Artificial Intelligence (AI) for Investments
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Lecture – 19
Hypothesis Testing

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In this video we will learn about Hypothesis Testing. **(Video Starts: 00:16)** Consider a hypothetical scenario where you have joined the mobile phone manufacturer brand A as a business analyst. Now, the company has come up with a new model called Max and the popular sentiment among the company's engineers is that it requires 30 minutes of charging to receive a day's power.

Based on this, finding the marketing team is planning to come up with a slogan that is a days power with 30 minutes. Now, you know that this value of 30 minutes is purely based on the popular sentiment among the company's engineers. And nobody knows for sure, if this 30 minutes is valid number or not? He also learned from the office that one of the managers was assigned to check if this slogan would be valid.

But when he picked up the Max phone he found that it took 33 minutes to fully charge. So, does this mean that the slogan is invalid? Obviously, the marketing team would not give up that easily. Since, in order to advertise, we usually want to use numbers that are easy to remember, such as 30 minutes 60 minutes and say therefore similar figures. Now, the marketing lead has approached you and asked you to conduct a proper statistical analysis.

Such that we can actually quantify the validity of the slogan. And find out how confident we are of the slogan being valid. Let us say we can acknowledge the validity of the slogan if we are able to prove with 95 percent confidence that the OnePlus Max phones can be fully charged within 30 minutes. Do you think you can solve this problem then? What if I tell you that you actually?

Know how to solve this problem, using the concepts that we already covered in the previous discussions. Well, the approach I would use is that I can collect a sample of say, 100 Max phones after collecting the sample. I would measure the time to fully charge each phone. Now, since the popular sentiment was that the phone charges within 30 minutes. My guess, is that most of these values will fall in the range of 25 to 30 minutes.

There may be also few phones that take more than 30 minutes, like the one that the manager had chosen. And some that may take less than 35 minutes to fully charge. With that sample I can come up with a confidence interval for the average time taken by the phones to charge. And let us say that my 95 percent confidence interval comes out to be in the range of 24 to 29 minutes.

In that case, I can confidently say that the belief that the charging time is below 30 minutes is correct if I consider a 95 percent confidence interval. However, if that same confidence interval on calculating comes out to say 26 to 30 minutes. Then I can see that my confidence interval also contains values between 30 and 32 minutes. So, I cannot say for sure that the charging time is below 30 minutes. Again, this is only considering a 95 percent confidence level.

My conclusion would completely change if I were to consider a 90 percent or 99 percent confidence level but do you feel this approach is logically correct? Yes, there is nothing wrong with this approach. In order to test the statement that the charging was below 30 minutes. I took out the sample and determined that the average charging time would lie between a certain confidence interval.

However, maybe if I had considered a 99 percent confidence interval then the range would increase to say 22 to 31 minutes. And then I cannot say anymore that the charging time is below 30 minutes given 99 percent confidence. So, why we are discussing this, I gave you a small

problem here that the objective was to test a certain claim that was made in the company. The claim was that the charging time of their latest mobile phone model is below 30 minutes.

And using influential statistics concepts you understood how you would test this claim correctly or not. **(Video Ends: 03:34)**

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(Video Starts: 03:36) So, you learned that hypothesis testing allows you to check the statistical credibility of the claims or assumptions that your organization has come up with. This claim could be claimed by a company or by a customer or just a form of popular belief that exists among the people and using hypothesis testing. You can gather evidence in the form of a sample and then prove whether this claim should be rejected or not.

As a result, hypothesis testing has been used in many businesses for making data-driven decisions rather than just relying on answers. So, let us look at some of the business decisions that can be taken using hypothesis testing. So, one of the most common use cases of hypothesis testing is campaign. Effectiveness campaign analytics is very important and using hypothesis testing we can analyse whether the campaign that a bank or a company has launched is effective or not.

