

# Simulation of a Real Life Problem in Flexible Manufacturing System without Breakdown and Having Alternate Machines Using SIMUL8

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**Abstract** - In recent days a number of approaches have been made to schedule FMSs using simulation and other analytical tools for studying their effect on the various performance parameters. This paper explores a real-time scheduling operation which uses simulation and dispatching rules for any flexible manufacturing systems. It improves and extends a previous research on simulation-based real-time scheduling by the use of SIMUL8. SIMUL8 is a computer package for Discrete Event Simulation used to simulate and model wide variety issues in flexible manufacturing systems. The performance measures like throughput, machine utilisation and vehicle utilization are studied for a model developed using Simul8. The objective is to comparing and minimizes the makespan when scheduling with various dispatching rules. The parameters like routing out, jobs matrix are studied while developing the models.

**Key Words:** FMS, Dispatching Rule, Job matrix, SIMUL8, Throughput time.

## 1. INTRODUCTION

A manufacturing system is an approach to making products based upon several factors such as how much of the product is needed, how quickly the product must be produced and how unique the product must be to ensure desirable sales. Planning and operating a manufacturing system includes different tasks done by many people. The layout of machines and flow of materials through the plant must be planned. Management and labour must be organized to operate and control the system. To coordinate among all of these activities, manufacturing must be viewed as a system where the action of two or more parts operates together. The model of manufacturing systems consist of four subsystems; input, process, output and control. The system's inputs can be defined as knowledge and skills of people along with tools and materials where as to vary the system inputs, the output, products and by-products, obtained from the process types used [1].

Simulation is the process of building and using a time dependent visual model which entertains every significant step that occurs in the process and every significant interaction between resources involved in a process so as to find insight about the impact of potential decisions on that process. The model shows visually what will happen in the process if changes are made to it and it records performance measures of the system under different scenarios. While selecting a modelling approach the characteristic of the system with respect to the question and the nature of the problems to be tackled have to be considered. More over the simulation model which is frequently used in the field of Manufacturing Systems Engineering (MSE) can be classified as Static and Dynamic Simulation Models, Continuous and Discrete Simulation Model, Stochastic and Deterministic Simulation Model, Parallel and Distributed Simulation [2].

SIMUL8 is advanced software for simulation of discrete events which allows the user for drawing objects directly on the computer window so as to create a visual model of the concerned system. Illustrative objects here may be service points or queues (buffers) in which characteristics of those objects can be defined with respect to their capacity or speed [3]. After complete building of the model of the system a simulation run can be performed. The flow of work items in the system is shown by animation on the screen so as to assured the appropriateness of the model. After the conformation of the structure of the model, a number of trials can be run and the system's performance can be described quantitatively. Quantity of interest may be throughput time average waiting times, utilization of work centres or resources, etc.

## 2. PROBLEM DETAILS

We have to develop a manufacturing system having five different parallel machines which will produce eight work parts of a product sequentially operated for various processing time as indicated in the Table 1 through four different operations [4].

( ) Indicates alternative machines and

- No more new part types are added;
- There is sufficient availability of raw material, tools, jigs and fixtures, pallets;
- Along the AGV path no collisions will occur;
- Operation processing times are deterministic in nature;
- A definite demand should be there for each part type;
- No part will be rejected due to quality inspection(no rework is allowed); and At the start of the simulation experiment all parts must be available for processing.

< > Indicates corresponding machining time.

DATA GIVEN:

Number of machines- 5

Number of operations to be done- 4

Number of part types-8

ASSUMPTIONS:

- There is one machine for each type;
- In a particular time each machine can process only one operation;
- The setup time of machines are ignored;
- Each part type uses all pallets interchangeably;

Table 1 : Processing times for different parts

Part Types	Operation 1		Operation 2		Operation 3		Operation 4	
	m/c	Time(min.)	m/c	Time(min.)	m/c	Time(min.)	m/c	Time(min.)
1	1	15	3	24	5	10	2	30
	(2)	<18>					(1)	<25>
2	2	20	3	10	5	35	4	25
	(3)	<24>	(2)	<16>				
3	5	40	1	25	4	30	2	15
					(3)	<27>		
4	4	30	2	30	5	20	3	25
							(1)	<15>
5	1	10	3	20	2	15	4	30
					(5)	<20>		
6	3	25	2	12	1	25	5	10
	(5)	<20>					(3)	<23>
7	4	35	5	10	1	10	2	15
	(1)	<38>			(4)	<15>		
8	5	15	4	40	3	25	1	20
	(4)	<10>	(5)	<30>				

### 3. SIMULATION STEPS FOR EXPERIMENTATION

As per the given problem, 8 Start points for 8 work types has been created followed by 7 activities out of which 5 are labelled as ‘machine’(m1,m2,m3,m4,m5), 1 as ‘Input’ and 1 as ‘Output’. Each of the Activity has been provided with a Queue (buffer). An Activity named ‘END’ has been created after the output to terminate the simulation.

