Continuing Education Course #399
Engineering Methods in Microsoft Excel
Part 5: Simulation and Systems Modelling II

1. Simulation can be described as
 ◯ a. the experimentation or modelling of a system or process, on a computer, using mathematical and statistical models.
 ◯ b. the formulation of large-scale models of engineering systems for testing in a laboratory.
 ◯ c. All the above.

2. In which of the following scenarios will simulation be useful?
 ◯ a. Assessing the impacts large-scale flooding in a large metropolitan area.
 ◯ b. Analyzing the structural performance of highway bridge components due to future traffic impacts and regulation changes.
 ◯ c. All the above.

3. In Monte Carlo simulation, the performance characteristics of the elements of a system are described by
 ◯ a. optimization models
 ◯ b. random variables
 ◯ c. simple trigonometric functions

4. Sources of probabilistic performance of elements of engineering systems include,
 ◯ a. quality of workmanship, uncertainty of logistics, failure of machinery and tools, vagaries of weather
 ◯ b. random effects in supply chains, scheduling conflicts, unforeseen delays in obtaining permits
 ◯ c. All the above

Use the following simulation model to answer Question 5 through Question 9

<u>Eye Clinic Simulation:</u>
An industrial engineer has been retained by an eye clinic to develop a simulation model of the patient visit duration in order to identify areas for improving the patient experience. A patient arrives at the facility and goes through a check-in process to verify identification, update paperwork, confirm insurance information and account status. The patient then proceeds to an initial consultation, preparation and testing with a nursing professional. Based on the patient's specifics there is a 70% - 30% chance the patient is moved to a consultation with either an Ophthalmologist (DO) or with a Physician (MD). After seeing the DO or MD, the patient goes through the check-out procedure where the patient makes payments for service and sets up future appointments. After check-out there is a 30% chance the patient will see the independent Optometrist on site to fit eyewear. The time (in minutes) for the patient visit duration can be broken into the following discrete steps, each modelled by a random variable as follows,

Step 1: Check-in (t_1): Uniform distribution, from 10 minutes to 20 minutes.

Step 2: Nurse consultation and testing (t_2): Exponential distribution, with mean of 10 minutes.

Step 3: DO Consultation (t_{31}): Lognormal distribution, with parameters α = 2.3 and β = 0.42,

or
MD Consultation (t_{32}): Loglogistic distribution, with parameters α = 2.48 and β = 0.25.

Step 4: Check-out (t_4): Lognormal distribution, with parameters α = 1.2 and β = 0.35.

Step 5: Optometrist (t_5): Normal distribution with mean of 15 minutes and standard deviation of 5 minutes.

The Patient Visit Duration (T) is therefore,

$$T = t_1 + t_2 + 0.7t_{31} + 0.3t_{32} + t_4 + 0.3t_5$$

A spreadsheet model of the patient visit duration is provided as *Simulation 1A* in the Test 2 Worksheet Excel file.

5. Conducting 5,000 simulations, the average patient visit duration is approximately
- ○ a. 25 minutes
- ○ b. 45 minutes
- ○ c. 75 minutes

6. Based on 5,000 simulations, the standard deviation of the patient visit duration is approximately
- ○ a. 5 minutes
- ○ b. 12 minutes
- ○ c. 22 minutes

7. Based on 5,000 simulations, the median patient visit duration is approximately
- ○ a. 83 minutes
- ○ b. 63 minutes
- ○ c. 43 minutes

8. Based on 5,000 simulations, the upper quartile of the patient visit duration is approximately
- ○ a. 90 minutes
- ○ b. 75 minutes
- ○ c. 50 minutes

9. Based on 5,000 simulations, the 95th percentile patient visit duration is approximately
- ○ a. 68 minutes
- ○ b. 88 minutes
- ○ c. 110 minutes

Use the following information to make changes to the simulation model and answer Question 10 through Question 14.

The clinic made changes to their processes resulting in the following:
Step 1: Check-in (t_1): Uniform distribution, from 5 minutes to 15 minutes.
Step 5: Optometrist (t_5): Normal distribution with mean of 25 minutes and standard deviation of 8 minutes, with a 20% chance a patient will see the Optometrist.

An incomplete (not updated) spreadsheet model of the patient visit duration is provided as *Simulation 1B* in the Test 2 Worksheet Excel file.

