



## Activity 7.1a - Prediction of Failure Rates with Dice

### Purpose

Many manufacturers offer warranties on their products. A one hundred thousand mile, bumper to bumper warranty could cost the car manufacturer a great deal. The manufacturer must do an analysis to figure out when and where failure might occur and how much it might cost the company. This price must be added to the price of the product. If the cost of the warranty is too great, the product will not be competitive. If the charge is too little, the company may lose money and go out of business.

Companies use statistics to predict what their failure rates might be. To learn about reliability statistics, dice can be used to model components. In this activity you will see if statistical theory can be demonstrated in reality.

### Materials

Dice - at least two of two different colors per group

### Procedure:

#### Single component case:

A single die will represent a mechanical component in a device which needs to be tested. For this simulation, if a "1" is rolled the component will have failed the test and need to be rejected. If a 2, 3, 4, 5, or 6 is rolled, the component will have passed.

1. According to pure mathematical probability, what is the predicted failure rate?  
\_\_\_\_\_ failure in every \_\_\_\_\_ tests
2. Express the failure rate as a decimal number: \_\_\_\_\_
3. Express the failure rate as a percentage: \_\_\_\_\_%

Now, roll the dice 100 times. Keep a record of successful and unsuccessful trials.

4. Calculate the experimental failure rate of the die. Express your answer as a percentage: \_\_\_\_\_%

5. How closely does this value compare to the predicted value from question #3 above?

**Independent component case:**

Two dice, one of each color, will represent two different components of a single mechanism. One die fails when a “1” is rolled, the other fails if either “1” or “2” are rolled.

6. What would probability theory predict the failure rate of the first die to be?  
\_\_\_\_ failure in every \_\_\_\_\_ tests
7. What would probability theory predict the failure rate of the second die to be?  
\_\_\_\_ failure in every \_\_\_\_\_ tests
8. Express each of these failure rates in decimal terms:  
Die #1 \_\_\_\_\_ failure rate      Die #2 \_\_\_\_\_ failure rate
9. Draw a sketch, using circles to represent each of the die, to show the dependency of each of the two components being described here.

10. If this “device” depends on BOTH dice (components) functioning properly, calculate the predicted failure rate for the device.  
Overall failure rate: \_\_\_\_\_

Roll both dice simultaneously, 100 times. Record the number of times the “device” succeeds and fails.

11. Calculate the experimental failure rate of the die. Express this in decimal form: \_\_\_\_\_
12. How closely does this value compare to the predicted value?

**Dependent component case, with redundancy:**

In this variation, we still have two dice components, but one of the components is used as a redundant twin. This means that there is a backup check system in case the first component fails. For example, in a space flight there are two onboard computers doing the exact same function. If the first computer fails, the second computer is there to instantly take its place. For this simulation, the first die (representing the first component) will fail if a “1” is rolled. The second die (the second component) will fail if a “1” or a “2” is rolled. The entire system fails, if and only if, the first component AND the second component both fail simultaneously.

13. Express these failure rates in decimal terms:

Die #1 \_\_\_\_\_ failure rate      Die #2 \_\_\_\_\_ failure rate

14. Draw a component sketch that shows the dependency of these two components.

15. If this “device” depends on either the first device OR the second device functioning properly at any given time, calculate the predicted failure rate for the device.

Overall failure rate: \_\_\_\_\_

Next, roll both dice simultaneously, 100 times. Record the times the “device” succeeds and fails.

16. Calculate the experimental failure rate of the die. Express this in decimal form: \_\_\_\_\_

17. How closely does this value compare to the predicted value?

## Conclusion

1. From what you observed, how accurate are statistical predictions based on probability?
2. How does statistical sampling of failure rates and factor of safety affect the design of a product?
3. Your company wants to change the warranty it offers from a one-year to a two-year. What types of statistical data would you need to know if you had to decide how much more it might cost to offer this?