They are placed as in the order given, Start points →Input→Machines (5)→Output→End. The model has been arranged in the particular order as shown in Fig- 1.

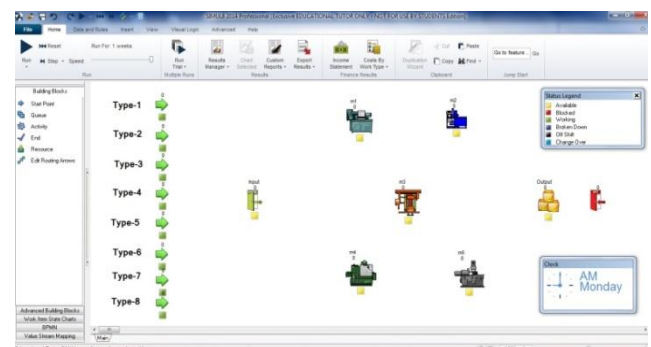


Fig- 1: Line layout of model for given problem

### 3.1 Clock Properties

After creating the model, the Clock properties have been set by double clicking on the clock at the main screen. This allows us to adjust the units of 'time-measurement', and how long to run the simulation. It has been noted that default Time Unit is minutes, and hence processing times etc should be specified in minutes. Default settings start at 9 am and run for 8 hours a day for 5 days. As per the given problem, the clock properties were set as shown in figure 2:

- Time units→Minutes; Time format→ Time Day; View→ Clock Face; Days→ Day;
- Days per week→1;Running Time→ Start Time each day→9:00;Duration of day→08:00

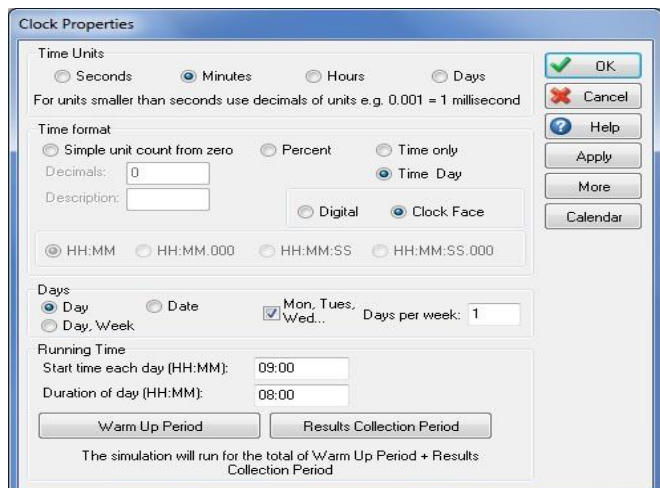


Fig- 2: Clock Properties for the model

### 3.2 Job Matrix

For alternative routing, a Jobs Matrix has to be set. The steps followed for that are as follows. Go to Data and Rules→Click on the Jobs Matrix icon, a dialog box appears named 'Jobs Matrix'→ Fill up the required spaces as per the problem statement as shown in figure 3→ Press OK.

