Chapter 02, Simulation Examples in a Spreadsheet
Example 09: Replacing Bearings in a Milling Machine
By Mohammad Abubakar Atiq, BSIE, F2022031002, To Sir Rehan Ashraf

Table 22 Distribution for Bearing Life

Distribution of Bearing-Life

Bearing Life	Probability	Cumulative Probability
1000	0.100	0.100
1100	0.130	0.230
1200	0.250	0.480
1300	0.130	0.610
1400	0.090	0.700
1500	0.120	0.820
1600	0.020	0.840
1700	0.060	0.900
1800	0.050	0.950
1900	0.050	1.000

Table 23 Distribution of Delay until Mechanic Arrives

Distribution of Delay Time

Delay Time	Proability	Cumulative Probability
5	0.600	0.600
10	0.300	0.900
15	0.100	1.000

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Example 9: Replacing Bearings in a Milling Machine
A milling machine has three different bearings that fail in service. The distribution of the life of each bearing is identical, as shown in Table 22. When a bearing fails, the mill stops, a mechanic is called, and he or she installs a new bearing (costing $32 per bearing). The delay time for the mechanic to arrive varies randomly, having the distribution given in Table 23. Downtime for the mill is estimated to cost $10 per minute. The direct on-site cost of the mechanic is $30 per hour. The mechanic takes 20 minutes to change one bearing, 30 minutes to change two bearings, and 40 minutes to change three bearings. The engineering staff has proposed a new policy to replace all three bearings whenever one bearing fails. Management needs an evaluation of the proposal, using total cost per 10,000 bearing-hours as the measure of performance.

Current Method

Bearing 1			
Step	Random#	Life (Hours)	Delay (minutes)
1	0.965	1900	15
2	0.917	1800	15
3	0.970	1900	15
4	0.448	1200	5
5	0.534	1300	5
6	0.263	1200	5
7	0.907	1800	15
8	0.908	1800	15
9	0.540	1300	5
10	0.462	1200	5
11	0.495	1300	5
12	0.224	1100	5
13	0.124	1100	5
14	0.454	1200	5
15	0.862	1700	10
TOTAL		21800	130

Bearing 2			
Step	Random#	Life (Hours)	Delay (minutes)
1	0.897	1700	10
2	0.849	1700	10
3	0.913	1800	15
4	0.186	1100	5
5	0.924	1800	15
6	0.844	1700	10
7	0.928	1800	15
8	0.576	1300	5
9	0.936	1800	15
10	0.598	1300	5
11	0.465	1200	5
12	0.553	1300	5
13	0.867	1700	10
14	0.333	1200	5
15	0.320	1200	5
		22600	135

Bearing 3			
Step	Random#	Life (Hours)	Delay (minutes)
1	0.393	1200	5
2	0.717	1500	10
3	0.755	1500	10
4	0.569	1300	5
5	0.449	1200	5
6	0.198	1100	5
7	0.388	1200	5
8	0.671	1400	10
9	0.671	1400	10
10	0.083	1000	5
11	0.172	1100	5
12	0.605	1300	10
13	0.557	1300	5
14	0.244	1200	5
15	0.775	1500	10
		19200	105

Costs of Bearing=	$ 32.00	per bearing			
Downtime cost=	$ 10.00	per minute			
Mechanic cost=	$ 30.00	per hour	$	0.50	per min
Replacement Time by Mechanic					
Replacement Time	20	minute			
2 Bearing	30	minute			
3 Bearing	40	minute			

The total life of all 45 bearings is	=	63600
Hours / 10,000 Bearings	=	6.360
The Total cost per 10,000 bearing - Hours is	=	$ 2,294.03

For Single Trial of the simulation, the cost of the current system is estimated as follows:

Cost of Bearing	=	$ 1,440.00
Cost of delay time	=	$ 3,700.00
Cost of downtime during repair	=	$ 9,000.00
Cost of Mechanics	=	$ 450.00
Total Cost	=	$ 14,590.00

Proposed Method

	Bearing 1
Step	Random#
1	0.488
2	0.380
3	0.315
4	0.134
5	0.801
6	0.836
7	0.125
8	0.487
9	0.758
10	0.463
11	0.966
12	0.249
13	0.937
14	0.476
15	0.761
Total	

Costs of Bearing=	$ 32.00
Downtime cost=	$ 10.00
Mechanic cost=	$ 30.00
Replacement Time by Mechanic	
1 Bearing	20
2 Bearing	30
3 Bearing	40

For Single Trial of the simulatior

Cost of Bearing	=
Cost of delay time	=
Cost of downtime during repair	=
Cost of Mechanics	=
Total Cost	=