So, let us say a particular pizza company plans to launch a special campaign in Houston for new pizza that they have come up with. Now, they want to check whether the sales through the campaign is significant or not, so they will divide the population into a test population and a

control population. The test population is where you run the campaign and the control population is where you do not run the campaign.

So, when they run the campaign on the test population and not on the control population, they measure the response rate of the customers in both populations. Now, the Assumption or claim in this case will be that campaign is not successful. And using hypothesis testing we can use this responsory data to prove or disapprove this assumption and conclude if the campaign is actually successful or not.

Such problems are known as A B testing. And this is one of the most popular application of hypothesis testing. Apart from marketing campaigns, A B testing is also used to compare different versions of the pages. So, for example, here you can see two different versions of the same web page and you want to know which version is more likely to get higher response rates from the users.

So, like you saw in the previous example, you divide the population into two groups where they launch version A in group 1 and version B in group 2. And using hypothesis testing you can easily conclude which version is more likely to get higher response rates. Apart from the applications you saw here, hypothesis testing can also be used to verify manufacturer or service provider claims.

For example, suppose a manufacturer of light bulbs advertises that their life well has very long life of more than 5000 dollars. Then, using the concepts in this module, you can easily test whether their claim is valid or not. Similarly, you will come across multiple applications of hypothesis testing in various fields, whether it will be quality control or efficiency management.

As you get into this module, you will see many of these applications in the form of examples covered by us as a practice problem. **(Video Ends: 06:23)**

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So, here we can clearly see the value brought forward by hypothesis testing. **(Video Starts: 06:27)** In this topic let us understand hypothesis testing. Let us consider the same marketing example discussed earlier and see how the position of a statement may influence the end consumer. Here we will test the claim that the new Max model takes exactly 30 minutes to charge.

So, this means that we will reject the claim if our test su ggests that the phone takes less than 30 minutes or greater than 30 minutes. So, considering this claim, let us understand how to proceed with the hypothesis test. The general approach that we follow in hypothesis testing is that we start off by assuming that the claim is true that is, the OnePlus Max model phones can fully charge in exactly 30 minutes.

Now, to start the hypothesis test, the first step is that you must define the null and alternate hypothesis. The null hypothesis which we denote as H-nought states that the default assumption about the population and is generally the status quo. So, when I say status quo, we are referring to the initial belief that we had before we begin our hypothesis testing. So, in this example, the initial belief will be that the claim that the phone can fully charge in exactly 30 minutes is R null hypothesis.

Now that R null hypothesis is clear, the next step is to state the alternative hypothesis. The alternative hypothesis is the claim that opposes the null hypothesis. It challenges status quo or the popular belief and is denoted by H A. In some places it would be mentioned as H alpha or

H 1. Hence, in our example, the alternate hypothesis will be the statement, contrary to the null hypothesis and that is that the Max phones do not charge in exactly 30 minutes.

So, what happens if alternate hypothesis holds true? If the time taken is less than 30 minute then we need to take some action. This action would be that we revive this claim to some superior figure by finding the average charging time. As we could also alter our slogan and instead say that it charges in exactly 30 minutes. We can say that just less than 30 minutes, whatever be it, it is good news for us.

However, if the time taken is more than 30 minutes then we should ask the engineer to fix the issue so that it charges exactly in 30 minutes. So, you can see that in both cases either the time taken is less than 30 minute or greater than 30 minute. Some action needs to be taken. Thus, you can see that if the null hypothesis does not hold true, there is some action that needs to be taken.

So, let us write down the null and alternate hypothesis in the mathematical form. We have null hypothesis or H-nought that charging time is equal to 30 minute and alternate hypothesis or H A or H 1 that charging time is not equal to 30 minute. **(Video Ends: 08:58)**

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Let us continue to talk about hypothesis testing in further depth. **(Video Starts: 09:02)** Here you saw the simple case of framing the null and alternate hypothesis. Now, using this example, let us understand some properties of the null and alternate hypothesis that will help you frame

them much better. Finally, the null and alternate hypothesis are always mutually exclusive events. So, what does mutually exclusive mean?