Jobs Matrix				
Work Type	Job	Location	Timing	Change Over
1	1	m1	15	0
1	1	m2	18	0
1	2	m3	24	0
1	3	m5	10	0
1	4	m1	25	0
1	4	m2	30	0
1	5	Output	10	0
2	1	m3	24	0
2	2	m2	16	0
2	2	m3	10	0
2	3	m5	35	0
2	4	m4	25	0
2	5	Output	10	0
3	1	m5	40	0
3	2	m1	25	0
3	3	m3	27	0
3	3	m4	30	0
3	4	m2	15	0
3	5	Output	10	0
4	1	m4	30	0
4	2	m2	30	0
4	3	m5	20	0
4	4	m3	25	0
4	4	m1	15	0
4	5	Output	10	0
5	1	m1	10	0
5	2	m3	20	0
5	3	m2	15	0
5	3	m5	20	0
5	4	m4	30	0
5	5	Output	10	0
6	1	m3	25	0
6	1	m5	20	0
6	2	m2	12	0
6	3	m1	25	0
6	4	m5	10	0
6	4	m3	23	0
6	5	Output	10	0
7	1	m4	35	0
7	1	m1	38	0
7	2	m5	10	0
7	3	m1	10	0
7	3	m4	15	0
7	4	m2	15	0
7	5	Output	10	0
8	1	m5	15	0
8	1	m4	10	0
8	2	m4	40	0
8	2	m5	30	0
8	3	m3	25	0
8	4	m1	20	0
8	5	Output	10	0

Fig- 3: Job Matrix for the model

### 3.3 Start Point Properties

To set the properties of start point→Double click on the Start point icon and a dialog box captioned as 'Start point properties' appears. →The title name has been given as Type-1 for the first start point →Inter-arrival time was set to 60 →Distribution was given exponential → Click on the 'Routing out' option and add 'Storage' and set the discipline to 'Priority'→Press OK which means all the work-parts will routing out to the Storage in a Priority manner.

This 'Storage' is the queue for Input being highlighted as the storage has been selected. Similarly, the properties of the rest seven start points can be assigned, where the title name will be Type-2,Type-3, Type-4, Type-5, Type-6, Type-7,Type-8 and the other properties remain same as that of Type-1.

To set the storage properties →double click on the Queue for input, a dialog box appears. →Change the title

to storage, capacity has been set to infinite → shelf life to none → Press OK, which means that infinite number of work-parts can be stored in it. It has been indicated in figure 4.

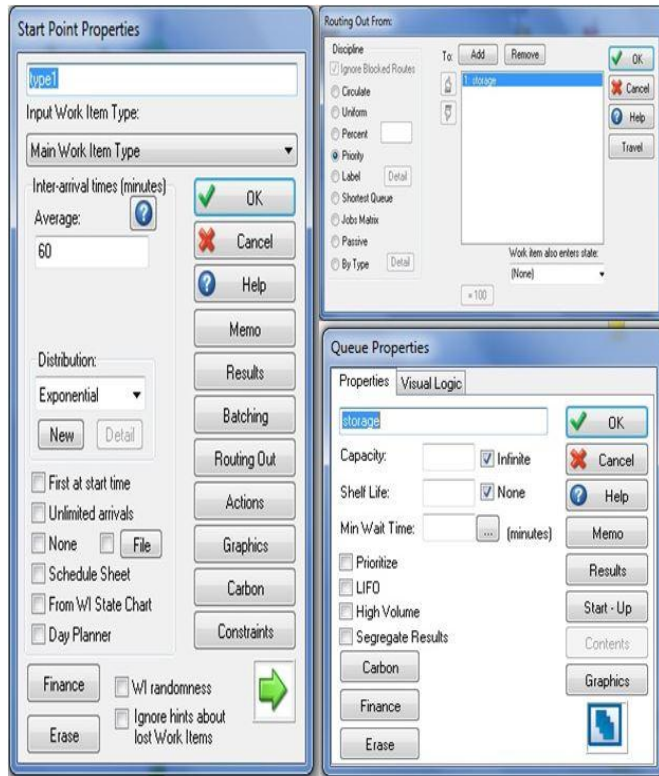


Fig- 4: Start point properties for the model

### 3.4 Input Properties

- Input or activity property has been set by → Double click on the Activity 'Input', a dialog box appears as shown in figure 5 → Timing has been set to 5 → Distribution as Average.
- Go to 'Routing In' option and add the 'storage', which is the queue for Input and select the discipline as 'Priority' → Press OK.
- Go to 'Routing Out' option and add the 'Queue for m1', 'Queue for m2', 'Queue for m3', 'Queue for m4', 'Queue for m5', and 'Queue for Output'

sequentially then set the discipline as 'Circulate' and tick the checkbox 'Ignore Blocked Routes' → Press OK so that the work parts can be processed in circulate manner without being blocked to the queues for the rest activities.