10. Conducting 5,000 simulations, the average patient visit duration will be approximately
- ○ a. 63 minutes
- ○ b. 43 minutes
- ○ c. 23 minutes

11. Based on 5,000 simulations, the standard deviation of the patient visit duration will be approximately
- a. 32 minutes
- b. 12 minutes
- c. 6 minutes

12. Based on 5,000 simulations, the median patient visit duration will be approximately
- a. 21 minutes
- b. 31 minutes
- c. 41 minutes

13. Based on 5,000 simulations, the upper quartile of the patient visit duration will be approximately
- a. 48 minutes
- b. 65 minutes
- c. 70 minutes

14. Based on 5,000 simulations, the 95th percentile patient visit duration is approximately
- a. 95 minutes
- b. 78 minutes
- c. 64 minutes

Use the following information to make changes to the simulation model and answer Question 15 through Question 19.

The engineer makes the following changes to the simulation model based on new data.
Step 1: Check-in (t_1): Triangular distribution, with parameters a = 8 minutes, b = 20 minutes, c = 12 minutes.

Step 2: Nurse consultation and testing (t_2): Uniform distribution, from 6 minutes to 18 minutes.

Step 3: DO Consultation (t_{31}): Lognormal distribution, with parameters α = 2.3 and β = 0.42,
or
MD Consultation (t_{32}): Loglogistic distribution, with parameters α = 2.48 and β = 0.25.
There is a 50% - 50% chance the patient is moved to a consultation with either an Ophthalmologist (DO) or with a Physician (MD).

Step 4: Check-out (t_4): Exponential distribution, with mean of 4 minutes.

Step 5: Optometrist (t_5): Logistic distribution with mean of 12 minutes and standard deviation of 4 minutes.
There is a 40% chance the patient will see the independent Optometrist

The Patient Visit Duration (T) is therefore,

$$T = t_1 + t_2 + 0.5t_{31} + 0.5t_{32} + t_4 + 0.4t_5$$

A partially completed spreadsheet simulation model of the patient visit duration with the above changes is provided as *Simulation 2* in the Test 2 Worksheet Excel file. Implement the following to complete the model.

Step 1: Check-in (t_1): Implement the parameters of the Triangular distribution.

Step 2: Nurse consultation and testing (t_2): Implement the parameters of the Uniform distribution.

Step 3: Update the probabilities of patients seeing the DO and MD, as well as the Optometrist, in the patient visit duration formula.

Step 4: Check-out (t_4): Implement the parameter of the Exponential distribution.

Step 5: Optometrist (t_5): Implement the Logistic distribution formula and its parameters.

15. Conducting 5,000 simulations, the average patient visit duration will be approximately
- ○ a. 47 minutes
- ○ b. 40 minutes
- ○ c. 37 minutes

16. Based on 5,000 simulations, the standard deviation of the patient visit duration will be approximately
- ○ a. 3 minutes
- ○ b. 5 minutes
- ○ c. 8 minutes

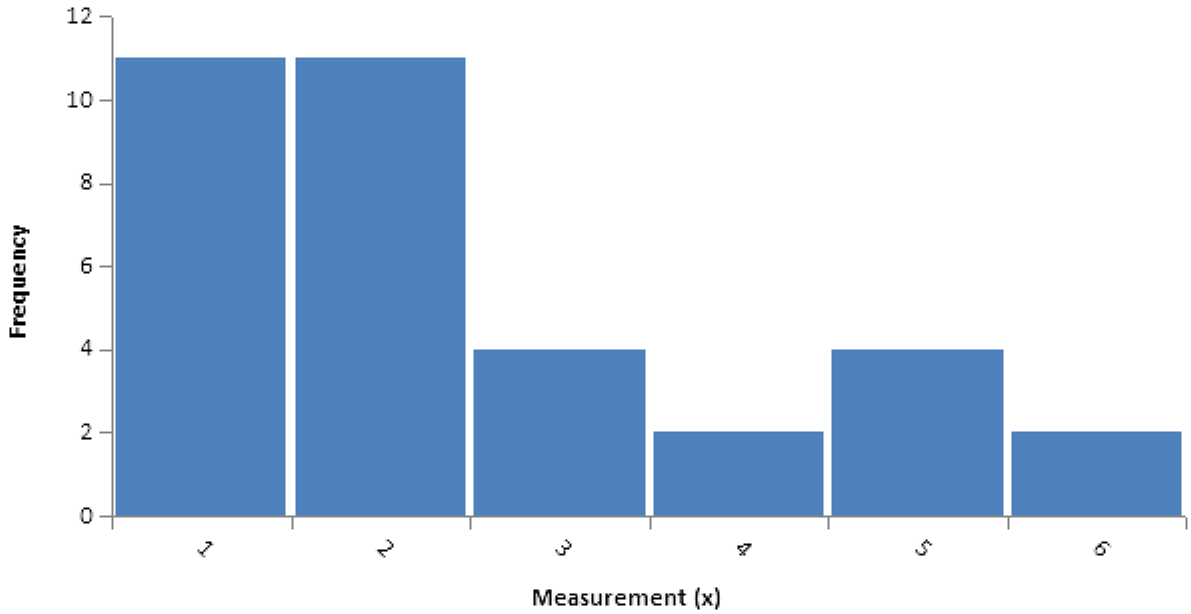
17. Based on 5,000 simulations, the median patient visit duration will be approximately
- ○ a. 46 minutes
- ○ b. 50 minutes
- ○ c. 55 minutes