Mutually exclusive events are events that do not occur at the same time as you can see in the Venn diagram here. For example, either the charging time has to be equal to 30 minutes which is the event H-nought, or it cannot be equal to 30 minutes. Both statements cannot be true simultaneously because they are mutually exclusive. So, if you were to write H-nought and H A as charging time less than equal to 35 as H-nought and charging time greater than 30 as H A.

Then automatically your hypothesis statements will be rejected because they are not mutually exclusive events. Second, the null and alternate hypothesis must be collectively exhaustive events. This means that at least one of these events must be true at any given time. This also means that these two events cover the complete sample space. So, coming back to our phone charging example, we can see that at any point, one of these two events must occur.

That is either the charging time exactly equal to 30 minutes or it is not equal to 30 minutes. Thus, from my previous two points, you understood that the null and alternative hypothesis are always mutually exclusive and exhaustive. In other words, you can also say that they are completely complementary events and basically are always perfect opposites of each other. Now suppose, the claim of the engineers was that the OnePlus Max phone charges in less than 30 minutes.

Then the null hypothesis which is the slow test score changes to H-nought which will be charging time is less than 30 minutes. And alternative ha will be charging time is more than 30 minutes. Now, when we write this mathematically one of these events must contain the equality sign else. These events will not be complement events anymore. Hence, the general rule that is followed by all statistician is that the null hypothesis always contains the equality sign.

So, when writing this in the mathematical form, we can write it as H-nought charging time is less than equal to 30 minute and H A which is charging time greater than 30 minutes. Similarly, if someone claimed that the phone takes at least 30 minutes to fully charge and you want to conduct a test to challenge this claim then this is how you should frame your null and alternate hypothesis, meaning that it takes more than 30 minutes.

Hence the null hypothesis H-nought becomes charging time is greater than 30 minutes. And the alternate hypothesis becomes charging time is less than 30 minutes. So, let us recap the key takeaways from this video. The null hypothesis is always the status quo which means that it is the popular belief or the claim that you as the researcher want to challenge or approve wrong.

And thus, since you are challenging a hypothesis, the alternative hypothesis becomes the complement of the null hypothesis. And since you want to challenge the null hypothesis, you are essentially trying to prove the statement in the alternative hypothesis. **(Video Ends: 11:48)**

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In this video we will discuss about null and alternate hypothesis testing. **(Video Starts: 11:55)** The next thing you learned is that the null and alternate hypothesis are framed such that they are mutually explosive and collectively exhaustive. And finally, the third point you learned is that the general convention we follow is that null hypothesis always contains an equality sign, while the alternate hypothesis contains an equality without the equal to sign.

Now, before we take some examples to frame the hypothesis, we would like to discuss some important points to conclude the hypothesis testing. Let us, go back to our charging time example, where we wanted to test the claim made by the engineers that the MaxOne can charge in exactly 30 minutes. So, this is how we framed an island alternate hypothesis. The null hypothesis or H-nought is the charging prime is 30 minute.

The alternate hypothesis is that charging time is not equal to 30 minutes. Now, since only one of them must be true. So, in order to find out which statement is correct, you perform some calculations. We will discuss these calculation in later segments and it turns out that the calculation is favouring the alternate hypothesis. Then the conclusion to your test should be you reject the null hypothesis or accept the alternate hypothesis.

Since, the alternative hypothesis in our test was that the charging time is not equal to 30 minutes. This is true and depending on whether it is higher or lower than 30 minutes, we need to accordingly take the required action. Now, what if your calculations suggest in favour of the null hypothesis. Remember that the null hypothesis was that the charging time is equal to 30 minutes?

