Lecture #19

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Quality - Reliability

- We already discussed some of the service quality dimensions.
- One of them is Reliability
- We will revisit Reliability today – how reliability of a product/service can influence the system performance

Product vs. Service Reliability

- **Product**
  - Refers to probability that product will perform intended function for specific period under specified conditions
    - Probability that transmission system will not require a repair for 6 years when maintained according to guidelines.
  - Many measures of reliability

Product vs. Service Reliability

- **Service**
  - **Ability to perform the service dependably and accurately. Organization performs service right the first time and honors its promises.**
  - **Examples include**
    - **Accuracy in billing**
    - **Keeping records correctly**
    - **Completing service as scheduled**

Reliability Indexes

- As experience is gained in quantifying reliability, many companies are learning that it is best to create an index that uniquely meets the needs of those who will use the index
  - Telephone system: Downtime of switching center should be a maximum of 24 hours per 40 years or 0.6 hour/year or 36 min/yr or about 0.1 min/day

Reliability Goals

- Setting overall reliability goals requires agreement on:
  - Reliability as a number
  - The environmental conditions to which the numbers apply
  - A definition of successful product/service performance

Reliability Quantification Process

- **Apportionment (or budgeting)**
  - Process of allocating reliability objectives among various elements that collectively make up a higher-level product/service.
- **Prediction**
  - The use of prior performance data plus probability theory to calculate the expected failure rates
- **Analysis**
  - Identification of the strong and weak portions of the design to serve as a basis for improvements, trade-offs, etc.

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Reliability Engineering Disciplines

- Reliability – time to failure
- Maintainability – time to repair
- Availability – relates to use time – includes fix time

- All three of these areas can be numerically quantified with the use of reliability engineering principles and life data analysis.

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Fundamental Concepts

- Probability density function (pdf), f(t), associated with lifetime or time to failure of a unit that is of interest
- F(t) denotes the probability that the unit fails before some time t, i.e. the cumulative distribution function or cdf, can be found by

$$F(t) = P(T \leq t) = \int_0^t f(x)\,dx$$

Important Functions

- **Reliability Function (or Survival Function)**
  - **The probability that a unit survives to time t:**

