Modeling and Analysis of Reliability and Maintenance Practices

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Topics to be Covered

- **Organization and management of reliability data. Data banks and data storage and retrieval system**
- Calculation of reliability parameters like; MTTF, MTBF MTTR etc from failure Data,
- Reliability in terms of hazard rate and failure density, Constant hazard model,
- Linearly increasing hazard and the weibull Model,
- Reliability and availability function, A k – out – of – m – structure,
- Calculation of reliability from FMEA and FTA,
- Preparation of computer programme for failure data analysis/calculations, Industrial case studies.

Organization and management of reliability data. Data banks and data storage and retrieval system

Databank/Storage/ Retrieval Management

What is Data/Reliability Data?

MONTH (2004)	TOTAL TIME IN HRS. (T_t)	UP TIME IN HRS. (U_t)	DOWN TIME IN HRS. (D_t)	NO. OF FREQ. OF FAILURE (N)	MTBF (HRS.)	HAZARD RATE (HRS.)	MDT (HRS.)	OPERATION AVAILABILITY (A_{op})	MTTR (HRS.)	MTBM (HRS.)	INHERENT AVAILABILITY (A_{in})
January	720	638	82	05	127.6	0.0078	16.4	0.886	4.92	127.6	0.962
February	720	636	84	03	212.0	0.0047	28.0	0.883	8.40	212.0	0.962
March	720	632	88	04	158.0	0.0063	22.0	0.877	6.50	158.0	0.959
April	720	630	90	07	090.0	0.0111	12.9	0.875	3.87	090.0	0.958
May	720	634	86	03	086.0	0/0047	28.7	0.880	8.61	086.0	0.960
June	720	648	72	01	072.0	0.0015	72.0	0.900	21.6	072.0	0.967
July	720	646	74	02	074.0	0.0030	37.0	0.923	11.1	074.0	0.966

Organization Structure of Effective Data (Main Parts)

1. Data
2. Hardware
3. Software
4. User – Programmer/System Analysts, End Users, Database Administrators, Database Designers

Continue…

Once data have been collected and recorded, the next concern is data storage.

- Properly storing data is a way to safeguard your effort.
- Data may need to be accessed in the future to explain or augment subsequent work.
- Other researchers/Analysts might wish to evaluate or use the results of your work task.
- Stored data can establish precedence in the event to minimize the effort.
- Storing data can protect task goals and man force in the event of legal allegations.

Research

Key Points

Storing data safeguards your research and your research investment. Storage allows future access to the data in order to re-create the findings, augment subsequent research, or establish a precedent.

Enough data should be stored so that a project and its findings can be reconstructed with ease.

Think Ahead Quiz: What Are Data?

True or False: In scientific research, only the information and observations that are made as part of scientific inquiry are considered data.

__True
__False

Answer: False. In fact, data also include the materials, products, procedures, and other data sources that are part of the research project. Essentially, data are considered to be anything and everything that informs the way in which individuals are able to understand and to process their world. Read on to learn more.

Reliability… What…?

- The **probability** that a system or component will perform its desired function without failure under stated conditions for a stated period of time.
- For systems with repairable components, repairs must be considered in the calculation of reliability. This parameter can be calculated for specific points in time

Continue…

Reliability is a time dependent characteristic.

- It can only be determined after an elapsed time but can be predicted at any time.

- It is the probability that a product or service will operate properly for a specified period of time (design life) under the design operating conditions without failure.

Unreliability

- The probability that a system or component will fail under stated conditions during a stated period of time. This parameter can be calculated for specific points in time.

Availability

- The probability that a system or component is in an operable state at a specified time.
- Logistic delay times and administrative downtime for maintenance are not included in the calculation of availability.
- If you want to include these times, you would choose to calculate operational availability instead

