Investigating How Car's Lap time is Affected by Its Weight

Name

Institution

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Problem Statement

Apart from the shape of the car, racing cars might have some other aspects that enable them to move faster than other cars. Different motorsport categories in the world have different shapes, but regardless of the categories, some aspects are common. With the advancement in technology, it is easy to notice how the shapes of racing vehicles have changed from way back to present. A single aspect is common in them despite the difference in shapes and parts (Thomas, Segal, Milliken & Michalowicz, 1996). When you are watching a car race, you will also notice that only small cars are suitable as they can maneuver very fast in a corner. Thus, this is a clear indication that small vehicles are suitable for racing as their speed is relatively high. Heavier vehicles are less preferable as they cannot negotiate a corner at a higher speed. In this research, I will find how the lap time of a car is affected by its weight.

For a successful study, I will gather data from different cars on their lap time and weight. After successful data collection, I will perform various statistical measures which involve descriptive and inferential test. Chi-Square test will be used as the main test to find whether the lap time of a car is dependent on its weight. Additionally, I will validate the hypothesis formulated on the Chi-square test.

Research Question

Watching vehicles rallying is very interesting. Thus, I felt that it was important for me to investigate how the lap time of the car was influenced by its weight. The question of interest follows

Is the lap time of a car dependent on its weight?

I expect that lighter vehicles take less lap time while heavier ones take more lap time

Data Used

It was not possible to carry out this research without collecting the relevant data required for answering the research question. In this case, the weight of the vehicle may be defined as the gravitational acceleration and mass product while lap time or rather the speed of the engine is the twisting force that leads to the rotation of the wheel (Barker, 1980). I used the two quantities, i.e. the torque and the speed of the engine to represent the weight and the lap time of the vehicle respectively. Since there is a direct relationship between the torque and the weight of the car and thus the torque is used as the weight. I collected data on 23 cars where the speed was measured on the number of revolutions per minute while Torque was measured on Newton Meter. Data is represented in the table below

Weight/Torque(Nm)	Lap time/ Speed(rpm)
32.3	7800
32.2	7600
32	7400
32	8000
31.8	7200
31.6	7000
31.5	6800
31.2	6600
31	6400
30.4	6200
29.6	6000
28.4	5800
27.6	5600
27.2	5400
26.8	5200
26.2	5000
24.9	4800
23.6	4600
23.2	4400
22.6	4200
21.6	4000
19.6	3800
16	3600