$$R(t) = P(T > t) = 1 - P(T \leq t) = 1 - F(t)$$

  - **The reliability function is always a decreasing function of time.**

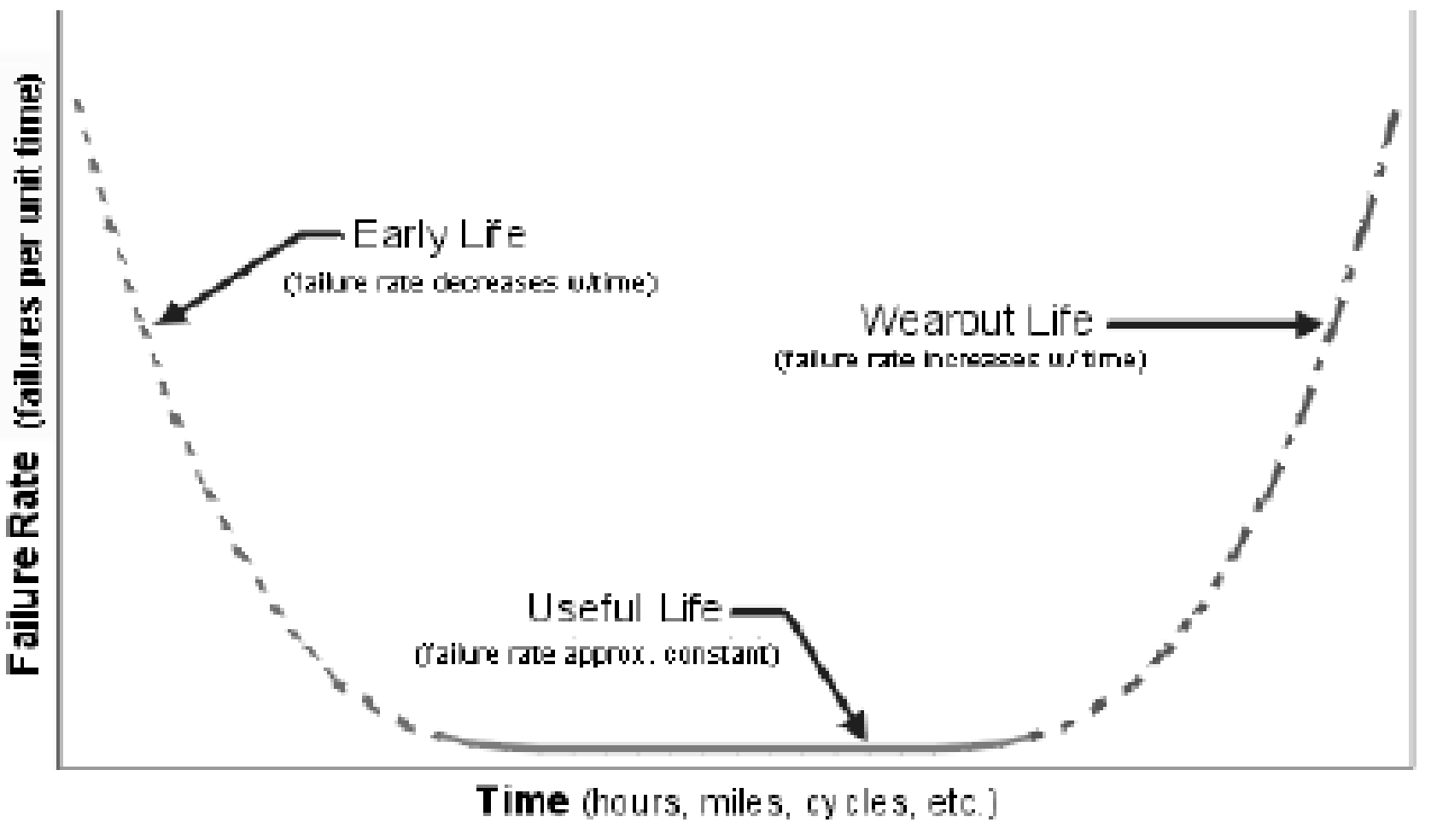
Important Functions

- **Hazard Function**
  - The rate of failure of units,

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

  - h(t) is the hazard or instantaneous failure rate function. It indicates the proneness to failure or risk of failure of a unit after time t has elapsed.

Important Functions



Important Functions

- **Mean Time Between Failures (MTBF)**

$$MTBF = \int_0^\infty tf(t)dt, \text{ or } MTBF = \int_0^\infty [1 - F(t)]dt$$

- **Average or expected lifetime of an item. Frequently used**

$$MTBF = \int_0^\infty R(t)dt$$

- **Most commonly expressed in terms of reliability fcn.**

System Reliability

- Consider components
  - In Series
  - In Parallel
  - Combination of Series and Parallel