	Bearing 2		Bearing 3		First Failure (Hours)	Random#	Delay (minutes)
Life (Hours)	Random#	Life (Hours)	Random#	Life (Hours)			
1300	0.811	1500	0.739	1500	1300	0.567	5
1200	0.610	1400	0.383	1200	1200	0.199	5
1200	0.940	1800	0.869	1700	1200	0.754	10
1100	0.830	1600	0.535	1300	1100	0.222	5
1500	0.945	1800	0.478	1200	1200	0.179	5
1600	0.265	1200	0.574	1300	1200	0.024	5
1100	0.870	1700	0.697	1400	1100	0.077	5
1300	0.837	1600	0.519	1300	1300	0.975	15
1500	0.751	1500	0.251	1200	1200	0.341	5
1200	0.576	1300	0.013	1000	1000	0.155	5
1900	0.848	1700	0.844	1700	1700	0.805	10
1200	0.417	1200	0.306	1200	1200	0.845	10
1800	0.923	1800	0.493	1300	1300	0.842	10
1200	0.445	1200	0.183	1100	1100	0.824	10
1500	0.566	1300	0.488	1300	1300	0.565	5
					18400		110

per bearing
per minute
per hour $ 0.50 per min

minute
minute
minute

ı, the cost of the current system is estimated as follows:

$ 1,440.00

$ 1,100.00

$ 6,000.00

$ 300.00
$ 8,840.00

The total life of all 45 bearings is	=	18400
Hours / 10,000 Bearings	=	1.840
The Total cost per 10,000 bearing - Hours is	=	$ 4,804.35

By: Mohammad Abubakar Atiq, To Sir Rehan Ashraf,
BSIE, F2022031002
Example 10: A Bombing Mission, page 68, Chapter 02
Consider a bomber attempting to destroy an ammunication depot. (This bomber has conventional rather than laser-guided weapons). If a bomb falls anywhere inside the target, a hit is scored; otherwise, the bomb is a miss. (Note that when a bomb appears appears visually to have touched a boundary line, it may or may not have hit the target; the model determines mathematically whether a hit has occurred, using the (X,Y) coordinates nd the equations of the piecewise-linear boundary of the depot.)
The bomber flies in the horizontal direction and carries 10 bombs. The aiming point is (0,0). The actual point of impact is assumed to be normally distributed around the aiming point with a standard deviation of 400 meters in the direction of flight and 200 meters in the perpendicular direction. The problem is to simulate the operation and estimate the number of bombs on target.
Recall that the standardized normal variate Z, having mean $\mu = 0$, and standard deviation $\sigma = 1$, is distributed as

$$Z = \frac{X - \mu}{\sigma}$$

Where X is a normal random variable, Then, with mean zero and standard deviations given by $\sigma_X = 400\ and\ \sigma_Y = 200$, we have

$$Z_X = \frac{X}{400}, Z_Y = \frac{Y}{200}$$

Where (X,Y) are the simulated coordinates where the bomb hits.

σ_X = 400

σ_Y = 200

X range: $X_{low} \leq X \leq X_{high}$,
Y range: $Y_{low} \leq Y \leq Y_{high}$,

Z_X and Z_Y Random Normal Number,

X_{low} = -1300

X_{high} = 1300

Y_{low} = -200

Y_{high} = 200

Bomb	Z_X	σ_X	X	Z_Y	σ_Y	Y	Hit Or Miss?	Number of Hits	Number of Miss
1	0.480715	400	192.2858	-0.67139	200	-134.278	Hit	6	4
2	0.866149	400	346.4597	0.083926	200	16.78522	Hit		
3	0.007354	400	2.941631	-1.20335	200	-240.671	Miss		
4	0.171848	400	68.73905	-1.05915	200	-211.831	Miss		
5	0.900941	400	360.3762	1.792649	200	358.5298	Miss		
6	0.125204	400	50.0817	0.956785	200	191.357	Hit		
7	-0.093	400	-37.2013	1.239118	200	247.8236	Miss		
8	2.175764	400	870.3055	0.343233	200	68.64653	Hit		
9	0.816129	400	326.4515	0.150031	200	30.00612	Hit		
10	-1.39877	400	-559.507	0.356495	200	71.29909	Hit		

Bomb	Z_X	σ_X	X	Z_Y	σ_Y	Y	Hit Or Miss?	Number of Hits	Number of Miss
1	2.2295	400	891.8	-2.0035	200	-400.7	Miss	6	4
2	-3.14325	400	-1257.3	-0.797	200	-159.4	Hit		
3	1.074	400	429.6	0.1265	200	25.3	Hit		
4	0.06125	400	24.5	1.218	200	243.6	Miss		
5	-0.8025	400	-321	0.7325	200	146.5	Hit		
6	-0.19325	400	-77.3	1.3035	200	260.7	Miss		
7	0.3285	400	131.4	-1.1415	200	-228.3	Miss		
8	0.76125	400	304.5	-0.31	200	-62	Hit		
9	-1.10675	400	-442.7	0.2485	200	49.7	Hit		
10	-1.00975	400	-403.9	0.255	200	51	Hit		