Statistics mean never having to say you're certain...

ABSTRACT

This column reminds us that statistics should be viewed as a tool rather than an infallible predictor. It emphasizes the importance of considering available data, historical patterns, and individual observations when making informed assessments. Regarding the transformers, we are performing tests and using statistical guidance to make informed decisions to the best of our ability.

KEYWORDS:

statistical uncertainty, binary outcomes, data analysis, historical patterns, condition assessment, deterioration, failure modes, expected values

Just because there are only two possible outcomes does not mean that they are both equally likely

> **What if the six-sided dice had letters on each face, A – F, rather than numbers, what happens to the ‘expected’ value then?**

Statistics: Avoiding the misconceptions of certainty

I was witnessing a ‘complete’ set of condition assessment tests on a large transmission transformer and asked one member of the test team: “How does it look? OK?” I should have known better. The response was: “Well, either it is OK, or it isn’t, so let’s say there is a 50 % chance of it being OK…”

Just because there are only two possible outcomes does not mean that they are both equally likely. If I am crossing the road, I will either make it or I will not: this does not mean that there is a 50 % chance of success because there are two possible outcomes.

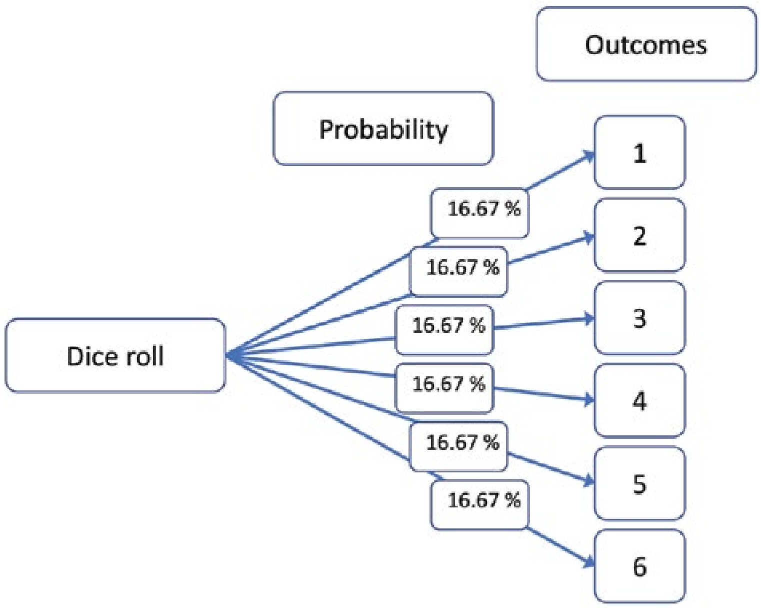
After 35 days of a severe drought, we may ask: “What is the chance of rain tomorrow?”

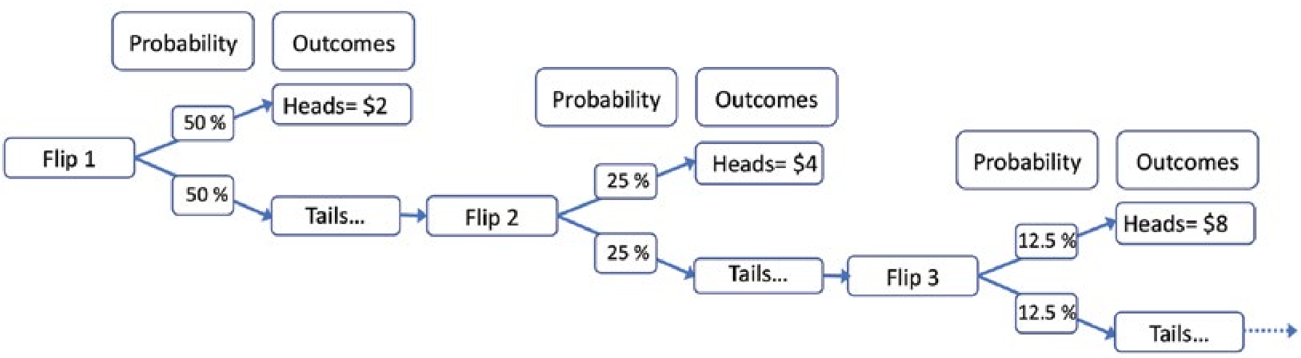
We could receive the following answer: “Well, either it will rain, or it will not, so the chance is 50 %...” However, that answer just isn’t right.