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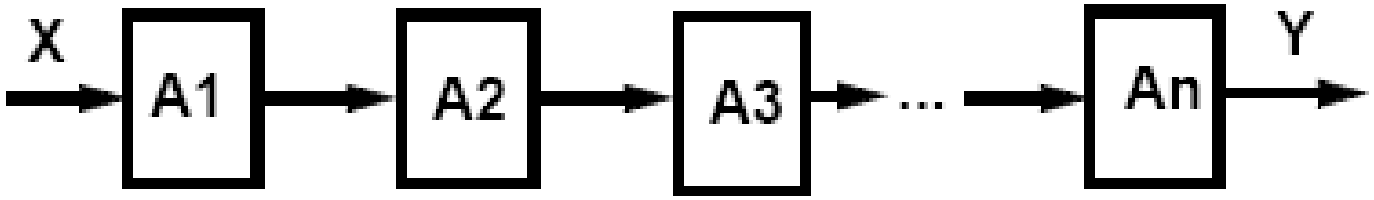
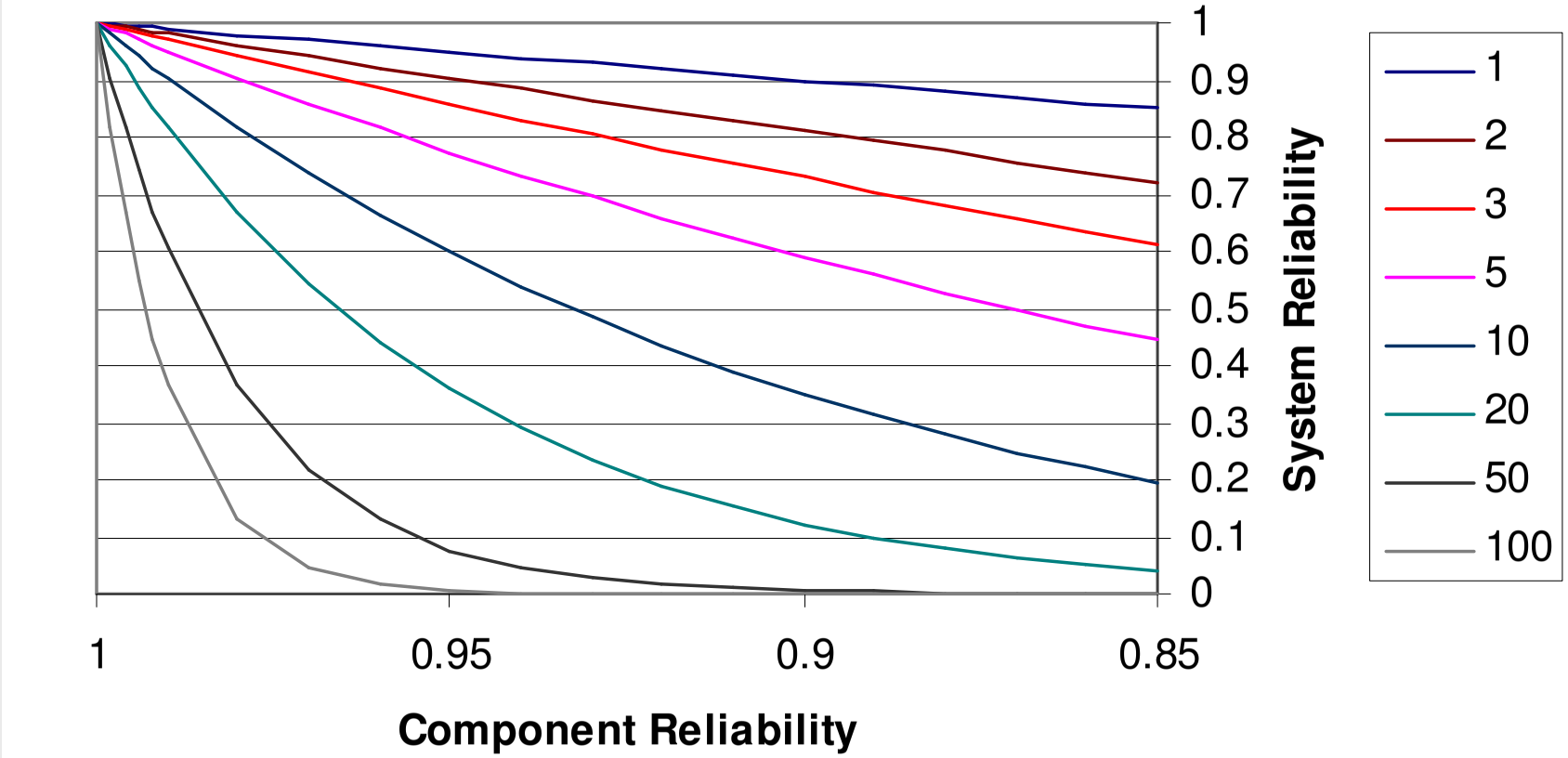
Series System



$$R_{system} = \prod_{i=1}^{n} R_i$$

R_i is probability component i will survive for design life.