18. Based on 5,000 simulations, the upper quartile of the patient visit duration will be approximately
- ○ a. 68 minutes
- ○ b. 51 minutes
- ○ c. 47 minutes

19. Based on 5,000 simulations, the 95th percentile patient visit duration is approximately
- ○ a. 54 minutes
- ○ b. 60 minutes
- ○ c. 66 minutes

20. Probability plotting is a technique by which
- ○ a. a random variable can be converted from one theoretical model to another.
- ○ b. a known probability distribution is assessed for its suitability to describe the observed data.
- ○ c. All the above.

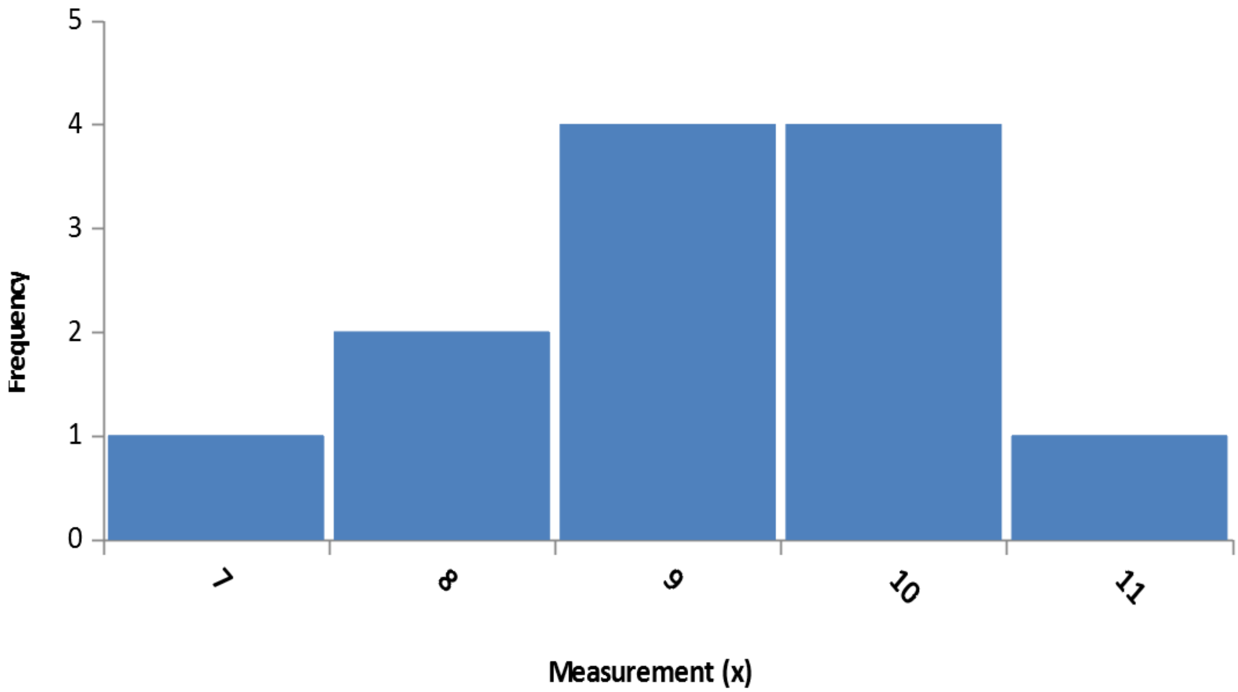
21. Consider the histogram for an observed data set.