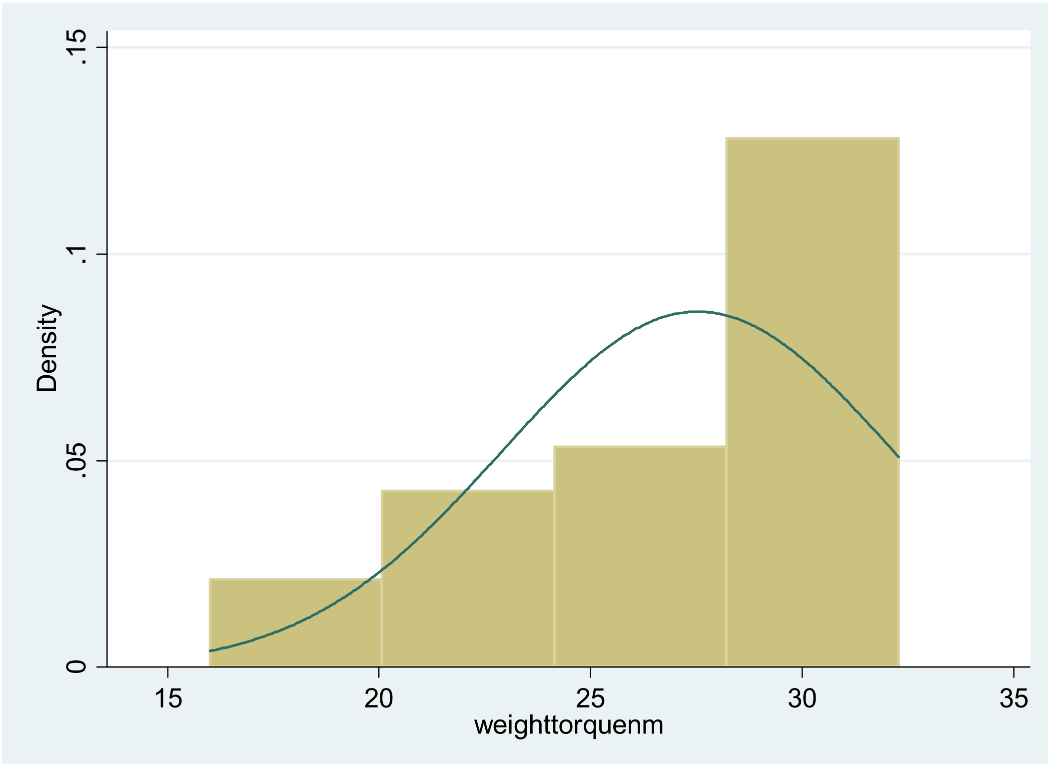
Statistical Data Analysis

To effectively answer the research question, I evaluated the Pearson's Chi-square where I was seeking to find if the lap time is dependent on the weight of the vehicle. Before carrying out the Chi-square test, I came up with a hypothesis that could tell us whether the association was significant at a given level of significance, i.e. 5%. The test was also accompanied by other evaluations such as the descriptive measures and other graphical representations. The car's lap time was the response variable while the weight was the explanatory variable. Hence, the study aimed to check whether there was dependence of the response variable on the explanatory variables. The analysis results are as follows

Results

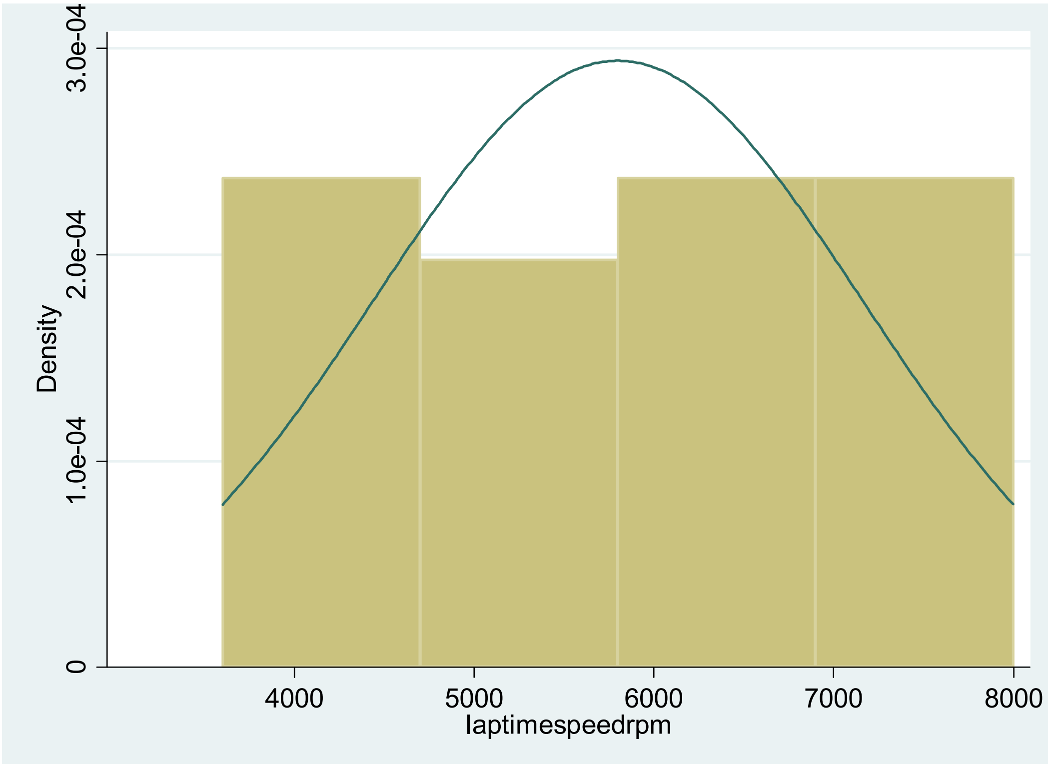
Below are the graphical representation of the lap time and the weight of a car, respectively. These plots are important in checking the normality and outliers in a distribution. Thus, the plots will help us identify whether there are cars with abnormally higher weight or lap time than others.

Weight Histogram



The plot indicates that most of the vehicles have a weight or Torque of around 30 Nm. Also, the plot illustrates that cars' weight distribution followed a normal distribution and skewed to the left. Thus, majority of the car weight data points are to the right of the mean. Additionally, there are no outliers in the cars' weight distribution.

Lap Time Histogram



The plot indicates that most of the vehicles have a lap time/engine speed of around 4000, 6000, and 7000 rpm. Also, the plot illustrates that the lap time distribution follows a uniform distribution as much of the observations have an equal density. Thus, most of the car engine speed data points have a similar density. Additionally, there are no outliers in the cars' weight distribution.