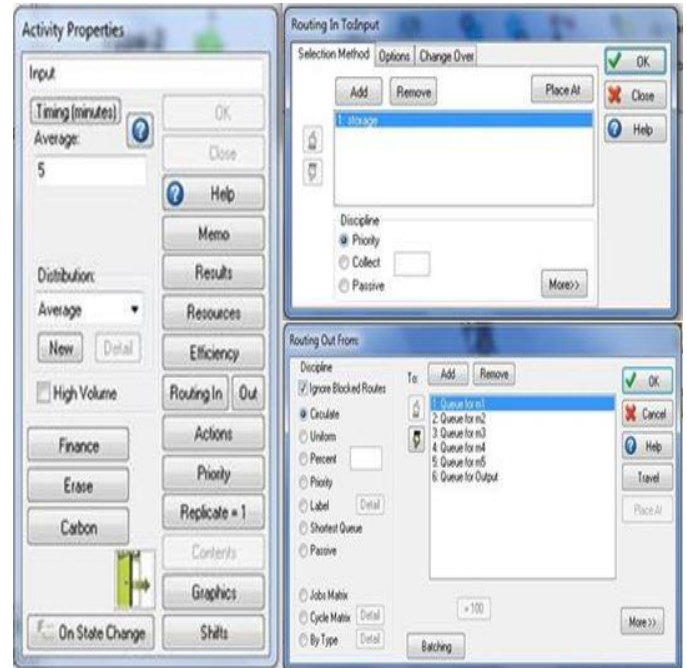


Fig- 5: Activity Properties for input of the model

### 3.5 Machine Properties

To set the machines' or workstations' properties → Double click on Activity 'm1', a dialog box 'Activity Properties' appears → Go to Timing, select 'Use Jobs matrix' that appears on the 'Timing Orientation' dialog box → Press OK, which indicates that the work centre/m1 will run for a period of time as assigned to it in the Jobs matrix. Go to 'Routing In' option, add the 'Queue for m1', then select the discipline as 'Priority' → press OK, which indicates that work parts are entered into the activity m1 in a priority basis as defined earlier. Go to 'Routing Out' option, add the 'Queue for m2', 'Queue for m3', 'Queue for m4', 'Queue for m5' and 'Queue for output' sequentially → Then click on the 'batching' option to set the batch size of the work parts to be entered → Set the Batch size leaving this object a fixed value (=1) with distribution 'Fixed' → Set the discipline of the routing out as 'Job Matrix'. → Press OK, which indicates that work parts are routed out to different work centres or queue in the order of job matrix assign to them. The sequence is shown in figure 6. Similarly the properties of activities m2, m3, m4 and m5 have been customised as above mentioned procedures.