The histogram suggests

- ◯ a. a skewed distribution will not be suitable for describing the data.
- ◯ b. a symmetrical bell-shaped distribution may be suitable for describing the data.
- ◯ c. None of the above.

22. Consider the histogram for an observed data set.



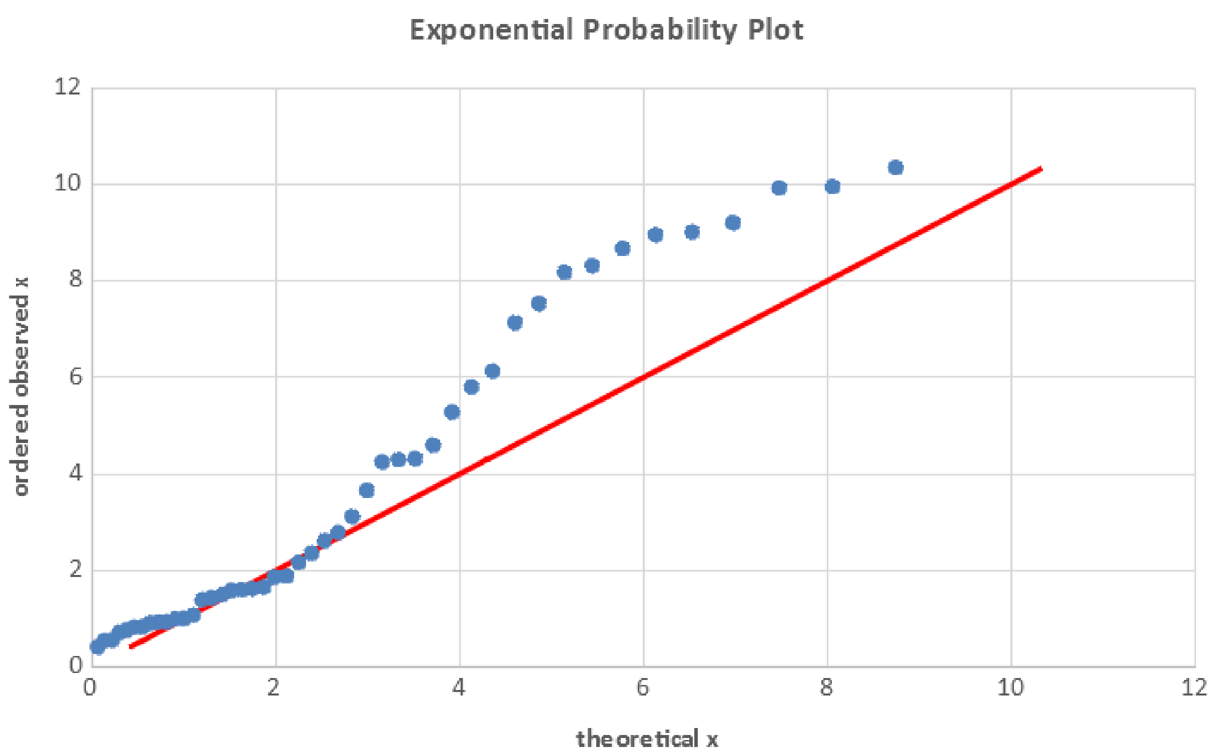
The histogram suggests

◯ a. an exponential distribution will not be suitable to describe the data.
◯ b. a logistic, or normal distribution will not be suitable to describe the data.
◯ c. an exponential, or uniform distribution may be suitable to describe the data.

23. The probability plot method involves

◯ a. comparing theoretical variates computed from the observed cumulative probabilities using the theoretical quantile function with the corresponding frequencies observed in the data.
◯ b. comparing theoretical variates computed from the observed cumulative probabilities using the theoretical quantile function with the corresponding values observed in the data.
◯ c. comparing theoretical frequencies computed from the observed cumulative probabilities using the theoretical quantile function with the corresponding frequencies observed in the data.

