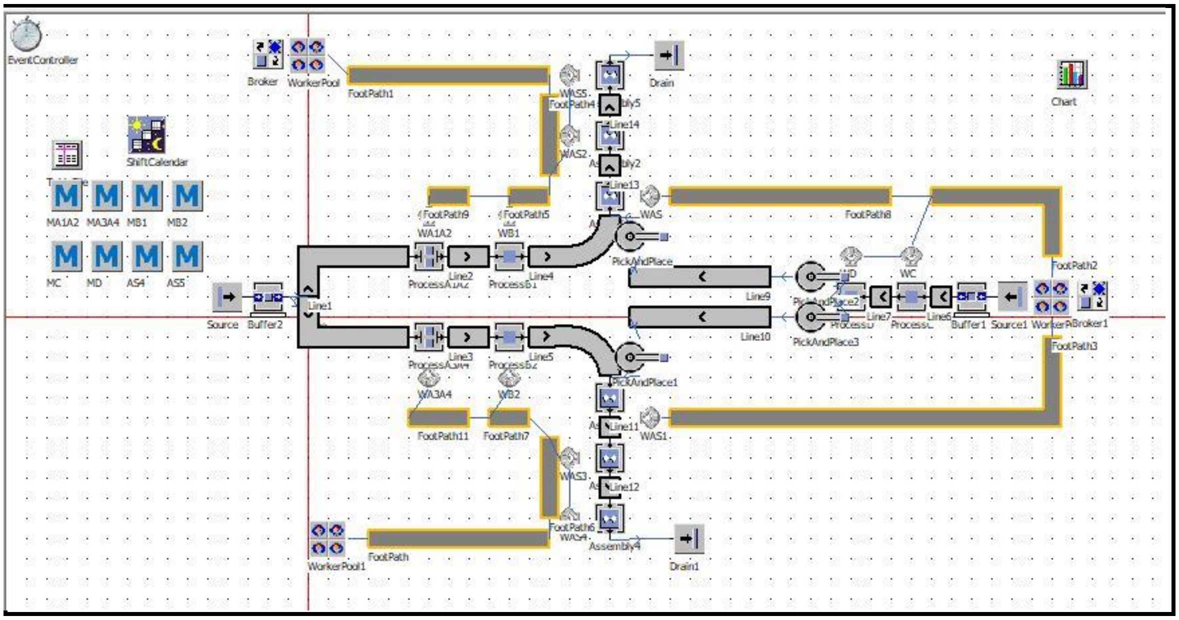
Least investment cost with fixed minimum building and equipment setup.

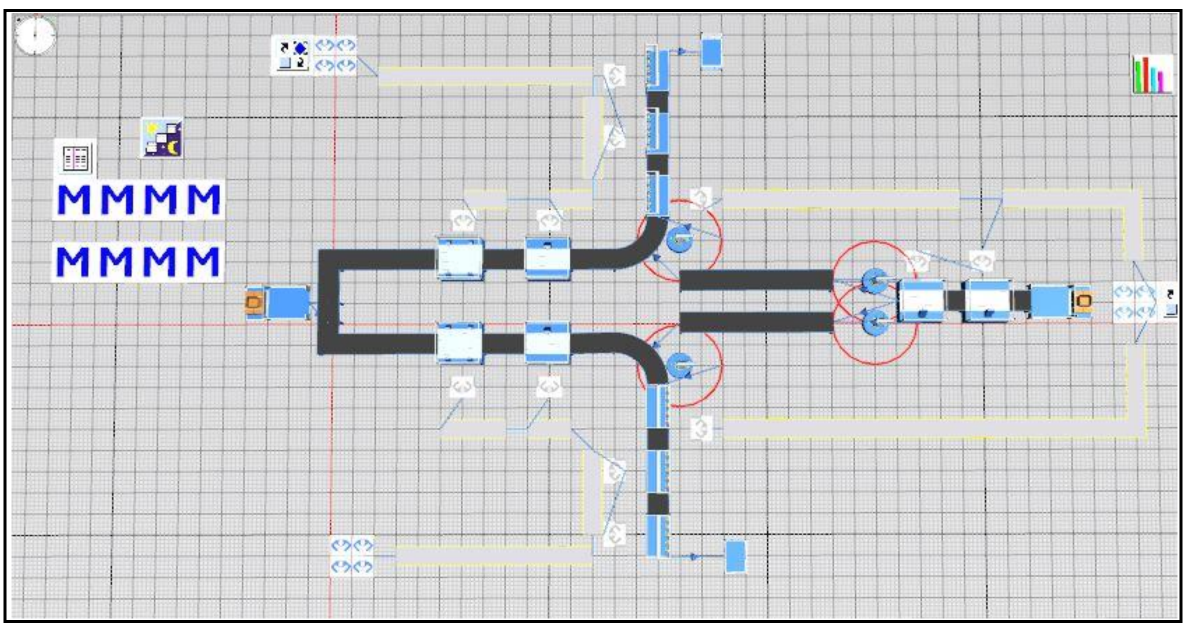
After making up numerous trials, we decided to change some of the machines which cost less, occupies less space and considering failure rates. Process C already had the better machine assigned from the given list of machines. For Process A, B the considered machine in case 2 gives the better output than compared to the other machines that are given in the list. For Process D, we decided to change the machine which has high failure rate compared to the case 2 as it shows no effect on the production rate and is less costly than the one used in case 2. With the change of machine for Process D, we save $11,000.