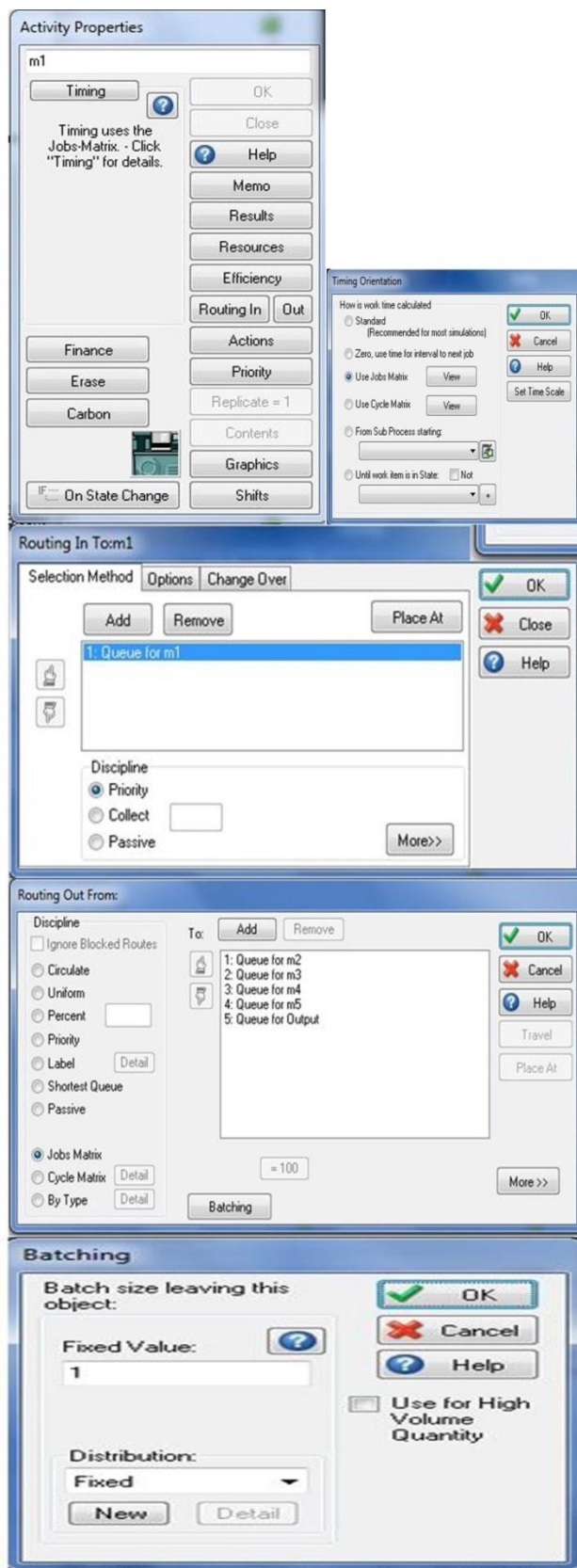


Fig- 6: Sequence of defining activity properties for various machines

#### 4. RESULT ANALYSIS AND DISCUSSIONS

After being run the created simulation model for specified clock timing i.e. a shift of 11 hours a day for one day output results has been obtained. Then the results or outcomes of various object (such as start point, activities, queue, end point) has been analysed in a detailed manner. SIMUL8 also provides the means to create several different types of user defined distributions. To optimize the process run it has been experimented on different distributions to be followed by the work parts while entering into the start point. Those distribution analysis are given below.

##### 4.1 Average Distribution

Average distribution allows the system to bring the work parts into it through the work entry point in an average manner having a specified average inter arrival time. In this model it has been set as 60 minutes. It simply indicates that a batch of work parts is arriving into the work entry point in every 60 minutes following an average arrival distribution. After the distribution has been set the model has been run for the specified period of time and the following outcomes have been obtained as indicated in figure 7.

Working percentage of different work stations;

- M1=81.833, M2=69.477, M3=81.355, M4=5.214, M5=47.878
- Number of jobs completed=28; Average time in the system=119.47 minutes.

Activities												
	Waiting %	Working %	Blocked %	Stopped %	Number Completed Jobs	Minimum Use	Average Use	Maximum Use	Current Contents	Change Over %	Off Shift %	Resource Starved %
m1	18.167	81.833	0	0	27	0	2.27	5	3	0	0	0
m2	30.553	69.447	0	0	17	0	1.658	6	0	0	0	0
m3	18.645	81.355	0	0	18	0	3.002	5	1	0	0	0
m4	94.786	5.214	0	0	11	0	0.052	1	0	0	0	0
m5	52.122	47.878	0	0	31	0	0.499	2	1	0	0	0
Output	93.952	6.048	0	0	29	0	0.021	1	0	0	0	0
Input	36.875	63.125	0	0	60	0	0.857	1	0	0	0	0

Ends							
	Average Time in System	Number Completed	"In System Less Than" time	% in System Less Than Time Limit	St Dev of	Maximum Time in System	Minimum Time in System
End 1	119.467	28	10	0	89.155	292.738	10.701

Fig- 7: System results of Activities and End point for average distribution

### 4.2 Fixed Distribution

In a fixed distribution arrival operation a fixed number of work parts are entered into the work entry point in a specified inter arrival time. In this model it has been set as 60 minutes for a batch of work parts which refers to a numbers of fixed part are entered into the system in every 60 minutes. After the distribution has been set the model has run for the specified period of time and the following outcomes have been obtained as indicated in figure 8.