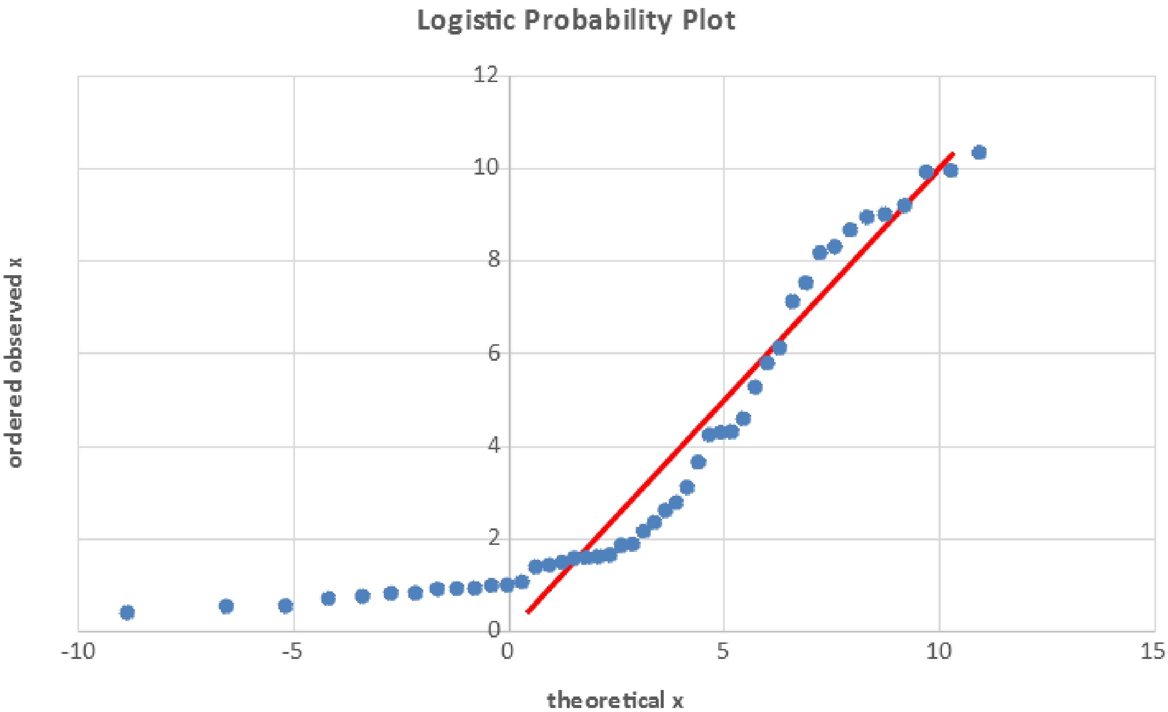
24. Consider the following probability plot.



The conclusion is the data

◯ a. does not come from an exponential distribution therefore it comes from another member of the family of gamma distributions.
◯ b. comes from an exponential distribution.
◯ c. does not come from an exponential distribution.

