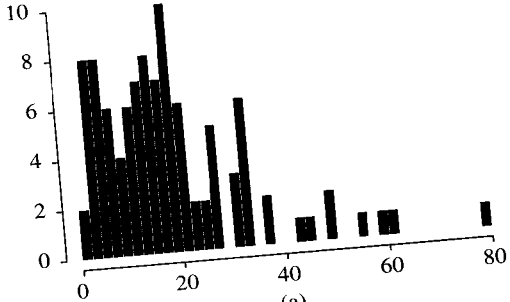
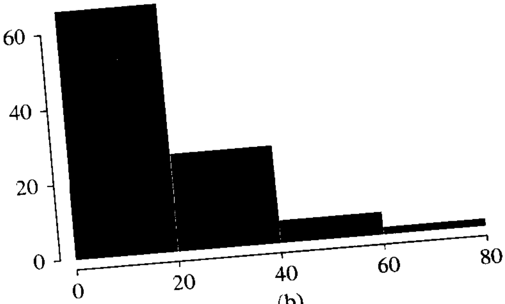
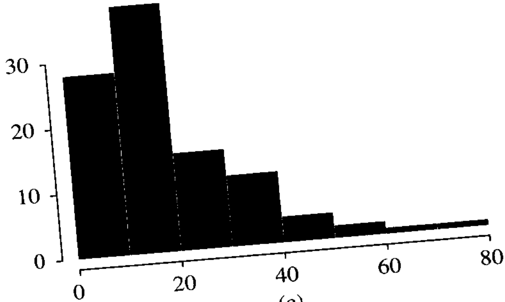


(a)



(b)



(c)

**Table 9.1** Number of Arrivals in a 5-Minute Period

| *Arrivals per Period* | *Frequency* | *Arrivals per Period* | *Frequency* |
|---|---|---|---|
| 0 | 12 | 6 | 7 |
| 1 | 10 | 7 | 5 |
| 2 | 19 | 8 | 5 |
| 3 | 17 | 9 | 3 |
| 4 | 10 | 10 | 3 |
| 5 | 8 | 11 | 1 |

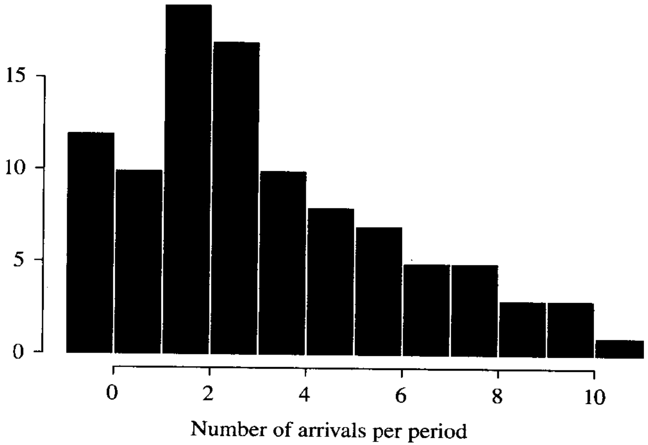



**Figure 9.4** Histogram of number of arrivals per period.

| | | | | |
|---|---|---|---|---|
| 79.919 | 3.081 | 0.062 | 1.961 | 5.845 |
| 3.027 | 6.505 | 0.021 | 0.013 | 0.123 |
| 6.769 | 59.899 | 1.192 | 34.760 | 5.009 |
| 18.387 | 0.141 | 43.565 | 24.420 | 0.433 |
| 144.695 | 2.663 | 17.967 | 0.091 | 9.003 |
| 0.941 | 0.878 | 3.371 | 2.157 | 7.579 |
| 0.624 | 5.380 | 3.148 | 7.078 | 23.960 |
| 0.590 | 1.928 | 0.300 | 0.002 | 0.543 |
| 7.004 | 31.764 | 1.005 | 1.147 | 0.219 |
| 3.217 | 14.382 | 1.008 | 2.336 | 4.562 |

usually considered a continuous variable, is recorded here to three-d histogram is prepared by placing the data in class intervals. The rang , from 0.002 day to 144.695 days. However, most of the values (30 of range. Using intervals of width three results in Table 9.2. The data of repare the histogram shown in Figure 9.5.