Does this mean that your null hypothesis becomes correct? No, you could say that I failed to reject none or you could say that I reject the null and I reject the alternate hypothesis. But you cannot say that I accept the null hypothesis. But then you may be asking what do you mean by fail to reject the null hypothesis? It means that whatever sample you have chosen do not have sufficient evidence to reject the null hypothesis does not that prove that the null hypothesis is true is not it?

It does not remember that your sample is only a subset of the population, even a well-designed sample may not have the exact same characteristics as that of the population. There is still a lot of data about the population which we still do not know and if we were to collect more sample data then we may be eventually able to prove that the null hypothesis is wrong. So, the null hypothesis could still be wrong.

Let us discuss one small story to give us a better idea. There was a time where all swans in the world were supposed to be white or claimed to be white. This claim was made based on the fact that we have only seen white swans in that period in Europe for centuries. So, the null hypothesis becomes that also on survive. But then, in 1697 a Dutch explorer found a black swan in Australia and brought back the black feathers to prove it.

And because of the single data point, the null hypothesis got rejected. But until then, since we always saw white swans, our sample evidence was in favour of the null hypothesis. This is why we should say we failed to reject the null because there might still be a black swan out there to

contradict the null. So, the necessary key takeaway from this discussion was that there are only two possible conclusions from our hypothesis experiment.

Either we reject the null, in which case we cannot accept the alternate, or we fail to reject the null on the grounds that we did not have sufficient evidence to reject it. Now that we have a good sense of how to frame ordinal and alternate hypothesis in the next discussion, we look at some of more real life examples to frame the null and alternate hypothesis. **(Video Ends: 15:11)**

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Hypothesis testing part 2: Critical value method. **(Video Starts: 15:15)** So, let us get back to our business problem that we are trying to solve. You are working at MaxOne as business analyst now, the company has come up with a new phone and the popular sentiment among the company of engineers is that it takes exactly 30 minutes of charging to receive a day's power.

Now, in order to test this claim, you have come up with the following null and alternate hypothesis daily. The null hypothesis states that the time needed to charge is equal to 30 minutes. The alternate hypothesis states, the opposite. It can be written as the time needed to charge is not equal to 30 minutes. Let us move on to the next step of hypothesis testing, we will start with the assumption that the null hypothesis is true.

And then we will try to disprove it. Your first task is to collect as much data as possible. For instance, let us say you sample 100 Max smartphones, you time taken by them to go from 0 percent battery to 100 battery power. S0, this data consisting of 100 point, becomes your

sample. You now calculate the mean and standard deviation of the sample on calculating the sample mean is 30.37.

For now, let us assume that based on the pass research performed by the engineers, the population standard deviation is equal to 2.477. Remember these figures only represent the sample you took and not the population a crucial thing to understand here is that all 100 data points make up only one sample with a sample size of 100. The actual population, however, consists of a very large number of Max smartphones.

You cannot test them all you will assume that the population has a meal of 30. If the null hypothesis is true, now you will have to construct the distribution of the sample mean recall the central limit here. So, how does this theorem help us here? We are going to use the distribution of the sample means to perform the hypothesis test. Once again recall that you should choose a sample which is sufficiently large in order to be able to approximate the sampling distribution to a normal distribution.

So, let us list the measures you will use, the sample mean is 30.37. The standard deviation of the sample is 2.477. Now, remember that the null hypothesis stated that the average charging time is 30 minutes. Hence, the population mean is assumed to be 30 under general hypothesis. Now, using the central limit theorem, the sampling distribution of this population will have a mean which will be equal to the mean of the population which is 30.

The standard deviation of the sampling distribution will be: $\frac{\text{the population standard deviation}}{sqrt\ (sample\ size)}$

Since we have assumed that the population standard deviation is known to us and is equal to 2.477. We can say that the standard deviation of the sampling distribution will be 2.477 divided by square root of 100 which is 0.2477. We now have a sampling distribution of mean 30 and standard deviation 0.2477.