Working percentage of different work stations;

- M1=74.45, M2=75.879, M3=80.083, M4=11.4, M5=57.97
- Number of jobs completed=29; Average time in the system=132.526 minutes

Activities

	Waiting %	Working %	Blocked %	Stopped %	Number Completed Jobs	Minimum Use	Average Use	Maximum Use	Current Contents	Change Over %	Off Shift %	Resource Starved %
m1	25.55	74.45	0	0	26	0	2.093	6	3	0	0	0
m2	24.121	75.879	0	0	15	0	1.986	5	5	0	0	0
m3	19.917	80.083	0	0	22	0	1.919	5	0	0	0	0
m4	88.53	11.47	0	0	11	0	0.115	1	0	0	0	0
m5	42.03	57.97	0	0	31	0	0.615	2	1	0	0	0
Output	93.952	6.048	0	0	29	0	0.094	1	0	0	0	0
Input	41.691	58.309	0	0	56	0	0.626	1	0	0	0	0

Ends

	Average Time in System	Number Completed	"In System Less Than" time	% In System Less Than Time Limit	St Dev of	Maximum Time in System	Minimum Time in System
End 1	132.526	29	10	0	85.808	293.173	16.654

Fig- 8: System results of Activities and End point for fixed distribution

### 4.3 Uniform Distribution

In uniform distribution work parts get entered into the system uniformly in a limited inter-arrival time. Limits such as lower bound and upper bound of the inter-arrivals times have to be defined here. Here the lower bound as 50 minutes and upper bound as 60 minutes has set. It indicates that a specified number of work parts are entered into the system uniformly in every 50 to 60 minutes of times. After the distribution has set the model has been run for the specified period of time and the

following outcomes have been obtained as indicated in figure 9.

Working percentage of different work stations;

- M1=82.433, M2=72.26, M3=85.078, M4=5.214, M5=53.077

Number of jobs completed=25; Average time in the system=125.661 minutes.

Activities

	Waiting %	Working %	Blocked %	Stopped %	Number Completed Jobs	Minimum Use	Average Use	Maximum Use	Current Contents	Change Over %	Off Shift %	Resource Starved %
m1	17.567	82.433	0	0	28	0	2.46	6	1	0	0	0
m2	27.74	72.26	0	0	17	0	1.268	4	4	0	0	0
m3	14.922	85.078	0	0	18	0	3.06	5	5	0	0	0
m4	94.786	5.214	0	0	12	0	0.052	1	0	0	0	0
m5	46.923	53.077	0	0	31	0	0.635	3	1	0	0	0
Output	94.786	5.214	0	0	25	0	0.063	1	0	0	0	0
Input	32.5	67.5	0	0	64	0	0.687	1	0	0	0	0

Ends

	Average Time in System	Number Completed	"In System Less Than" time	% In System Less Than Time Limit	St Dev of	Maximum Time in System	Minimum Time in System
End 1	125.661	25	10	0	105.487	397.692	12.587

Fig- 9: System results of Activities and End point for Uniform distribution

### 4.4 Normal Distribution

In Normal Distribution the work parts get entered into the start point following a normal distribution having a standard deviation value. Here the standard deviation has been set as 0 and inter arrival average time as 60 minutes. This indicates that the batch of work parts is entered into the system in every 60 minutes of time by following a normal distribution. After the distribution has set the model has been run for the specified period of time and the following outcomes are obtained as indicated in figure 10.

Working percentage of different work stations;

- M1=74.45, M2=75.879, M3=80.083, M4=11.47, M5=57.97
- Number of jobs completed=29; Average time in the system=132.526 minutes

Activities												
	Waiting %	Working %	Blocked %	Stopped %	Number Completed Jobs	Minimum Use	Average Use	Maximum Use	Current Contents	Change Over %	OffSHt %	Resource Starved %
m1	25.55	74.45	0	0	26	0	2.093	6	3	0	0	0
m2	24.121	75.879	0	0	15	0	1.986	5	5	0	0	0
m3	19.917	80.083	0	0	22	0	1.919	5	0	0	0	0
m4	88.53	11.47	0	0	11	0	0.115	1	0	0	0	0
m5	42.03	57.97	0	0	31	0	0.615	2	1	0	0	0
Output	93.952	6.048	0	0	29	0	0.094	1	0	0	0	0
Input	41.691	58.309	0	0	56	0	0.626	1	0	0	0	0

Ends							
	Average Time in System	Number Completed	Tn System Less Than Time	% In System Less Than Time Limit	St Dev of	Maximum Time in System	Minimum Time in System
End 1	132.526	29	10	0	85.808	293.173	16.654

Fig- 10: System results of Activities and End point for Normal distribution

### 4.5 Poisson Distribution

In Poisson distribution the work parts get entered into the system through start point following a Poisson distribution having average inter-arrival time. Here the value has been set as 60 minutes. It indicates that a batch of work parts is entered into the system in every 60 minutes following a Poisson distribution. After the distribution has set the model has been run for the specified period of time and the following outcomes have obtained as indicated in figure 11.

