

Chapter 02, Simulation Examples in a Spreadsheet

Example 09: Replacing Bearings in a Milling Machine

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Table 22 Distribution for 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

| Delay Time | Probability | 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.

| Bearing 1 |         |              |                 |
|-----------|---------|--------------|-----------------|
| Step      | Random# | Life (Hours) | Delay (minutes) |
| 1         | 0.565   | 1300         | 5               |
| 2         | 0.854   | 1700         | 10              |
| 3         | 0.308   | 1200         | 5               |
| 4         | 0.297   | 1200         | 5               |
| 5         | 0.638   | 1400         | 10              |
| 6         | 0.886   | 1700         | 10              |
| 7         | 0.654   | 1400         | 10              |
| 8         | 0.940   | 1800         | 15              |
| 9         | 0.707   | 1500         | 10              |
| 10        | 0.099   | 1000         | 5               |
| 11        | 0.431   | 1200         | 5               |
| 12        | 0.860   | 1700         | 10              |
| 13        | 0.663   | 1400         | 10              |
| 14        | 0.202   | 1100         | 5               |
| 15        | 0.398   | 1200         | 5               |

| Bearing 2 |         |              |                 |
|-----------|---------|--------------|-----------------|
| Step      | Random# | Life (Hours) | Delay (minutes) |
| 1         | 0.264   | 1200         | 5               |
| 2         | 0.694   | 1400         | 10              |
| 3         | 0.014   | 1000         | 5               |
| 4         | 0.706   | 1500         | 10              |
| 5         | 0.308   | 1200         | 5               |
| 6         | 0.600   | 1300         | 10              |
| 7         | 0.733   | 1500         | 10              |
| 8         | 0.733   | 1500         | 10              |
| 9         | 0.859   | 1700         | 10              |
| 10        | 0.438   | 1200         | 5               |
| 11        | 0.329   | 1200         | 5               |
| 12        | 0.143   | 1100         | 5               |
| 13        | 0.488   | 1300         | 5               |
| 14        | 0.400   | 1200         | 5               |
| 15        | 0.991   | 1900         | 15              |

| Bearing 3 |         |              |                 |
|-----------|---------|--------------|-----------------|
| Step      | Random# | Life (Hours) | Delay (minutes) |
| 1         | 0.731   | 1500         | 10              |
| 2         | 0.726   | 1500         | 10              |
| 3         | 0.072   | 1000         | 5               |
| 4         | 0.561   | 1300         | 5               |
| 5         | 0.621   | 1400         | 10              |
| 6         | 0.678   | 1400         | 10              |
| 7         | 0.533   | 1300         | 5               |
| 8         | 0.087   | 1000         | 5               |
| 9         | 0.258   | 1200         | 5               |
| 10        | 0.811   | 1500         | 10              |
| 11        | 0.605   | 1300         | 10              |
| 12        | 0.108   | 1100         | 5               |
| 13        | 0.430   | 1200         | 5               |
| 14        | 0.689   | 1400         | 10              |
| 15        | 0.846   | 1700         | 10              |

120

115

115

|           |           |
|-----------|-----------|
| 3 Bearing | 40 minute |
|-----------|-----------|

Total Cost = \$ 14,390.00

Proposed Method

|       | Bearing 1 |              | Bearing 2 |              | Bearing 3 |              | First Failure (Hours) | Random# | Delay (minutes) |
|-------|-----------|--------------|-----------|--------------|-----------|--------------|-----------------------|---------|-----------------|
| Step  | Random#   | Life (Hours) | Random#   | Life (Hours) | Random#   | Life (Hours) |                       |         |                 |
| 1     | 0.044     | 1000         | 0.815     | 1500         | 0.217     | 1100         | 1000                  | 0.397   | 5               |
| 2     | 0.936     | 1800         | 0.781     | 1500         | 0.185     | 1100         | 1100                  | 0.072   | 5               |
| 3     | 0.236     | 1200         | 0.909     | 1800         | 0.899     | 1700         | 1200                  | 0.065   | 5               |
| 4     | 0.294     | 1200         | 0.639     | 1400         | 0.261     | 1200         | 1200                  | 0.253   | 5               |
| 5     | 0.358     | 1200         | 0.141     | 1100         | 0.495     | 1300         | 1100                  | 0.973   | 15              |
| 6     | 0.763     | 1500         | 0.786     | 1500         | 0.205     | 1100         | 1100                  | 0.005   | 5               |
| 7     | 0.674     | 1400         | 0.535     | 1300         | 0.729     | 1500         | 1300                  | 0.420   | 5               |
| 8     | 0.837     | 1600         | 0.140     | 1100         | 0.710     | 1500         | 1100                  | 0.728   | 10              |
| 9     | 0.196     | 1100         | 0.902     | 1800         | 0.857     | 1700         | 1100                  | 0.891   | 10              |
| 10    | 0.395     | 1200         | 0.807     | 1500         | 0.991     | 1900         | 1200                  | 0.193   | 5               |
| 11    | 0.598     | 1300         | 0.743     | 1500         | 0.840     | 1700         | 1300                  | 0.239   | 5               |
| 12    | 0.551     | 1300         | 0.597     | 1300         | 0.807     | 1500         | 1300                  | 0.605   | 10              |
| 13    | 0.429     | 1200         | 0.263     | 1200         | 0.689     | 1400         | 1200                  | 0.367   | 5               |
| 14    | 0.094     | 1000         | 0.669     | 1400         | 0.241     | 1200         | 1000                  | 0.253   | 5               |
| 15    | 0.051     | 1000         | 0.660     | 1400         | 0.056     | 1000         | 1000                  | 0.027   | 5               |
| Total |           |              |           |              |           |              | 17200                 |         | 100             |

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

1 Bearing 20 minute

2 Bearing 30 minute

3 Bearing 40 minute

The total life of all 45 bearings is = 17200

Hours / 10,000 Bearings = 1.720

The Total cost per 10,000 bearing -  
Hours is = \$ 5,081.40

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 = \$ 1,000.00

Cost of downtime during repair = \$ 6,000.00

Cost of Mechanics = \$ 300.00

Total Cost = \$ 8,740.00