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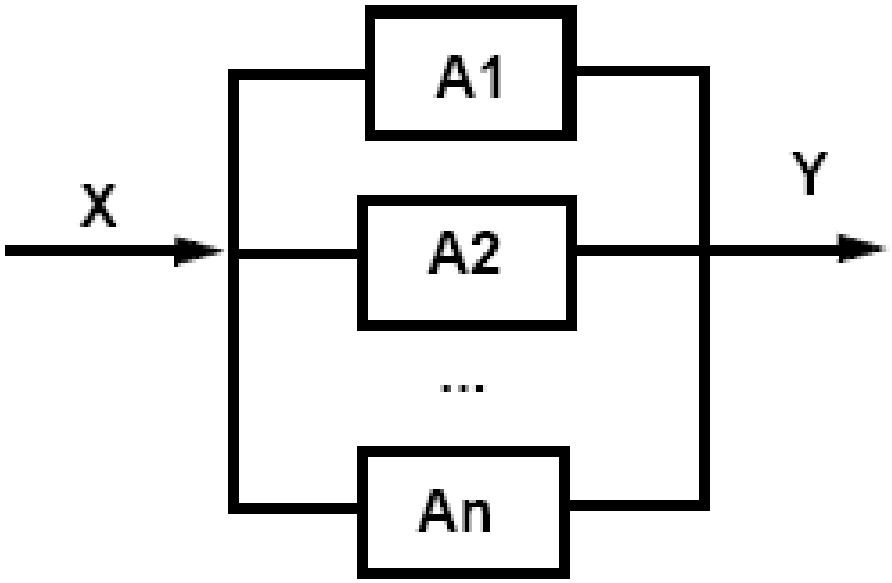
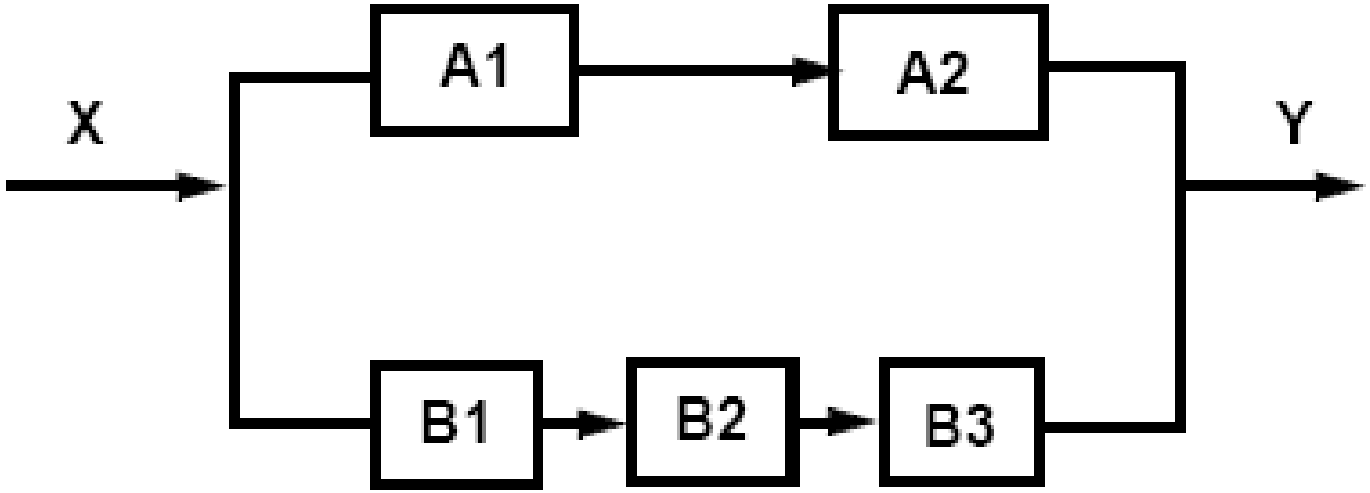
Parallel System



$$R_{system} = 1 - \prod_{i=1}^{n} (1 - R_i)$$

Mixed System

Example:



$$R_{system} = 1 - (1 - R_{A_1A_2}) \times (1 - R_{B_1B_2B_3})$$

$$R_{A_1A_2} = R_{A_1} \times R_{A_2'} \qquad R_{B_1B_2B_3} = R_{B_1} \times R_{B_2} \times R_{B_3}$$

System Reliability Example

- Pyzdek (1994) discusses the design of an ambulance service to handle emergency calls
- It is developed on a reliability block diagram for the rescue system
  - The reliability of the system is (0.998)(0.999)…(0.994) = 0.9195; i.e., the system would succeed in its mission about 92 % of the time.