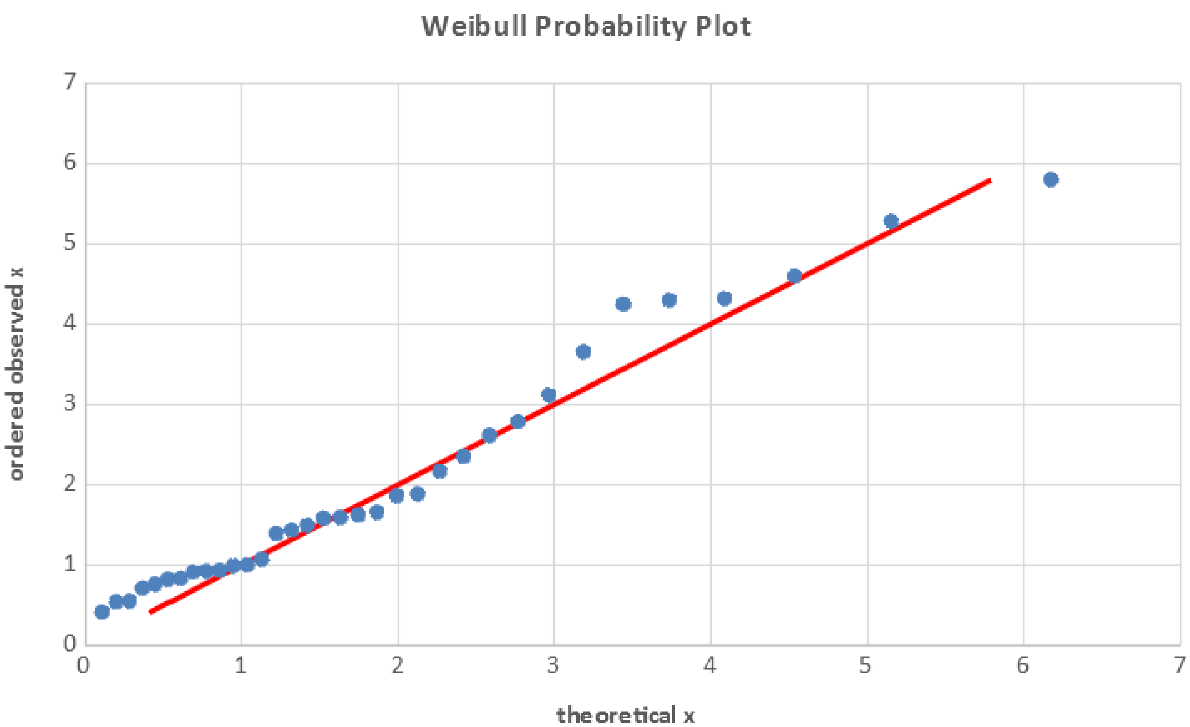
25. Consider the following probability plot.



The conclusion is the data

- ◯ a. does not come from a logistic distribution.
- ◯ b. comes from a loglogistic or lognormal distribution.
- ◯ c. does not come from a logistic distribution and therefore all bell-shaped distributions are excluded.

26. Consider the following probability plot.



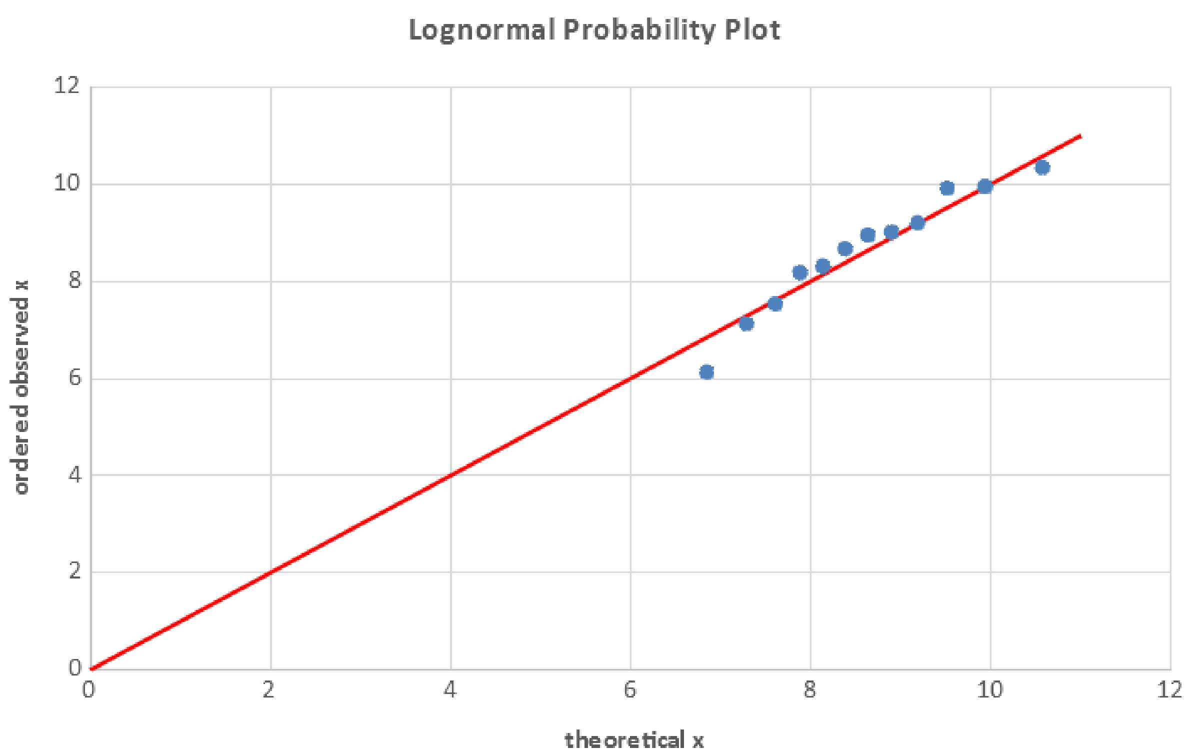
The conclusion is the data

○ a. shows complete departure from the Weibull distribution.