Also, to optimize the cost, we decreased the labor force. As Process D takes place after Process C and takes less time than C, a common worker has been assigned for both the processes. As we have considered 100% efficiency for the Assemblies, some common workers are assigned to them.

We replaced a buffer with 2 pick and place robots after Process D which reduced our cost significantly that is approximately $2,960,991.

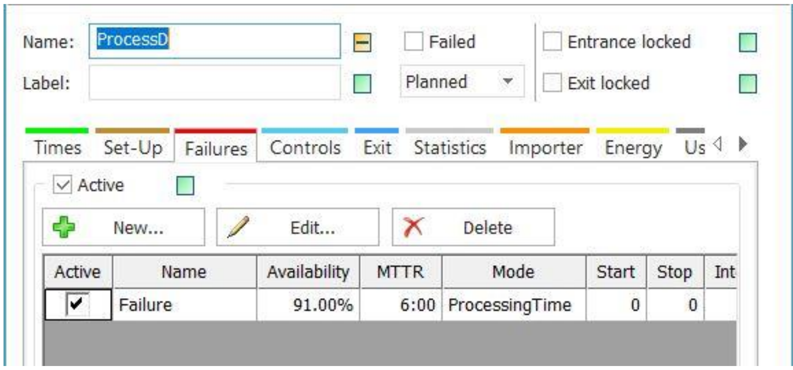
Plant layout:



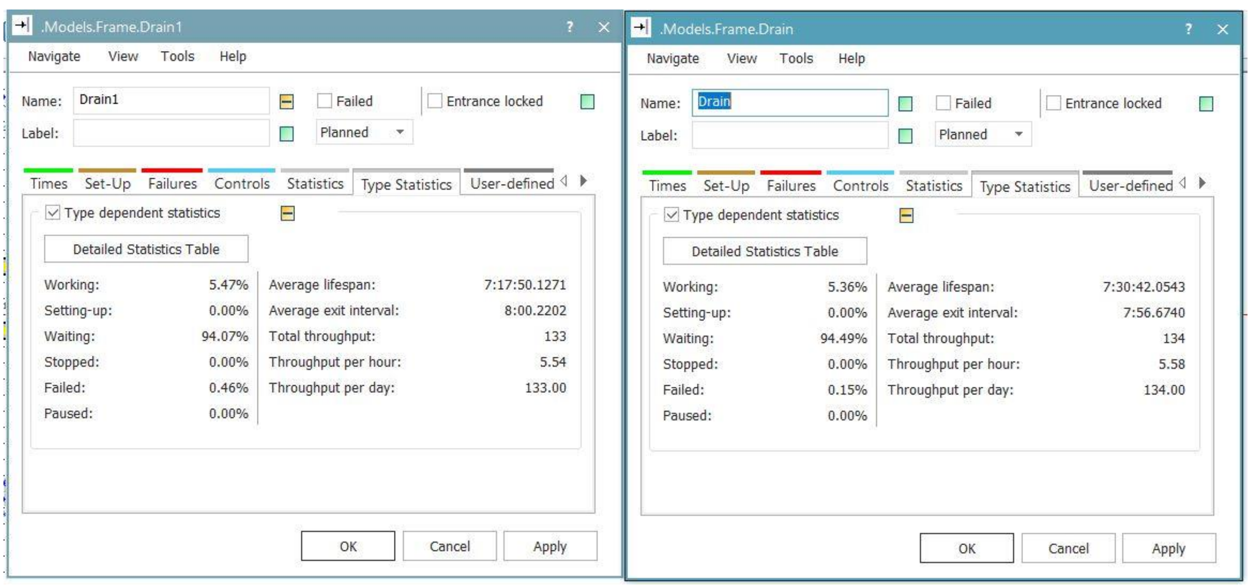


Breakdowns and repair times:

For Process D,

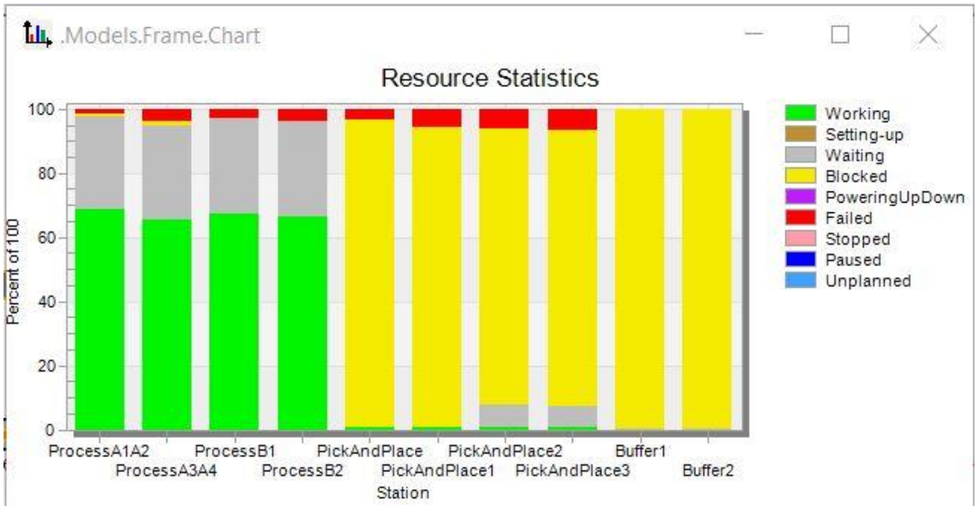


Hourly Production:



It can be seen that there is no change in the production rate and number of parts produced per day is 267.

Resource utilization chart:



3. COSTING.

Calculate a total cost of manufacture for Case 2 and Case 3. Include all cost categories that have been reviewed in class.

Case 2:

1. Model with 8 hours shift time

Cost of Labor:

The following table shows the calculation of takt time.

$$Takt\ time = \frac{Time\ for\ production}{Output\ required}$$

$$Minimum\ number\ of\ machines = \frac{Sum\ of\ avg\ weighted\ process\ time}{Takt\ time}$$

$$Time\ for\ production\ in\ hours\ per\ year = (Shift\ duration - Break) \times No.of\ Shifts \times Working\ days\ per\ week\ \times Weeks\ per\ year$$

Parameter	Value	Unit
No. of shifts	**2**	**-**
No. of hrs/ shift	**9**	**Hours**
No of working days/week	**5**	**Days**
Break/ shift	**0.5**	**Hours**
Total no. of vehicles produced/year	**70000**	**Units/ year**
Takt time	**227.3**	**Seconds**
Sum of average weighted process time	**1278**	**Seconds**
No. of machines required	**6**	**-**

Here, each worker would work for a shift 9 hours with half an hour of break in between. (Break is paid brake). There are two shifts, and the plant works for 5 days a week.