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Emergency Rescue System

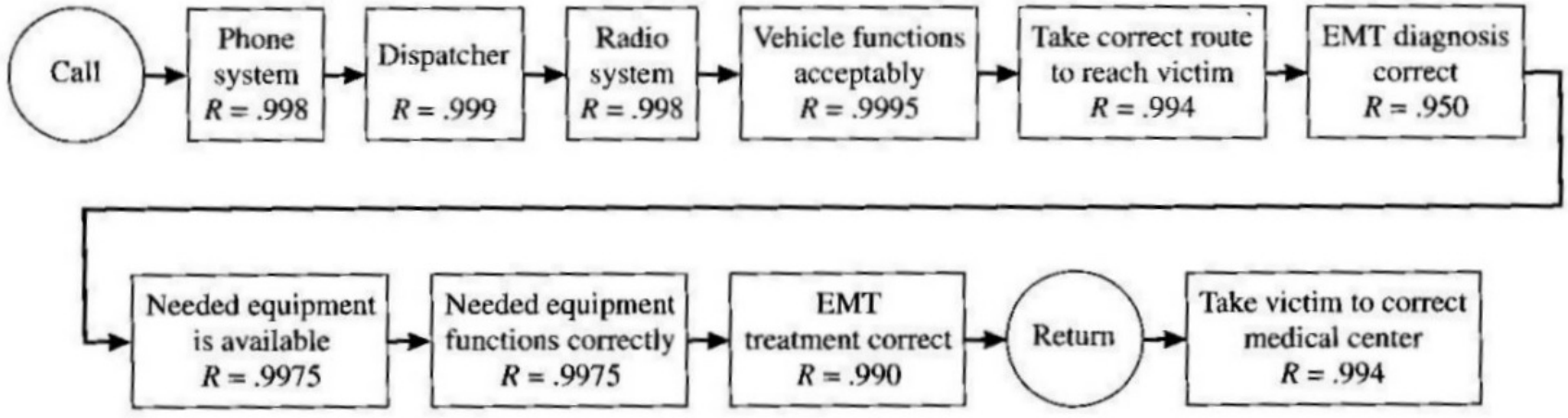

FIGURE 14.4
Reliability block diagram of emergency rescue system. (*Reprinted with permission by the ASQ.*)

Gryna 2001

Predicting Reliability during Design

- **Define the product and function**
  - The system, subsystems, and units must be precisely defined in terms of their functional configurations and boundaries
- **Prepare a reliability block diagram**
  - For systems in which there are redundancies or other special interrelationships among parts
- **Develop the probability model**
  - A simple model may only add failure rates; or a complex model can account for redundancies and other conditions

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Predicting Reliability during Design

- Collect information relevant to part reliability
- Select parts reliability data
- Combine all of the above to obtain numerical reliability prediction

More on Predicting Reliability…

- Based on the exponential distribution
- Based on the Weibull distribution
- As a function of applied stress and strength.

Failure Modes & Effects Analysis (FMEA)

- Important tool for predicting and analyzing reliability
- Evolved at NASA – where interest in preventing failures is extremely high
- Later popularized by automotive industry.
- Now routine in many organizations

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Failure Modes and Effects Analysis

- FMEA is a system for analyzing the design of a product or service system to identify potential failures, then taking steps to counteract or minimize the risk of failure
- The FMEA process begins by identifying "failure modes", the ways in which a product, service, or process could fail
- A project team examines every element, starting from the inputs and working through to the output delivered to the customer

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Failure Modes – truck stop coffee

- One of the inputs to process is “clean coffee pot.” What could go wrong? Water in the dishwasher is not hot enough, so pot is not cleaned
- First step in process is to fill the brewing machine with water. What could go wrong? Perhaps water is not the right temperature or too much/little water is added
- Output from process is hot cup of coffee delivered to the customer. What could go wrong? Coffee could cool before it is served.

RPN

- RPN = Risk Priority Number
- All failures are not the same
- Being served a cup of coffee that is just hot water is much worse than being served a cup that is just a bit too cool.
- A key element of FMEA is analyzing three characteristics of failures:
  - How severe they are
  - How often they occur
  - How likely it is that they will be noticed when they occur.

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More on RPN

- Typically, the project team scores each failure mode on a scale of 1 to 10 or 1 to 5 in each of the three areas, then calculates a Risk Priority Number:
  - RPN = (Severity) x (freq. of occurrence) x (likelihood of detection)

FMEA

- Idea is to focus improvement efforts on the failures that have the biggest impact on customers
- Highest scoring failure modes are those that happen frequently, are bad when they happen, and/or are difficult to detect.
- Difficult-to-detect errors – more likely to get through to customers

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More on FMEA

- Team completes FMEA analysis for highest-scoring failure modes and for the highest severity scores
- Want to make sure possible disasters are prevented – even if they are unlikely to occur
- "Completing the analysis" means:
  - Looking at potential causes for error mode
  - Identifying ways to detect the problem
  - Developing recommended actions
  - Assigning responsibility for monitoring the process and taking action when warranted

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