Working percentage of different work stations;

- M1=81.279, M2=68.067, M3=82.053, M4=5.214, M5=55.266
- Number of jobs completed=27; Average time in the system=130.156 minutes

Activities												
	Waiting %	Working %	Blocked %	Stopped %	Number Completed Jobs	Minimum Use	Average Use	Maximum Use	Current Contents	Change Over %	OffSHt %	Resource Starved %
m1	18.721	81.279	0	0	25	0	2.465	6	6	0	0	0
m2	31.933	68.067	0	0	16	0	1.258	6	4	0	0	0
m3	17.947	82.053	0	0	20	0	2.564	5	1	0	0	0
m4	94.786	5.214	0	0	11	0	0.052	1	0	0	0	0
m5	44.734	55.266	0	0	31	0	0.708	3	0	0	0	0
Output	94.369	5.631	0	0	27	0	0.063	1	0	0	0	0
Input	38.017	61.983	0	0	59	0	0.625	1	0	0	0	0

Ends							
	Average Time in System	Number Completed	Tn System Less Than Time	% In System Less Than Time Limit	St Dev of	Maximum Time in System	Minimum Time in System
End 1	130.156	27	10	0	95.88	292.918	10.904

Fig- 11: System results of Activities and End point for Poisson distribution

### 4.6 Exponential Distribution

In Exponential distribution work parts have been fed into the system start point exponentially with a defined average inter-arrival time. Here it has set as 60 minutes which indicates that in every 60 minutes a batch of work parts is entered into the system by following an exponential distribution. After the distribution has set the model has been run for the specified period of time and the following outcomes have obtained as indicated in figure 12.

Working percentage of different work stations;

- M1=83.701, M2=74.244, M3=79.262, M4=5.214, M5=59.022
- Number of jobs completed=29; Average time in the system=122.173 minutes

Activities												
	Waiting %	Working %	Blocked %	Stopped %	Number Completed Jobs	Minimum Use	Average Use	Maximum Use	Current Contents	Change Over %	OffSHt %	Resource Starved %
m1	16.299	83.701	0	0	31	0	2.52	7	3	0	0	0
m2	25.756	74.244	0	0	16	0	2.06	7	4	0	0	0
m3	20.738	79.262	0	0	20	0	2.477	5	5	0	0	0
m4	94.786	5.214	0	0	13	0	0.052	1	0	0	0	0
m5	40.978	59.022	0	0	32	0	0.833	3	1	0	0	0
Output	93.952	6.048	0	0	29	0	0.031	1	0	0	0	0
Input	26.038	73.962	0	0	70	0	0.73	1	1	0	0	0

Ends							
	Average Time in System	Number Completed	Tn System Less Than Time	% In System Less Than Time Limit	St Dev of	Maximum Time in System	Minimum Time in System
End 1	122.173	29	10	0	105.244	365.391	11.203

Fig- 12: System results of Activities and End point for Exponential distribution

## 5. CONCLUSIONS

By analysing all of the above distributions i.e. Fixed, Average, Uniform, Normal, Poisson, Exponential distribution; we can obtain a fact that the best suited distribution at the start point for the work parts to be entered is Exponential Distribution. The reasons to provide an Exponential distribution at the start point are;

- Maximum number of the product output obtained at the END.
- Less make spans or Process Cycle time or average time in the system.

- More average machine utilization of all machines.
- Fewer buffers collected at the queue.
- Less traffic during the process run.

The detailed of this comparison is illustrated in the following table 2.

**Table-2:** Comparison of various parameters with respect to various distributions

Distributions →	Average	Fixed	Uniform	Normal	Poisson	Exponential
Parameters ↓						
Total No. of parts completed	28	29	25	29	27	29
Avg. time in the System	119.46	132.52	125.66	132.52	130.16	122.17
Working % of M1	81.83	74.45	82.43	74.45	81.27	83.7
Working % of M2	69.44	75.87	72.26	75.87	66.06	74.24
Working % of M3	81.35	80.08	85.07	80.08	82.05	79.26
Working % of M4	5.21	11.47	5.21	11.47	5.21	5.21
Working % of M5	47.87	57.97	53.07	57.97	55.26	59.02
Avg. working % of all machines	57.14	59.968	59.608	59.968	57.97	60.286

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