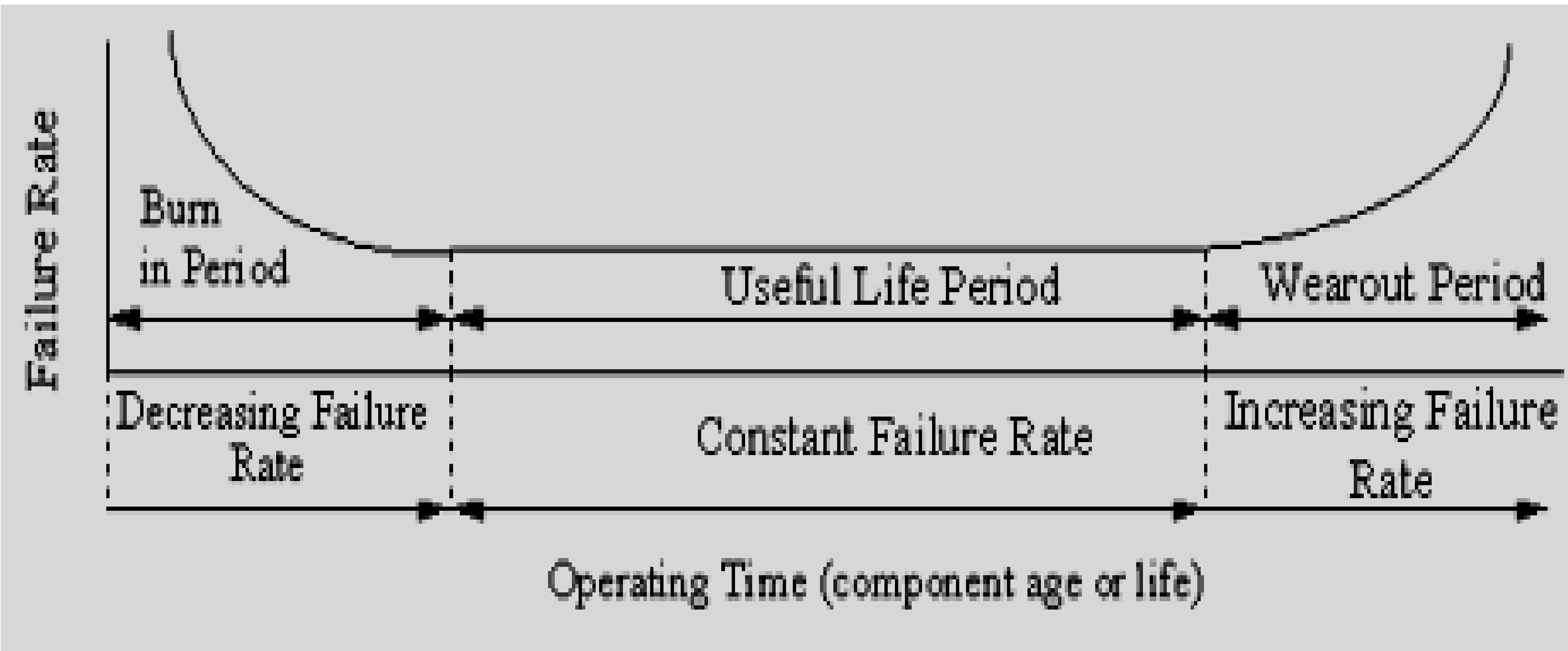
Other Measures of Reliability

Availability is used for repairable systems

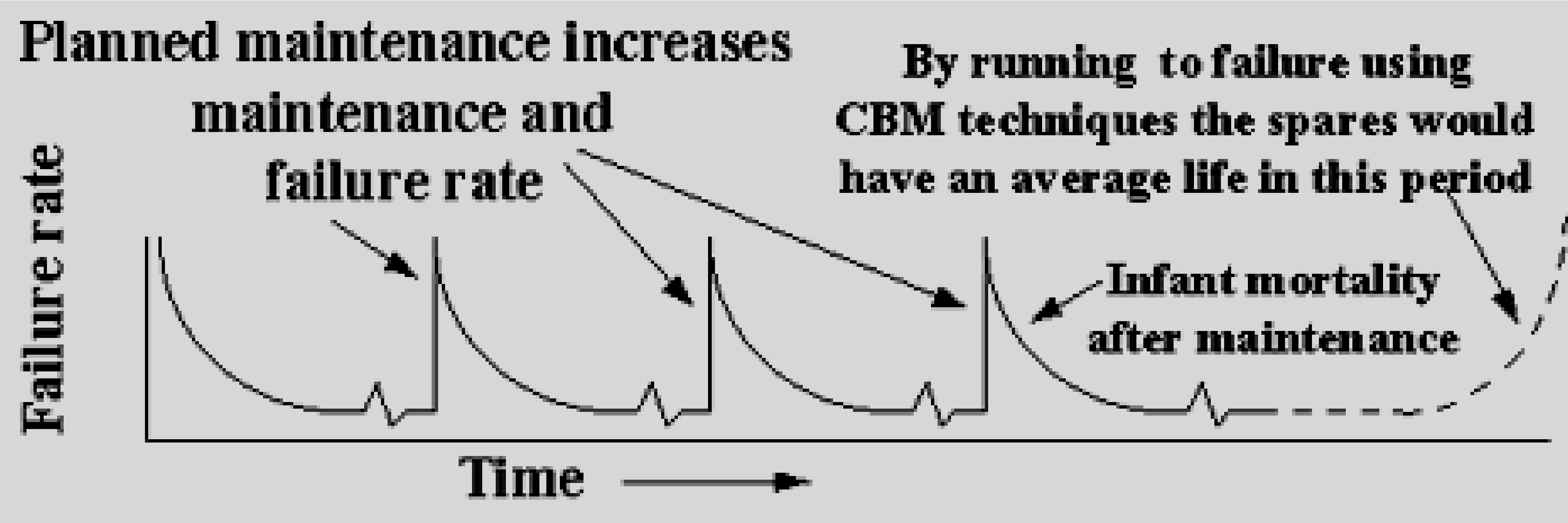
- It is the probability that the system is operational at any random time t.

- It can also be specified as a proportion of time that the system is available for use in a given interval (0,T).

BATH-TUB (Mortality) Curve



- In the first of the three stages, the failure rate plunges downward rapidly from a very high starting point - this is "infant mortality".
- Failure during this stage can be attributed almost entirely to manufacturing & installation defects.
