# Failure rate

From Wikipedia, the free encyclopedia
(Redirected from Hazard rate)

**Failure rate** is the frequency with which an engineered system or component fails, expressed for example in failures per hour. It is often denoted by the Greek letter λ (lambda) and is important in reliability theory.

The failure rate of a system usually depends on time, with the rate varying over the life cycle of the system. For example, as an automobile grows older, the failure rate in its fifth year of service may be many times greater than its failure rate during its first year of service. One does not expect to replace an exhaust pipe, overhaul the brakes, or have major transmission problems in a new vehicle.

In practice, the Mean Time Between Failures (MTBF) is often used instead of the failure rate. The MTBF is an important system parameter in systems where failure rate needs to be managed, in particular for safety systems. The MTBF appears frequently in the engineering design requirements, and governs frequency of required system maintenance and inspections. In special processes called renewal processes, where the time to recover from failure can be neglected and the likelihood of failure remains constant with respect to time, the failure rate is simply the multiplicative inverse of the MTBF (1/λ).

A similar ratio used in the transport industries, especially in railways and trucking is 'Mean Distance Between Failure', a variation which attempts to correlate actual loaded distances to similar reliability needs and practices.

Failure rates and their projective manifestations are important factors in insurance, business, and regulation practices as well as fundamental to design of safe systems throughout a national or international economy.

Contents [hide]



## Failure rate in the discrete sense [edit]

In words appearing in an experiment, the failure rate can be defined as

> The total number of failures within an item population, divided by the total time expended by that population, during a particular measurement interval under stated conditions. (MacDiarmid, *et al.*)

Here failure rate $\lambda(t)$ can be thought of as the probability that a failure occurs in a specified interval, given no failure before time $t$. It can be defined with the aid of the reliability function or survival function $R(t)$, the probability of no failure before time $t$, as:

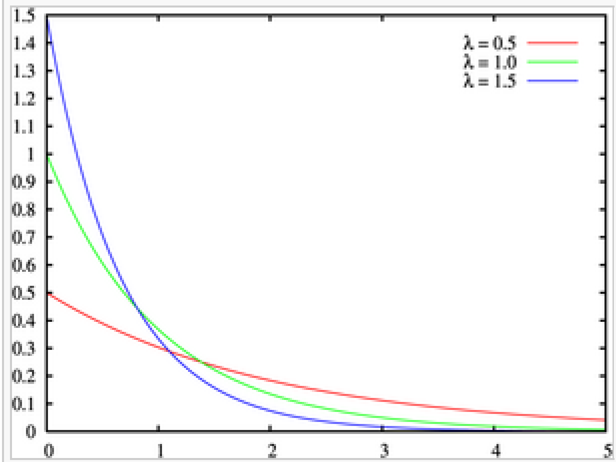
$$\lambda = \frac{R(t_1) - R(t_2)}{(t_2 - t_1) \cdot R(t_1)} = \frac{R(t) - R(t + \triangle t)}{\triangle t \cdot R(t)}$$

where $t_1$ (or $t$) and $t_2$ are respectively the beginning and ending of a specified interval of time spanning $\Delta t$. Note that this is a conditional probability, hence the $R(t)$ in the denominator.

## Failure rate in the continuous sense [edit]

By calculating the failure rate for smaller and smaller intervals of time $\Delta t$, the interval becomes infinitely small. This results in the hazard function, which is the *instantaneous* failure rate at any point in time:

$$h(t) = \lim_{\triangle t \to 0} \frac{R(t) - R(t + \triangle t)}{\triangle t \cdot R(t)}.$$



Exponential failure density functions

Continuous failure rate depends on a failure distribution, $F(t)$, which is a cumulative distribution function that describes the probability of failure prior to time $t$,

$$P(\mathbf{T} \le t) = F(t) = 1 - R(t), \quad t \ge 0.$$

where $T$ is the failure time. The failure distribution function is the integral of the failure *density* function, $f(x)$,

$$F(t) = \int_0^t f(x)\, dx.$$

The hazard function can be defined now as

$$h(t) = \frac{f(t)}{R(t)}.$$

Many probability distributions can be used to model the failure distribution (*see List of important probability distributions*). A common model is the exponential failure distribution,

$$F(t) = \int_0^t \lambda e^{-\lambda x}\, dx = 1 - e^{-\lambda t},$$

which is based on the exponential density function.

$$h(t) = \frac{f(t)}{R(t)} = \frac{\lambda e^{-\lambda t}}{e^{-\lambda t}} = \lambda$$

For an exponential failure distribution the hazard rate is a constant with respect to time (that is, the distribution is "memoryless"). For other distributions, such as a Weibull distribution or a log-normal distribution, the hazard function may not be constant with respect to time. For some such as the deterministic distribution it is monotonic increasing (analogous to "wearing out"), for others such as the Pareto distribution it is monotonic decreasing (analogous to "burning in"), while for many it is not monotonic.

## Failure rate data

[edit]

Failure rate data can be obtained in several ways. The most common means are:

- Historical data about the device or system under consideration.

  Many organizations maintain internal databases of failure information on the devices or systems that they produce, which can be used to calculate failure rates for those devices or systems. For new devices or systems, the historical data for similar devices or systems can serve as a useful estimate.

- Government and commercial failure rate data.

  Handbooks of failure rate data for various components are available from government and commercial sources. MIL-HDBK-217F, *Reliability Prediction of Electronic Equipment*, is a military standard that provides failure rate data for many military electronic components. Several failure rate data sources are available commercially that focus on commercial components, including some non-electronic components.

- Testing.

  The most accurate source of data is to test samples of the actual devices or systems in order to generate failure data. This is often prohibitively expensive or impractical, so that the previous data sources are often used instead.