And since the sample size is 100 which is greater than 30. We can also say that sampling distribution follows the normal distribution. I can say that the sample mean of 30.37 which we previously calculated lies in the distribution. So, let us define the confidence level that is expected from the hypothesis testing. Previously, we discussed that the team is happy with the 95 percent confidence level.

This means you are happy as long as the sample lies within this shaded region which covers 95 percent of the overall area. Let us recall the properties of a normal curve, the mean lies at the centre and divides the distribution into two equal houses. Roughly 68 percent of the area lies within one standard deviation from the centre, 95 percent of the area lies within two standard deviation from the centre and 99.7 percent of the area light within three standard dimensions from the centre.

Now you have selected a 95 percent confidence level for this test. This means that the sample mean lies between plus minus 2 standard deviations. To be more precise, it lies between plus minus 1.96 standard deviations. Thus 1.96 is your critical z-score. Let us check how many standard deviations from the centre does our sample mean lie? This value is nothing but the z-score. It is an easy calculation, (30.37 – 30) / 0.2477 and your answer should be 1.4937.

Therefore, your sample mean lies 1.4937 standard deviations away from the centre and this is the z-score of the sample. Now, your sample set score is less than that of the critical z-score. This means your sample is closer to the centre than your critical that score. In such a case, you will fail to reject the null hypothesis which means you will stick to the default belief that the Max phone will not take 30 minutes to recharge again.

This does not mean that we accept the null hypothesis. It only means that we do not have sufficient evidence to reject the null hypothesis. If the samples that score was further away from the centre then the critical values to get the null hypothesis as it would fall outside the 95 region. So, for example, if instead of 30.37, your sample mean had come out to be 30.62 then your z-score in this case will be (30.62 – 30) / 0.2477 which is approximately 2.5.

Then this would fall outside 95 region and in that case, you would be able to reject the null hypothesis. So, let us quickly recap all the stuff that we have used to solve them. We wanted to challenge the popular belief that the charging time is exactly equal to 30 minutes. The first step was to frame the null and alternate hypothesis. The second step is to decide the confidence level.

The third step is to determine the critical grade score. The fourth step is to compute the sample z-score or the z statistic for a general hypothesis test. Fifth and final step is to reach a decision

interpret the result. Now, in our case, we tested for the deviation from the hypothesized mean which was 30 minutes on both sides of the sample mean distribution. Hence, we saw that the region rejection region lies on both sides of the mean of the sampling distribution.

This type of test is called two-tailed test, as the null hypothesis can be rejected on obtaining extreme values on both sides of the curve. **(Video Ends: 21:06)**

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Hypothesis testing part 3: One-tailed test critical value method. **(Video Starts: 21:13)** It is sometimes sufficient to test only one side of the sample mean distribution. This is called the one-tailed test. We will see an example of this in this discussion. In the previous discussions, we learned how to conduct a simple hypothesis test. You may have noticed that in the MaxOne example, we performed the test on both sides of the normal distribution.

That is, we would have rejected the null hypothesis if the same was significantly different in either direction. This is because we wanted to test if the time taken is exactly 30 minutes. But what, if you are a maximum customer instead of a business analyst? Imagine that the OnePlus Max phone was advertising the phone using slogan a day chart in less than 30 minutes and as their customer, you felt that this claim was not true.

You now want to conduct the hypothesis test. So, let us remember the steps that we discussed in the earlier discussions. Step 1 is to frame the null and alternate hypothesis. So, let us formulate null and alternate hypothesis recall that the original claim made by the company was

that the charging time is less than 30 minutes. So, our null hypothesis will state that the time needed is less than 30 minutes.

The alternative hypothesis states that time needed is more than 30 minutes note that the null and alternate hypothesis are still perfect opposites of each other. So, let us move to step 2. Step 2 involve deciding the confidence level. Let us say you still want to perform the test with 95 percent confidence, so this is step 2. Let us see step 3. The third step is to determine the critical z-value now.