- The term "Burn In" which can also be used to describe this period comes from the computer industry where new machines are run in a hot environment before dispatch.


Planned maintenance increases maintenance and failure rate
By running to failure using CBM techniques the spares would have an average life in this period
Infant mortality after maintenance
Failure rate
Time

Measures of Reliability

Mean Time To Failure (MTTF): *It is the average time that elapses until a failure occurs.*

It does not provide information about the distribution of the TTF, hence we need to estimate the variance of the TTF.

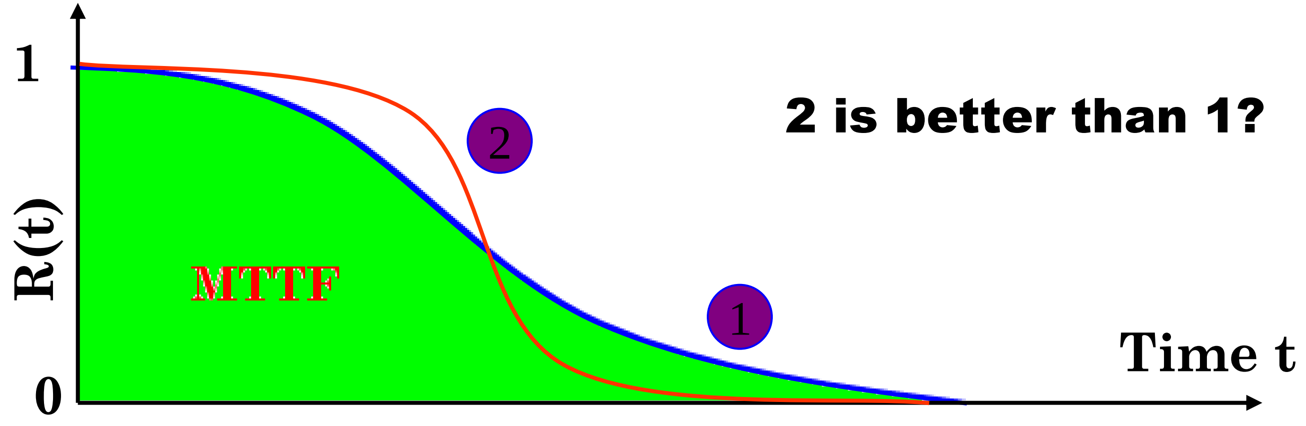
Mean Time Between Failure (MTBF): It is the average time between successive failures.