### Units

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Failure rates can be expressed using any measure of time, but hours is the most common unit in practice. Other units, such as miles, revolutions, etc., can also be used in place of "time" units.

Failure rates are often expressed in engineering notation as failures per million, or $10^6$, especially for individual components, since their failure rates are often very low.

The Failures In Time (FIT) rate of a device is the number of failures that can be expected in one billion ($10^9$) device-hours of operation. (E.g. 1000 devices for 1 million hours, or 1 million devices for 1000 hours each, or some other combination.) This term is used particularly by the semiconductor industry.

### Additivity

[edit]

Under certain engineering assumptions (e.g. besides the above assumptions for a constant failure rate, the assumption that the considered system has no relevant redundancies), the failure rate for a complex system is simply the sum of the individual failure rates of its components, as long as the units are consistent, e.g. failures per million hours. This permits testing of individual components or subsystems, whose failure rates are then added to obtain the total system failure rate.

### Example

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Suppose it is desired to estimate the failure rate of a certain component. A test can be performed to estimate its failure rate. Ten identical components are each tested until they either fail or reach 1000 hours, at which time the test is terminated for that component. (The level of statistical confidence is not considered in this example.) The results are as follows:

Failure Rate Calculation Example

| Component | Hours | Failure |
|---|---|---|
| Component 1 | 1000 | No failure |
| Component 2 | 1000 | No failure |
| Component 3 | 467 | Failed |
| Component 4 | 1000 | No failure |
| Component 5 | 630 | Failed |
| Component 6 | 590 | Failed |
| Component 7 | 1000 | No failure |
| Component 8 | 285 | Failed |
| Component 9 | 648 | Failed |
| Component 10 | 882 | Failed |
| Totals | 7502 | 6 |

Estimated failure rate is

$$\frac{6 \text{ failures}}{7502 \text{ hours}} = 0.0007998 \frac{\text{failures}}{\text{hour}} = 799.8 \times 10^{-6} \frac{\text{failures}}{\text{hour}},$$

or 799.8 failures for every million hours of operation.

## See also [edit]

- Failure
- Failure mode
- Reliability
- Reliability theory
- Reliability theory of aging and longevity
- Reliability engineering
- Survival analysis
- Weibull distribution
- MTBF
- Annualized failure rate
- Burn in
- User Reengineering (products)

*Statistics portal*

## References [edit]

### Print [edit]


- Blanchard, Benjamin S. (1992), *Logistics Engineering and Management, Fourth Ed.*, pp 26-32, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.
- Ebeling, Charles E., (1997), *An Introduction to Reliability and Maintainability Engineering*, pp 23-32,

McGraw-Hill Companies, Inc., Boston.

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- Kapur, K.C., and Lamberson, L.R., (1977), *Reliability in Engineering Design*, pp 8-30, John Wiley & Sons, New York.
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- MacDiarmid, Preston; Morris, Seymour; et al., (no date), *Reliability Toolkit: Commercial Practices Edition*, pp 35-39, Reliability Analysis Center and Rome Laboratory, Rome, New York.
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## Online [edit]


- Mondro, Mitchell J, (June 2002), "Approximation of Mean Time Between Failure When a System has Periodic Maintenance", *IEEE Transactions on Reliability*, v 51, no 2. (available from MITRE Corp.)
- *Reliability Prediction of Electronic Equipment*, MIL-HDBK-217F(2), (DOD download site.)
- Bathtub curve issues by ASQC.
- Fault Tolerant Computing in Industrial Automation by Hubert Kirrmann, ABB Research Center, Switzerland


## External links [edit]

- Google Answers question on MTBF
- Usenet FAQ about MTBF
- Reliability and Availability Basics
- Product failure behaviour and wear out
- Burn in and reliability
- The Safety and Reliability Society
- MTBF Calculation Tutorial
- Online Reliability calculator
- Reliability Prediction Tool


| v • d • e | | Statistics [hide] | |
|---|---|---|---|
| Descriptive statistics | Continuous data | Location | Mean (Arithmetic, Geometric, Harmonic) · Median · Mode |
| | | Dispersion | Range · Standard deviation · Coefficient of variation · Percentile |
| | | Moments | Variance · Semivariance · Skewness · Kurtosis |
| | Categorical data | | Frequency · Contingency table |
| Inferential statistics and hypothesis testing | Inference | | Confidence interval (Frequentist inference) · Credible interval (Bayesian inference) · Significance · Meta-analysis |
| | Design of experiments | | Population · Sampling · Stratified sampling · Replication · Blocking · Sensitivity and specificity |
| | Sample size estimation | | Statistical power · Effect size · Standard error |
| | General estimation | | Bayesian estimator · Maximum likelihood · Method of moments · Minimum distance · |

| | | |
|---|---|---|
| | | Maximum spacing |
| | Specific tests | Z-test (normal) · Student's t-test · F-test · Chi-square test · Pearson's chi-square test · Wald test · Mann–Whitney U · Wilcoxon signed-rank test |
| | Survival analysis | Survival function · Kaplan-Meier · Logrank test · Failure rate · Proportional hazards models |
| Correlation and regression | Correlation | Pearson product-moment correlation · Rank correlation (Spearman's rho, Kendall's tau) · Confounding variable |
| | Linear models | General linear model · Generalized linear model · Analysis of variance · Analysis of covariance |
| | Regression analysis | Linear · Nonlinear · Nonparametric · Semiparametric · Logistic |
| Statistical graphics | Bar chart · Biplot · Box plot · Control chart · Forest plot · Histogram · Q-Q plot · Run chart · Scatter plot · Stemplot | |

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Categories: Actuarial science | Statistical terminology | Failure | Reliability engineering | Survival analysis | Maintenance | Statistical ratios