This is where the problem will be slightly different from the earlier problem, where the null hypothesis stated that the charging time was exactly 30 minutes. In our current example, the null hypothesis states that the charging time is less than 30 minutes. This means that we can only reject the null hypothesis if we can prove that the sample means that we get a significantly greater than 30 minutes.

Hence the rejection region is going to lie only on the right side of the curve and such a test is called right-tailed test. Let us, compare this with the rejection region from the previous example, the shaded region in the image layer still represents 95 percent of the area. As you can see in the two-tailed test, you had 2.5 percent shaded area on the right side and 2.5 percent shaded area on the left side. In the case of a right-tailed test, the entire 5 percent will be on the right side.

Thus, your critical z-value will not be the same as the one in the previous example. Previously it was plus minus 1.96 let us, calculate the critical z-value for this case. Let us go to the z table or our software to compute. These z-values recall that we determine the z-value if we know the area under the curve to the left of the z-value. We know that the area to the left was z-value of 95 percent, as this is the confidence level given to us.

So, let us search for the z-value corresponding to this confidence level. So, if you compute this z-value from the z table or R software, you will get the value as 1.645 to be more precise. So now, we have found out our z-value which is a 1.645. As you can see in the figure, the rejection region will lie to the right side of the 1.645. Now that we have our critical z-score, let us move to the fourth step which is to compute the sample z-score.

From here the rest of the process of the hypothesis test stream is the same. So, let us do the math for calculating the sample z-score. Let us say you manage to get the data of 100 phones and their respective charging times, so your sample size is 100 as it was before. Now, let us say you calculated the sample mean and found it to be 30.79. Let us assume that we also know the population standard deviation from before and found it to be 2.477 which is the same value that we had considered when solving for the two-tailed test.

So, let us calculate our sample z-score. We know that samples at score equal to sample mean minus hypothesized mean divided by a standard deviation of population divided by square root of sample size which here is (30.79 – 30) / (2.477 / sqrt(100)). This value is approximately equal to 3.19, so we have our samples that score as 3.19. This was a step number 4. Let us move to step number 5.

$$Z\ Score = \frac{X - \mu 0}{S/\sqrt{n}} = \frac{30.79 - 30}{2.477/\sqrt{100}} = 3.19$$

It was to reach a decision and interpret the result. As you can see, our value of 3.19 is greater than the critical z-score of 1.645. Therefore, this value lies in the rejection region and we can say that we reject the null hypothesis. What you just did was the right-tailed test. This is because the rejection region lies on the right side of the curve, so there are three types of tests that you will come across.

First is the two-tailed test that you saw where the rejection region lies on both sides of the distribution. Then you saw a problem where the rejection region was completely on the right side of the distribution and you learned that such tests are called right-tailed tests. We also have a left-tailed test. This is when the rejection region lies on the left of the curve. Now, let us discuss, how we can tell the type of test and position of the rejection region by looking at the alternate hypothesis.

If your alternate hypothesis has not equal to sign then it is going to be a two-tailed test and the rejection region will lie on both sides of the distribution. So, if you recall the example where we had formulated the alternate hypothesis as charging time is not equal to 30. Then the rejection region was on both sides of the curve and we call it two-tailed test. Now, let us take the next case if your alternate hypothesis has a greater than sign.

Then you need to apply a right-tailed test and rejection region will lie on the right side of the distribution. So, in this example, remember that the alternate hypothesis stated that the charging time is greater than 30 minutes. Hence this will be a right-tailed test and the rejection region is on the right side of the distribution. Then there is a third type of test which is left-tailed test.

If your alternate hypothesis has a less than sign then you know that you need to apply the left-tailed test and the rejection region will fall on the left side of the distribution. Let us consider an example of this. Let us consider the hypothetical case where you may want to apply the left-tailed test. Cadbury chocolate states that the average weight of one of it is chocolate product, dairy milk silk is 60 gram as an analyst in the internal quality assurance team.