It is used for repairable systems.

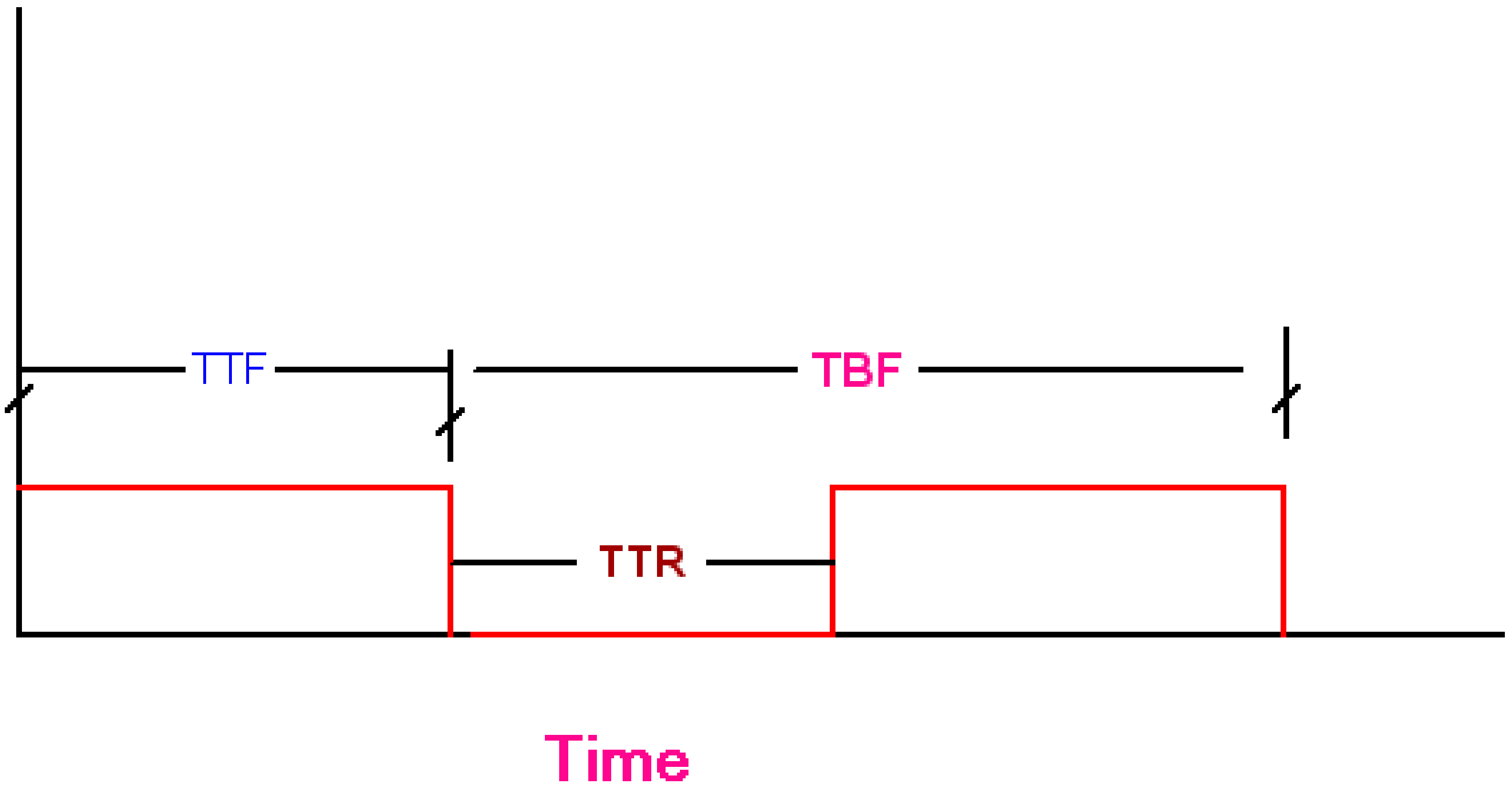
Mean Time to Failure: MTTF

$$MTTF = \int_0^\infty t f(t)dt = \int_0^\infty R(t)dt$$

$$MTTF = \frac{1}{n}\sum_{i=1}^{n} t_i$$



Mean Time Between Failure: MTBF



- *Failure Rate (FITs failures in 10^9 hours):* The failure rate in a time interval $[t_1 - t_2]$ is the probability that a failure per unit time occurs in the interval given that no failure has occurred prior to the beginning of the interval.
- *Hazard Function:* It is the limit of the failure rate as the length of the interval approaches zero.