○ b. shows departure from the Weibull distribution towards the tails of the distribution and shows consistency with the Weibull distribution towards the center of the distribution.

○ c. shows departure from the Weibull distribution towards the middle of the distribution and shows consistency with the Weibull distribution towards the tails of the distribution.

27. Consider the following probability plot.



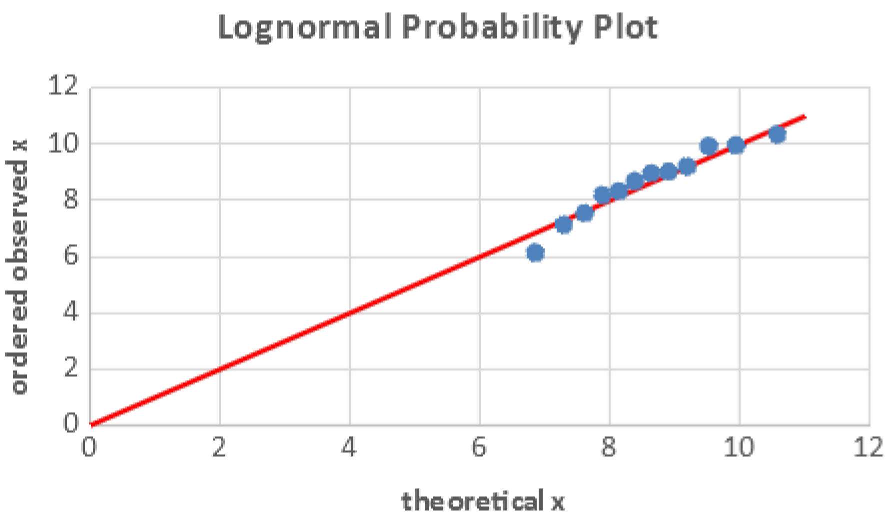
The conclusion is

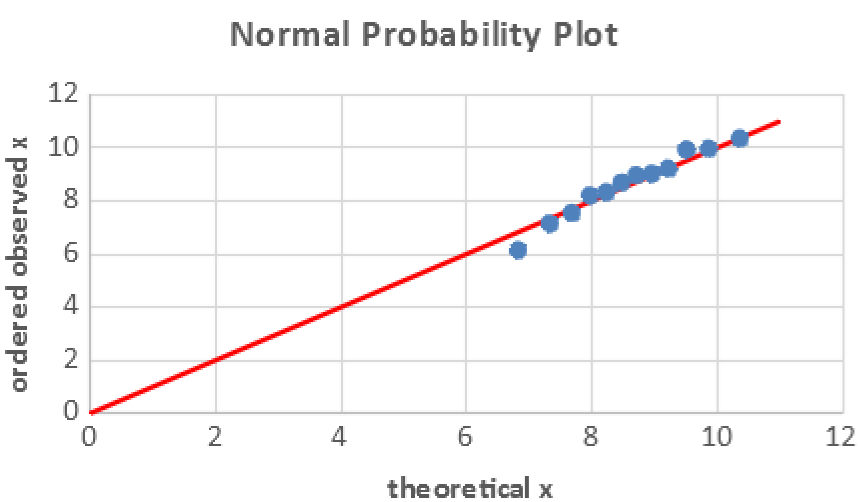
○ a. the lognormal distribution is suitable to describe this data.