You would like to test whether the weight is lesser than 60 gram or not at 2 percent significance level. Since you want to test whether the weight is less than 60 gram, this will be your alternate hypothesis and the null hypothesis will become used greater than 60. You can say that this will be a left-hand test because the alternative hypothesis contains less than sign. Can you try solving this question? Let us explain the approach.

You learned that any hypothesis test can be solved in five steps. All the steps will remain the same, except for the step 3 which is where you determine the critical z-score and rejection region. Since this is a left-tailed test, the rejection region will lie on the left side of the curve. As you can see in the shaded area of this curve, since we are considering a 2 percent significance level.

Hence the area of this coloured region will be 0.02. Hence the critical z-value will be the value corresponding to this value of 0.02 and your rejection. Criter will be to reject the null hypothesis if your z statistic lies outside this rejection region. This means that you can reject the null hypothesis. If you calculated z statistic greater than your critical z-value. In the next set of discussions, we will be learning about another approach, known as P-value method. **(Video Ends: 28:34)**

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Now, let us understand the P-value method in hypothesis testing part 4. **(Video Starts: 28:39)** Now that you are comfortable with the overall process of hypothesis testing, I will introduce us to a new approach called P-value method. Both the critical value method and P-value method give the same results when testing hypothesis. In the critical value method remember that we had to compute two values to test statistic and the critical value corresponding to the given confidence level.

However, the P-value method has the advantage that you just need to compute one value and that is the P-value. Hence most statistical software and calculators use the P-value approach for hypothesis testing. We will take up the same problem of MaxOne charging time for the P-value method. Recall we wanted to test the claim that the smartphone model requires exactly 30 minutes of charging to receive a day's power.

We also know the population standard deviation which is 2.477 and it is also given that the sample mean of the 100 data points that we considered is 30.37. So, using this information, let us solve this problem with the P-value approach. We will solve this step by step like we did for the critical value. However, unlike the critical value method, where we had five steps, we have divided the complete process of P-value method in four steps.

Let us explain what these four steps are. Step 1, is to state the appropriate null and alternate hypothesis. We know that the null hypothesis was that mu equal to 30 minutes and the alternate hypothesis was that mu was not equal to 30 minutes, mu here is the mean. Now, step 2 is here

you decide the level of significance. As you already know, the level of significance is 5 percent, or in other words the confidence level is 95 percent.

The most important step for P-value method is step 3 is to compute the test statistic and calculate the P-value from there. Let us first calculate the test statistic. As you know, the test statistic is nothing but the z is statistic or the sample z-score that we calculated earlier. The formula for calculating z statistic given by:

$$Z\ Score = \frac{\bar{x} - \mu 0}{S/\sqrt{n}}$$

Using the values that we mentioned above, we know that statistic comes around to 1.4937. How do we calculate the P-value? Graphically the P-value is the area in the tail of the probability distribution for our MaxOne example since this is a two-tailed test, we would need to calculate the area at both tails. Since R z-score R z-statistic is 1.4937, the P-value will be the area from this minus infinity to –1.4937 and +1.4937 to plus infinity.

But since the curve is symmetric on both sides, we can directly calculate the area at any one tail and then double it in order to calculate the beam. So, let us calculate the area on the left-tail. At the left-tail, the z-value is –1.4937. Now, let us go to our z table to calculate the area on the left-tailed. So, here we have this is z-table. First, let us break z-score into –1.4 and 0.09. So, I will search for the corresponding value to –1.4.

We can use z-table or R software to compute these values and get the value which is 0.06811, doubling it turns out to 0.136. So now, we have our P-value and we can complete the third step. In the final step we reach a decision interpreter result. If the P-value is less than or equal to alpha or the significance level then we reject the null hypothesis. Remember that alpha is your significance level.