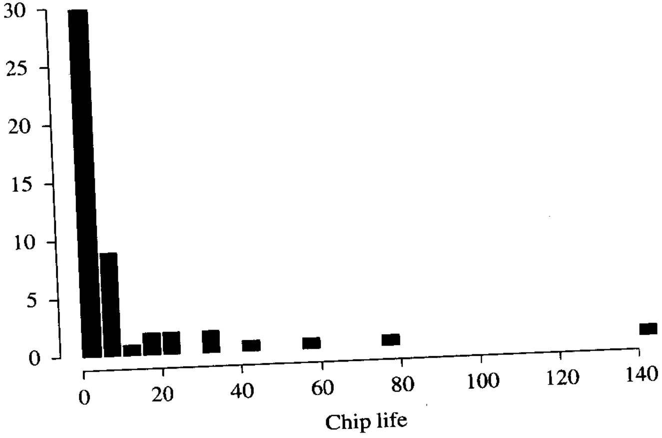



**Figure 9.5** Histogram of component life.

**Table 9.2** Electronic Component Data

| *Component Life (days)* | *Frequency* |
|---|---|
| $0 \le x_j < 3$ | 23 |
| $3 \le x_j < 6$ | 10 |
| $6 \le x_j < 9$ | 5 |
| $9 \le x_j < 12$ | 1 |
| $12 \le x_j < 15$ | 1 |
| $15 \le x_j < 18$ | 2 |
| $18 \le x_j < 21$ | 0 |
| $21 \le x_j < 24$ | 1 |
| $24 \le x_j < 27$ | 1 |
| $27 \le x_j < 30$ | 0 |
| $30 \le x_j < 33$ | 1 |
| $33 \le x_j < 36$ | 1 |
| $\vdots$ | $\vdots$ |
| $42 \le x_j < 45$ | 1 |
| $\vdots$ | $\vdots$ |
| $57 \le x_j < 60$ | 1 |
| $\vdots$ | $\vdots$ |
| $78 \le x_j < 81$ | 1 |
| $\vdots$ | $\vdots$ |
| $144 \le x_j < 147$ | 1 |

| | | | |
|---|---|---|---|
| 99.79 | 99.56 | 100.17 | 100.33 |
| 100.26 | 100.41 | 99.98 | 99.83 |
| 100.23 | 100.27 | 100.02 | 100.47 |
| 99.55 | 99.62 | 99.65 | 99.82 |
| 99.96 | 99.90 | 100.06 | 99.85 |

The sample mean is 99.99 seconds, and the sample variance is $(0.2832)^2$ seconds$^2$. These values can serve as the parameter estimates for the mean and variance of the normal distribution. The observations are now ordered from smallest to largest as follows:

| $j$ | *Value* | $j$ | *Value* | $j$ | *Value* | $j$ | Value |
|---|---|---|---|---|---|---|---|
| 1 | 99.55 | 6 | 99.82 | 11 | 99.98 | 16 | 100.26 |
| 2 | 99.56 | 7 | 99.83 | 12 | 100.02 | 17 | 100.27 |
| 3 | 99.62 | 8 | 99.85 | 13 | 100.06 | 18 | 100.33 |
| 4 | 99.65 | 9 | 99.90 | 14 | 100.17 | 19 | 100.41 |
| 5 | 99.79 | 10 | 99.96 | 15 | 100.23 | 20 | 100.47 |