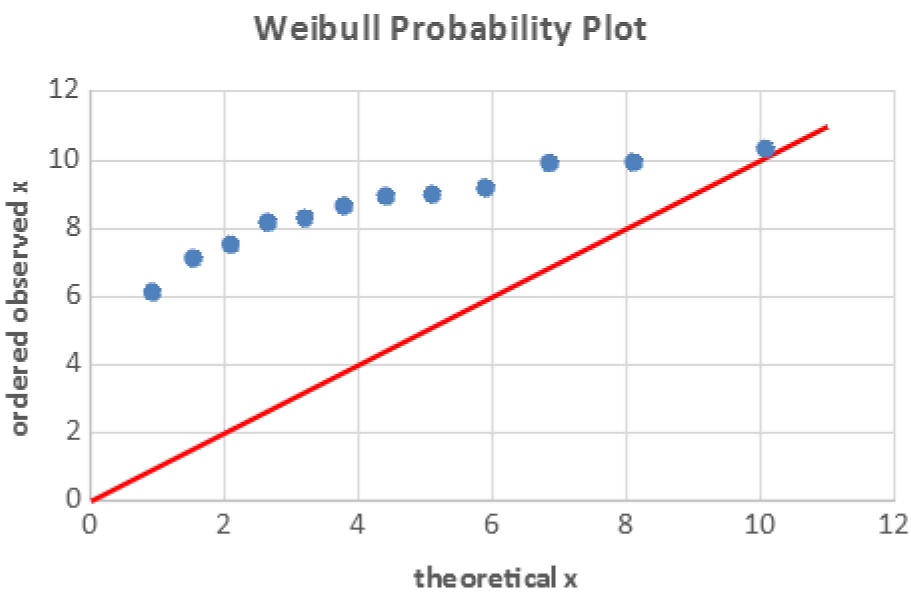
○ b. the lognormal distribution is suitable to describe this data, therefore the loglogistic distribution will also be suitable.

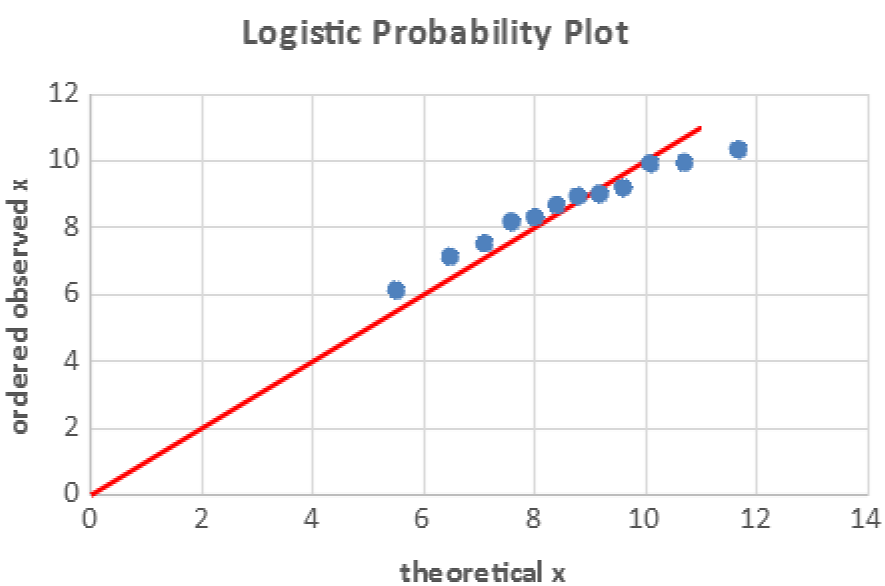
○ c. the lognormal distribution is not quite suitable therefore the normal distribution will not be suitable.

28. Consider the following probability plots for a data set.


Lognormal Probability Plot
ordered observed x
theoretical x
0
2
4
6
8
10
12


Normal Probability Plot
ordered observed x
theoretical x
0
2
4
6
8
10
12





The conclusion is

◯ a. all of the distributions are suitable for the data.

◯ b. the results for the lognormal distribution and normal distributions are contradictory and therefore there must errors in the data or the analysis.

◯ c. the Weibull distribution and the logistic distribution shall be eliminated from further consideration with regards to selecting a suitable distribution for the data.

29. Goodness-of-fit tests to select a theoretical distribution for a data set are based on

◯ a. a formula for identifying trends on a frequency diagram.

◯ b. the conclusions of a hypothesis test.

◯ c. the parameters needed to calibrate the experimental model.

30. Examples of Goodness-of-fit tests include the

- ○ a. Mannering test
- ○ b. Chi-Square test
- ○ c. Tukey method