So, since our confidence level is 0.95 alpha equal to 0.05. Hence our condition for rejecting the null hypothesis is that our P-value should be less than or equal to 0.05. Now, our p- value is 0.136. However, since 0.136 is not less than 0.05, we fail to reject our null hypothesis at 95 percent confidence level. Now, let us see how we calculate the P-value based on the type of test. For a two-tailed test then the P-value falls on both sides of the curve.

This is where you are calculating P-value for a two-tailed test for the left-tailed test. The P-value will be on the left side of the curve. So, let us say your test statistic is some value z. Then the cumulative probability that you get from the table will be your P-value. Let us see for the right-tailed test. For the right-tailed test the P-value will be on the right side of the curve.

So, if the value of the test statistic is z then the cumulative probability from the table will give you the area to the left of z. Since the P-value is the area to the right of the curve. Hence your P-value will be 1 – the cumulative probability that you calculate from the table. Once you have the P-value then the condition for rejecting the null hypothesis remains the same for whatever test it is, be it right-tailed, left-tailed or two-tailed.

The condition is always that you reject the null hypothesis if your P-value is less than or equal to alpha. **(Video Ends: 33:19)**

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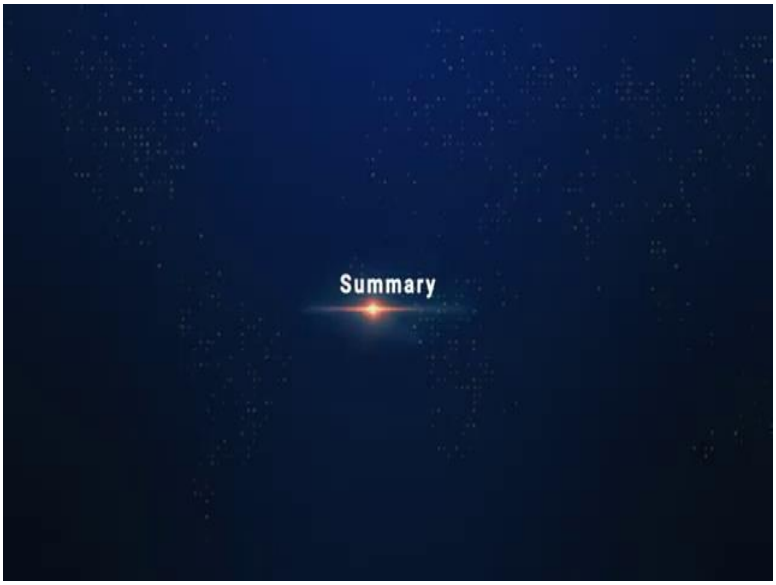

Summary and concluding remarks. **(Video Starts: 28:39)** In this discussion we learned about the need for hypothesis testing. We realized that we cannot rely on hunches to make business decisions, since the stakes are often too high and mistakes needs to be avoided. Hypothesis testing gave us a way to check all the claims with statistical rigor. We learned that null hypothesis is defined as the assumptions you are testing and the alternate type hypothesis is defined deposit.

You then saw an example where you used a hypothesis test to verify Max phone claims. Here we define the null hypothesis as the time needed to charge is equal to 30 minutes. And the

alternate hypothesis is the time needed to charge is not equal to 30 minutes. You then learn how to collect several data points that comprise a single sample. You found the z-score of the sample on the sample means distribution using concepts learned from the previous discussions.

We also learned about confidence, levels and critical z-scores associated with them. We rejected the hypothesis if your samples at score was further away from the hyper size means then the critical z-scores. This approach is known as critical value method. You then saw another measure known as P-value which is more intuitive than z-score and can be used directly to find the highest confidence level at which the test can be rejected.

You learned the P-value can be easily visualized as the probability of null hypothesis being the true and this lower P-value means a higher chance of the null being false. The P-value can be used to directly find out the confidence levels at which the null hypothesis can be rejected but now we know the basis of hypothesis testing.