Labor costs are calculated as follows:

$$\begin{aligned}&Labour\ cost\ per\ year\ for\ permanant\ workers\\&\quad = Cost\ per\ hour\ for\ permanant\ workers \times Shift\ duration\\&\quad \times Working\ Days\ per\ week \times weeks\ per\ year\end{aligned}$$

$$\begin{aligned}&Labour\ cost\ per\ year\ for\ temporary\ workers\\&\quad = Cost\ per\ hour\ for\ temporary\ workers \times Shift\ duration\\&\quad \times Working\ Days\ per\ week \times weeks\ per\ year\end{aligned}$$

There are 8 machines in total which run 2 shifts a day and 5 days a week. There are 12 workers working each shift in which 6 are permanent workers and the other 6 are temporary.

Worker type	Total count	Cost/ hr ($)	Cost/ year ($)
Permanent associate	12	20	561600
Temporary associate	12	12	421200

Labor cost = Labor cost/year for temporary workers + Labor cost/year for permanent workers

Therefore, Total labor cost for case2 is $982800

Capital equipment cost of ownership per year (USD)

Assuming,

Annual tax and insurance (TI) = 5%

Annual maintenance allowance (M) = 3%

Annual depreciation allowance (D) = 10%

$C_c = C_{inv} (D+TI+M)$

Process	Machine	Cost/ Annum (USD)
A, B, D	Emcon Mill E850	243180
C	Okuma T453	15300

Cost of other material handling equipment: Equipment cost is calculated using the formula for 'Capital equipment cost of ownership per year' formula.

Process	Item name	No. of units	Capital cost/ year (USD)
Conveyor	Belt- 2m wide	50.24 meters	23512.32
Pick and place	ABB IRB 1600	2	7021.54
Buffer	Vertical storage (20R10C)	1	1530000
Buffer	Vertical storage (10R10C)	1	1080000
Buffer	Vertical storage (5R10C)	1	540000

Cost of shipment

Assuming the number of parts shipped per month to be 6000.

Then, the number of shipments required = 6000/300 = 20 shipments.

Therefore, the total cost of shipment per annum= 20*12*200 = $48000.

We could not include other costs such as material costs, tooling costs and energy costs due to the unavailability of data.

Case 3

Cost of Labor:

The following table shows the calculation of takt time.

$$Takt\ time = \frac{Time\ for\ production}{Output\ required}$$

$$Minimum\ number\ of\ machines = \frac{Sum\ of\ avg\ weighted\ process\ time}{Takt\ time}$$

$$Time\ for\ production\ in\ hours\ per\ year = (Shift\ duration - Break) \times No.of\ Shifts \times\ Working\ days\ per\ week\ \times Weeks\ per\ year$$

Parameter	Value	Unit
No. of shifts	2	-
No. of hrs/ shift	9	Hours
No of working days/week	5	Days
Break/ shift	0.5	Hours
Total no. of vehicles produced/year	70000	Units/ year
Takt time	227.3	Seconds
Sum of average weighted process time	1278	Seconds
No. of machines required	6	-

Here, each worker would work for a shift 9 hours with half an hour of break in between. (Break is paid brake). There are two shifts, and the plant works for 5 days a week.

Labor costs are calculated as follows:

$$Labour\ cost\ per\ year\ for\ permanant\ workers = Cost\ per\ hour\ for\ permanant\ workers \times Shift\ duration \times Working\ Days\ per\ week \times weeks\ per\ year$$

$$Labour\ cost\ per\ year\ for\ temporary\ workers = Cost\ per\ hour\ for\ temporary\ workers \times Shift\ duration \times Working\ Days\ per\ week \times weeks\ per\ year$$

There are 8 machines in total which run 2 shifts a day and 5 days a week. There are 9 workers working each shift in which 6 are permanent workers and the other 6 are temporary.