Basic Calculation

- MTBF = Uptime (U_t)/ No. of frequency of failure (N)
- Hazard rate (H_r)

  = No. of frequency of failure (N)/Uptime (U_t)

  = 1/MTBF
- MDT = Downtime (D_t)/ No. of frequency of failure (N)
- MTTR = 0.3 X MDT
- A_{op} = MTBF/(MTBM + MDT)
- A_{in} = MTBF/(MTBF + MTTR)

Example: 01

- The powder manufacturing unit of dairy plant runs 24 hrs/day with one day as shut down/month. Calculate the following reliability parameters for month of January; if total down time is 82 hrs. (i) MTBF (ii) Hazard Rate (iii) MDT (iv) Operational Availability (v) MTTR (vi) MTBM (vii) Inherent Availability.

Solution: 01

- Total 31 days for January so;
- Total Running Time = 24 x 30 = 720 Hrs (Considering one day as shut down period)
- Total Down Time = 82 Hrs (Given)
- Effective Up Time = 720 – 82 = 638 Hrs

- (i) Calculation of MTBF:
- MTBF = Uptime (U_t)/ No. of frequency of failure (N)
- MTBF = 638/5
- = 127.6
- (ii) Calculation of Hazard Rate (H_r):
- Hazard rate (H_r) = No. of frequency of failure (N)/Uptime (U_t)
- = 1/MTBF
- = 1/127.6
- = 0.0078
- (iii) Calculation of MDT:
- MDT = Downtime (D_t)/ No. of frequency of failure (N)
- = 82/05
- = 16.4

- (iv) Calculation of MTTR:
- MTTR = 0.3 X MDT
- = 0.3 X 16.4
- = 4.92
- (v) Calculation of MTBM:
- MTBM = [Total Time (T_t)/N] – MDT
- = [720/5] – 16.4
- = 127.6 = MTBF
- (vi) Calculation of operational availability:
- A_{op} = MTBF/(MTBM + MDT)
- = 127.6/(127.6 + 16.4)
- = 0.886

- (vii) Calculation of inherent availability:
- $$A_{in} = MTBF/(MTBF + MTTR)$$
- $$= 127.6/(127.6 + 4.92)$$
- $$= 0.962$$

- Reliability in terms of hazard rate and failure density, Constant hazard model

Reliability Parameter Equations

Suppose n_0 identical units are subjected to a test. During the interval (t, t+Δt), we observed $n_f(t)$ failed components. Let $n_s(t)$ be the surviving components at time t, then the MTTF, failure density, hazard rate, and reliability at time t are:

$$MTTF = \frac{\sum_{i=1}^{n_0} t_i}{n_0}, \qquad \hat{f}(t) = \frac{n_f(t)}{n_0 \Delta t}$$

$$\hat{\lambda}(t) = \frac{n_f(t)}{n_s(t)\Delta t}, \qquad \hat{R}(t) = P_r(T > t) = \frac{n_s(t)}{n_0}$$

The unreliability $F(t)$ is;

$$F(t) = 1 - R(t)$$

Example: 02

Example: 200 light bulbs were tested and the failures in 1000-hour intervals are

Time Interval (Hours)	Failures in the interval
0-1000	100
1001-2000	40
2001-3000	20
3001-4000	15
4001-5000	10
5001-6000	8
6001-7000	7
Total	200