What we need is some idea of how often each outcome occurs in repeated trials based on available data:

- **For the transformer:** What does the data indicate? Is there any deterioration? Is there any movement of key components? Have any failure modes been identified as being in operation? We have to investigate this and ‘take a look’, and it has to be an appropriately detailed one.
- **For crossing the road:** How many people cross the roads every day, and how many don’t make it – and for whatever reason? That could give us some insight into how successful we will be, but a 50 % chance of failure is likely way too high.
- **For the drought:** Have we seen similar weather patterns previously? After how many days did it rain? Are previous examples actually relevant here? Weather is not like rolling a dice.

A single dice roll has 6 equally likely outcomes, each with a probability of ~16.67 %.





If the first flip yields heads, as it does 50 % of the time, the game stops and you win $2. But if it’s tails, we do the flip again, and the ‘other’ 50 % is now split evenly between heads and tails, and so on. If we sum the probabilities for the infinite series of all possible outcomes, we get:
50 % + 25 % + 12.5 % + 6.25 % + 3.125 %+… = 100 %

Statistics as a tool, not a crystal ball

How can we use history to help?

If we roll a fair six-sided dice, each of the six possible outcomes is equally likely. If we have many such rolls, we can look at the results and produce an average of all those rolls, which is also called the 'expected value' of a single roll in a set of many rolls. This value turned out to be 3.5 for a fair six-sided dice, which is, obviously, not a number you can, in fact, roll with such a dice.

The expected value relates not to an individual roll but to the aggregate of many rolls. In order to see what we will get the next time we roll the dice; we actually have to take a look at what is on its topmost face! Statistics apply to the population, not the individual, and should only be used with that in mind.

What if the dice had letters on each face, A – F, rather than numbers? What happens to the 'expected' value then? When it comes to letters, we are left with the outcomes and probabilities together and can no longer do the math on the results: there is no 'expected value', as such.

The expected values can lead to some strange conclusions – see the sidebar on the St. Petersburg Paradox – but are often used without considering what they really mean.

During the condition assessment of transformers, we often look at the family of similar units, possibly sister units of the same design, to give an indication of what to expect regarding the test results. This is useful, as it provides a background for the assessment, but we still have to perform the measurements and draw the conclusions for each individual unit. To work out which transformer is most likely to fail, statistics may help us by telling us where to look, but we still have to go and look! We can look to the sister units to help us fill in the missing data, but these will be the 'expected values', and we have to understand where they came from.

Conclusion

To get back to the transformer tests I witnessed: everything went as planned, and there were no surprises – the outcome was 'OK', but I never had any doubts about it.

Acknowledgements

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Bibliography

https://en.wikipedia.org/wiki/St._Petersburg_paradox

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St. Petersburg Game

Let's play a game…

You flip a fair coin repeatedly until you get 'heads.' If it happens on the first flip, you win \$2; if it happens on the second flip, you get \$4, on the third flip: \$8, and so on… The value doubles for each additional individual flip until you finally flip a head. How much would you be prepared to pay to play the game? Take a moment to think about that…

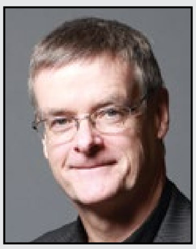
We could calculate the 'expected value' of the game based on possible outcomes and their probabilities. On each flip, there's a 50 % chance of heads and a 50 % chance of tails, and we have to look at the cumulative overall probability of each outcome, ending the game when we get a head:

- There is a 50 % chance a head will appear on the first flip, winning \$2 and ending the game.
- There is an overall 25 % chance the head will appear on the second flip, winning \$4 and ending the game again.
- There is an overall 12.5 % chance of it appearing on the third flip, winning \$8, and so on.

As the probability halves, the reward doubles, so for each outcome, the net 'contribution' of each outcome is the same: \$1. As there are an infinite number of possible outcomes, each worth \$1, the expected value of the game is infinite!

However, how much would you pay to play? How many times in a row do you think you could flip tails? The 'expected value' of the game may be infinite, but that statistic applies to the infinite 'population' of possible outcomes. In practice, there's a 75 % chance the game will be over after two flips, winning you \$4, and an 87.5 % chance it will be over after three, winning you \$8. How much would you wish to invest in the game knowing that?

Author



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