Worker type	Total count	Cost/ hr ($)	Cost/ year ($)
Permanent associate	9	20	421200
Temporary associate	9	12	315900

Labor cost = Labor cost/year for temporary workers + Labor cost/year for permanent workers
Therefore, Total labor cost for case3 is $737100

Capital equipment cost of ownership per year (USD)

Assuming,
Annual tax and insurance (TI) = 5%
Annual maintenance allowance (M) = 3%
Annual depreciation allowance (D) = 10%
$C_c = C_{inv} (D+TI+M)$

Process	Machine	Cost/ Annum (USD)
A, B	Emcon Mill E850	208440
C	Okuma T453	15300
D	Matsuura MC800	32760

Cost of other material handling equipment: Equipment cost is calculated using the formula for 'Capital equipment cost of ownership per year' formula.

Process	Item name	No. of units	Capital cost/ year (USD)
Conveyor	Belt- 2m wide	50.24 meters	23512.32
Pick and place	ABB IRB 1600	4	14043
Buffer	Vertical storage (20R10C)	1	1530000
Buffer	Vertical storage (10R10C)	1	1080000

Cost of shipment

Assuming the number of parts shipped per month to be 6000.

Then, the number of shipments required = 6000/300 = 20 shipments.

Therefore, the total cost of shipment per annum= 20*12*200 = $48000

We could not include other costs such as material costs, tooling costs and energy costs due to the unavailability of data.

The costs which are not included are:

a. Tooling Cost
b. Material Cost
c. Electricity

4. CONCLUSIONS:

a. **Based on your findings, what do you recommend?**

Based on the above plant simulation model, our team would recommend the modal case 3 which is optimized plant layout which is like realistic modal where it has failure rates, maintenance, efficiency of the workers.

The advised plant design can effectively accommodate the transmission's demand rise, resulting in an expensive condition of production line famine. Because of the resilience of the proposed plant structure, it can also accommodate various auxiliary equipment failures that were not included in modeling, such as machining tools, raw materials, and so on.

Furthermore, the model optimizes the two opposing aspects, cycle time and cost.

b. **What tradeoffs did you consider? Estimate the cost, and support your analysis with assumptions**.

Several trade-offs are examined after obtaining an optimum solution for cases 1, 2, and 3 over several iterations. To accomplish the target output, shift duration, shift number, labor utilization, and so on all play vital roles. With increasing the number of machines and shift time, the overall production increases. Increasing workforce will lead to poor resource utilization and will raise the cost of the process, but at the same time, there should not be a shortage in the total number of workers. Additionally, the availability of the equipment, maintenance, and repair length influences production

While optimizing plant design, we discovered that the number of machines and shift duration were appropriate factors to test with while keeping the number of people necessary to be just sufficient. Multiple models with varying machine counts and shift durations result in the final optimum designs in each situation. While experimenting with these factors, the cost was consistently the goal, with the production demand being the constraint to be met.

The entire cost estimation is best stated in this report's costing section. Given that Situation 3 is the most realistic model, it makes appropriate to discuss costs just for this case. It is assured that the line does not go hungry; otherwise, going hungry might cost millions of dollars. However, this costing model excludes material costs, rework costs, energy costs, inventory costs, tool costs, and so forth.

On the other hand as production experts, we believe that if all of these charges are factored in, the cost will be 1.5 - 1.75 times the predicted cost. This estimate is adequate because material and tool costs are often high. Defective components, quality inspections, and reworking also would increase the cost of the part. Defective parts also create delays, which indirectly contribute to the cost. Inventory costs are anticipated to be negligible when Just-in-Time manufacturing and Lean methods are implemented. The cost of energy is also a substantial component of the entire cost.

To conclude, the value estimates are entirely primarily based totally at the aforementioned judgment, experience, and assumptions, and statistics for the value of materials, rework, tools, energy, and numerous different required gadgets must be received earlier than finalizing the plant layout and implementation, as those range with the aid of using enterprise and different working factors.