Calculations

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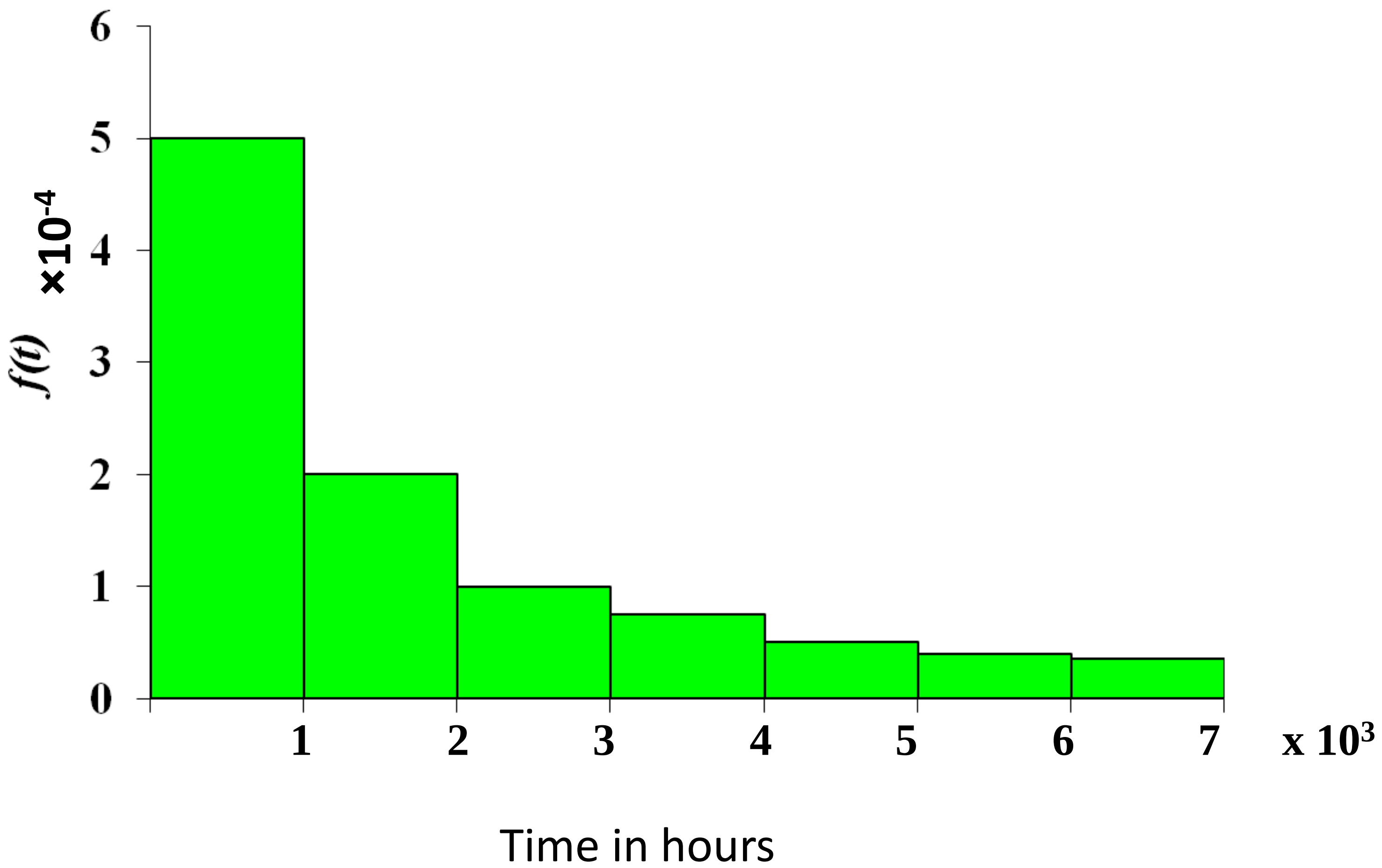
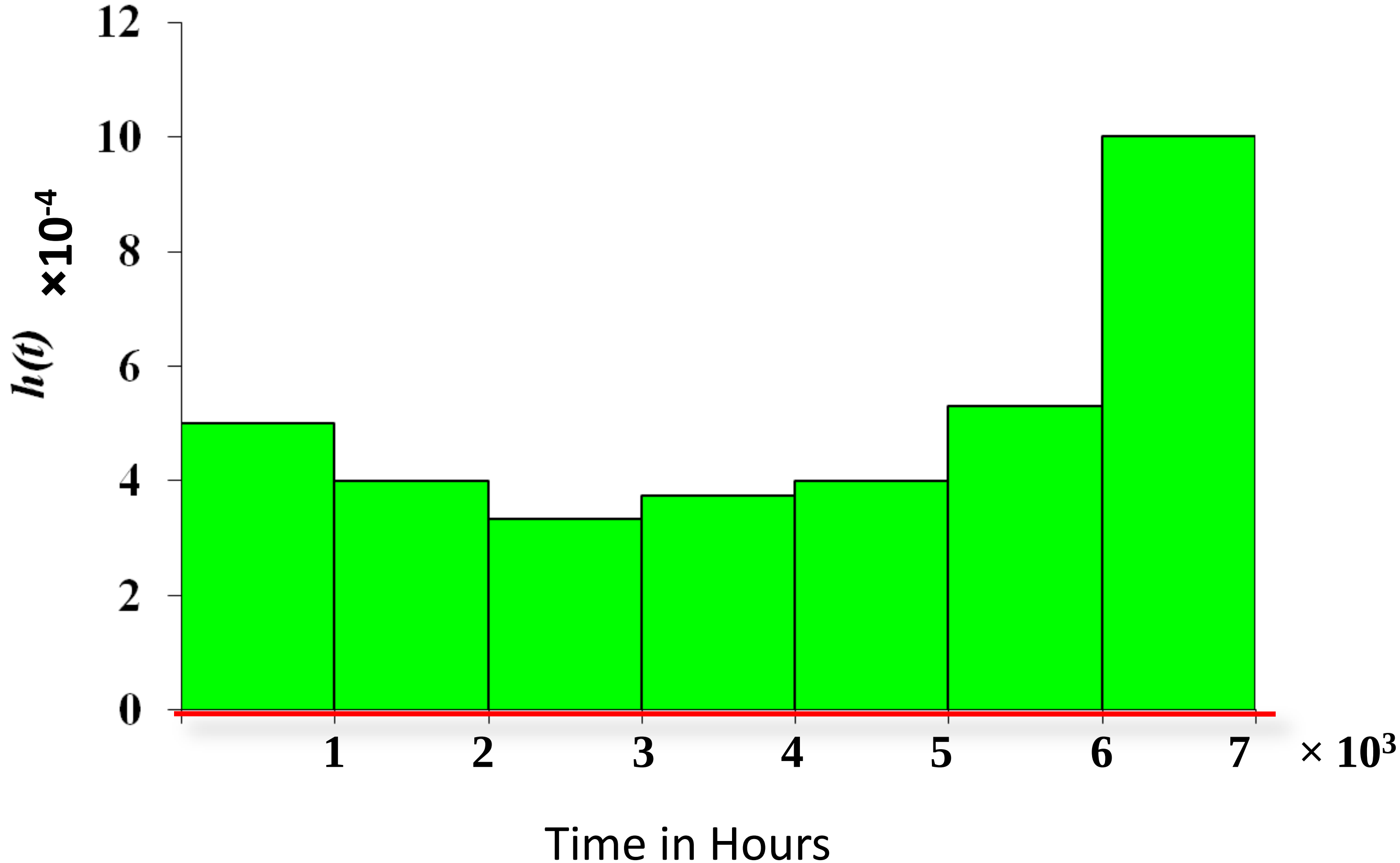
Total	200

Time Interval	Failure Density $f(t)$ x 10^{-4}	Hazard rate $h(t)$ x 10^{-4}
0–1000	$\frac{100}{200 \times 10^3} = 5.0$	$\frac{100}{200 \times 10^3} = 5.0$
1001–2000	$\frac{40}{200 \times 10^3} = 2.0$	$\frac{40}{100 \times 10^3} = 4.0$
2001–3000	$\frac{20}{200 \times 10^3} = 1.0$	$\frac{20}{60 \times 10^3} = 3.33$
……	……..	……
6001–7000	$\frac{7}{200 \times 10^3} = 0.35$	$\frac{7}{7 \times 10^3} = 10$

Failure Density vs. Time



Hazard Rate vs. Time



Calculations

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6001-7000	7
Total	200

Time Interval	Reliability $R(t)$
0–1000	200/200=1.0
1001–2000	100/200=0.5
2001–3000	60/200=0.33
……	……
6001–7000	0.35/10=.035

Reliability vs. Time