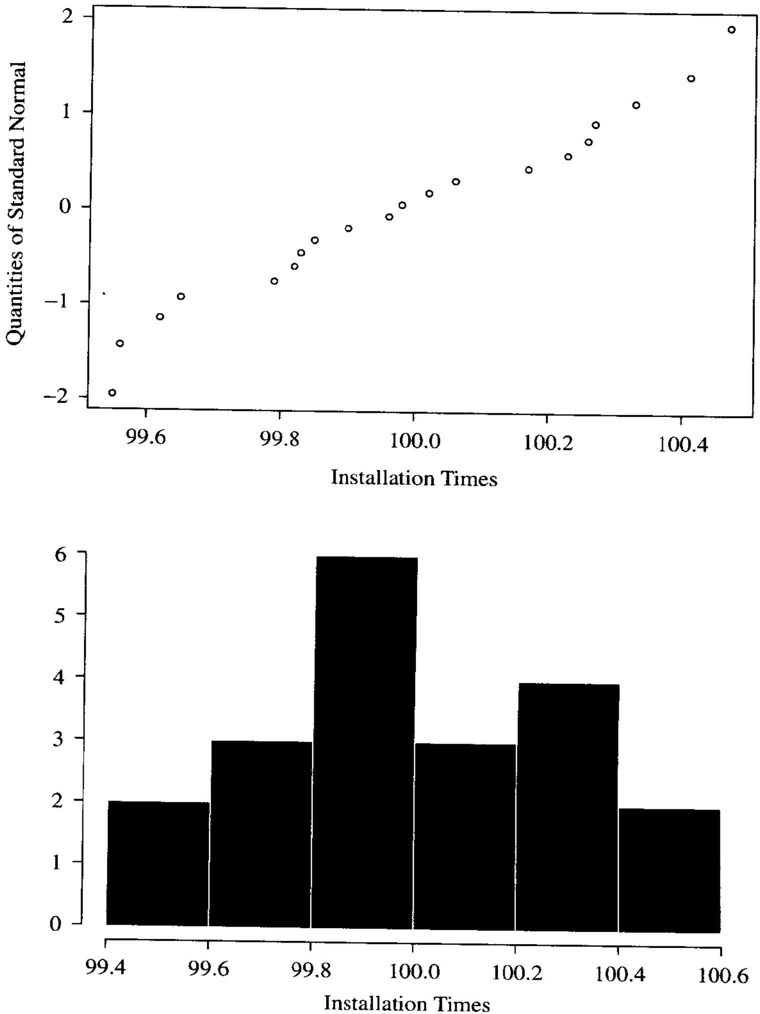



**Figure 9.6** A $q$-$q$ plot and histogram of the installation times.

**Table 9.3** Suggested Estimators for Distributions Often Used in Simulation

| *Distribution* | *Parameter(s)* | *Suggested Estimator(s)* |
| --- | --- | --- |
| Poisson | $\alpha$ | $\widehat{\alpha} = \bar{X}$ |
| Exponential | $\lambda$ | $\widehat{\lambda} = \dfrac{1}{\bar{X}}$ |
| Gamma | $\beta, \theta$ | $\widehat{\beta}$ (see Table A.9)<br>$\widehat{\theta} = \dfrac{1}{\bar{X}}$ |
| Normal | $\mu, \sigma^2$ | $\widehat{\mu} = \bar{X}$<br>$\widehat{\sigma}^2 = S^2$ (unbiased) |
| Lognormal | $\mu, \sigma^2$ | $\widehat{\mu} = \bar{X}$ (after taking ln of the data)<br>$\widehat{\sigma}^2 = S^2$ (after taking ln of the data) |
| Weibull with $\nu = 0$ | $\alpha, \beta$ | $\widehat{\beta}_0 = \dfrac{\bar{X}}{S}$<br>$\widehat{\beta}_j = \widehat{\beta}_{j-1} - \dfrac{f(\widehat{\beta}_{j-1})}{f'(\widehat{\beta}_{j-1})}$<br>See Equations (9.11) and (9.14) for $f(\widehat{\beta})$ and $f'(\widehat{\beta})$<br>Iterate until convergence<br>$\widehat{\alpha} = \left(\dfrac{1}{n}\sum_{i=1}^{n} X_i^{\widehat{\beta}}\right)^{1/\widehat{\beta}}$ |
| Beta | $\beta_1, \beta_2$ | $\Psi(\widehat{\beta}_1) + \Psi(\widehat{\beta}_1 - \widehat{\beta}_2) = \ln(G_1)$<br>$\Psi(\widehat{\beta}_2) + \Psi(\widehat{\beta}_1 - \widehat{\beta}_2) = \ln(G_2)$<br>where $\Psi$ is the digamma function,<br>$G_1 = \left(\prod_{i=1}^{n} X_i\right)^{1/n}$ and<br>$G_2 = \left(\prod_{i=1}^{n}(1 - X_i)\right)^{1/n}$ |

| *Order* | *Lead Time (days)* | *Order* | *Lead Time (days)* |
|---|---|---|---|
| 1 | 70.292 | 11 | 30.215 |
| 2 | 10.107 | 12 | 17.137 |
| 3 | 48.386 | 13 | 44.024 |
| 4 | 20.480 | 14 | 10.552 |
| 5 | 13.053 | 15 | 37.298 |
| 6 | 25.292 | 16 | 16.314 |
| 7 | 14.713 | 17 | 28.073 |
| 8 | 39.166 | 18 | 39.019 |
| 9 | 17.421 | 19 | 32.330 |
| 10 | 13.905 | 20 | 36.547 |

**Table 9.6** Chi-Square Goodness-of-Fit Test for Example 9.17

| $x_i$ | *Observed Frequency* $O_i$ | | *Expected Frequency* $E_i$ | | $\frac{(O_i - E_i)^2}{E_i}$ |
|---|---|---|---|---|---|
| 0 | 12 | 22 | 2.6 | 12.2 | 7.87 |
| 1 | 10 | | 9.6 | | |
| 2 | 19 | | 17.4 | | 0.15 |
| 3 | 17 | | 21.1 | | 0.80 |
| 4 | 10 | | 19.2 | | 4.41 |
| 5 | 8 | | 14.0 | | 2.57 |
| 6 | 7 | | 8.5 | | 0.26 |
| 7 | 5 | 17 | 4.4 | 7.6 | 11.62 |
| 8 | 5 | | 2.0 | | |
| 9 | 3 | | 0.8 | | |
| 10 | 3 | | 0.3 | | |
| $\geq 11$ | 1 | | 0.1 | | |
| | 100 | | 100.0 | | 27.68 |

**Table 9.7** Chi-Square Goodness-of-Fit Test for Example 9.18

| *Class Interval* | *Observed Frequency* $O_i$ | *Expected Frequency* $E_i$ | $\frac{(O_i - E_i)^2}{E_i}$ |
|---|---|---|---|
| [0, 1.590) | 19 | 6.25 | 26.01 |
| [1.590, 3.425) | 10 | 6.25 | 2.25 |
| [3.425, 5.595) | 3 | 6.25 | 0.81 |
| [5.595, 8.252) | 6 | 6.25 | 0.01 |
| [8.252, 11.677) | 1 | 6.25 | 4.41 |
| [11.677, 16.503) | 1 | 6.25 | 4.41 |
| [16.503, 24.755) | 4 | 6.25 | 0.81 |
| [24.755, $\infty$) | 6 | 6.25 | 0.01 |
| | 50 | 50 | 39.6 |