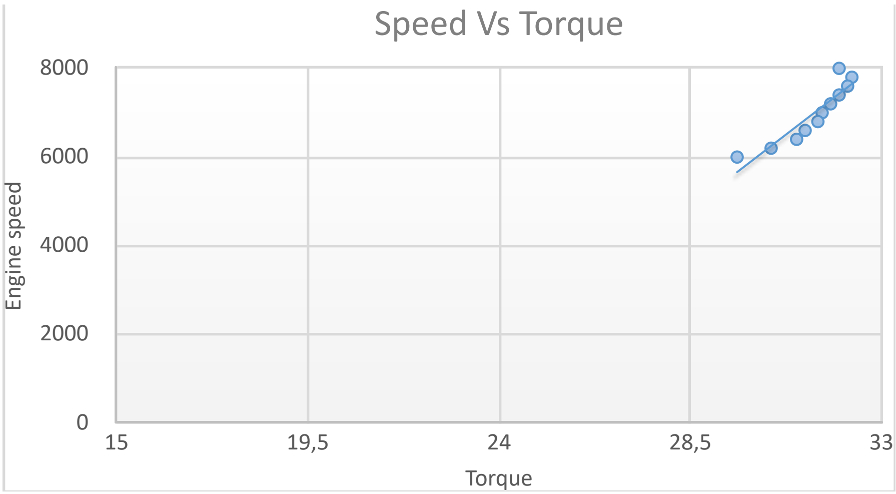
Central Tendency and Dispersion Measures

Weight/Torque(Nm)		*Lap time/ Speed(rpm)*	
Mean	27.53478	Mean	5800
Standard Error	0.966527	Standard Error	282.8427
Median	28.4	Median	5800

Mode	32	Mode	#N/A
Standard Deviation	4.6353	Standard Deviation	1356.466
Sample Variance	21.48601	Sample Variance	1840000
Kurtosis	0.061567	Kurtosis	-1.2
Skewness	-0.90387	Skewness	4.42E-17
Range	16.3	Range	4400
Minimum	16	Minimum	3600
Maximum	32.3	Maximum	8000
Sum	633.3	Sum	133400
Count	23	Count	23

The mean car Torque from the table is 27.53 Nm while the average engine speed is 5800 rpm. The mode Torque is 32 Nm while the median Torque and engine speed is 28.4 NM and 5800 rpm respectively. There is a lower variation in the Torque of cars (4.64) than in the engine speed (1356.47). The range of car weight is given by 16.3 while the engine speed range is given by 4400. Vehicle torque has a positive kurtosis (platykurtic distribution) while the engine speed has a positive kurtosis (leptokurtic distribution). Additionally, torque has a negative skewness while the engine speed has positive skewness.

Scatter plot (Engine speed Vs. Torque)



From the plot above, there is an upward slope between the torque of a car and the engine speed. Equivalently, there is an increasing linear trend between the car's torque and the engine speed. Hence, a positive linear relationship exists between car's torque and the engine speed. In other words, an increase in the torque/weight of the vehicle is likely to increase the engine speed, therefore, reducing the lap time. Thus, the weight of the vehicle reduces the lap time of the vehicle, and hence, the heavier the vehicle the, the lesser the lap time.

The linear model is

$$Y = 277.47x - 1840.2$$

The engine speed increases by 277.47 rpm with a unit increase in the torque of the vehicle. Also, the car's engine speed is -1840.2 at a zero torque (Graybill, 1976). Generally, the model illustrates a positive linear relationship between the car's torque and its engine speed.

Chi-Square Test

This test was important as it would enable me to find if the association between the car's lap time/ engine speed and torque/weight is independent or not. Before I undertook the test, I came up with the hypothesis below

H_0: The lap time of a car is independent on its weight

H_A: The lap time of a car is dependent on its weight

To carry out the test, I groped my data into a 2 by 2 contingency table as illustrated below

		Weight/Torque		total
Engine Speed/Lap Time		16-25	25.1-33	
	3600-5800 Exp. count	7 3.7	5 8.3	12
	5801-7800 Exp. count	0 3.3	11 7.7	11
	total	7	16	23

The expected count for the cell can be found as follows

$$Cell\ 11(C11) = \frac{12*7}{23} = 3.7$$

$$C12 = \frac{12*16}{23} = 8.3$$

$$C21 = \frac{11*7}{23} = 3.3$$

$$C22 = \frac{11*16}{23} = 7.7$$

Since we have evaluated the expected values, then the Chi-square is given by the formula below

$$\chi^2 = \sum \frac{(o-e)^2}{e}$$

O	e	$(O\text{-}e)^2$	$\frac{(O-e)^2}{e}$
7	3.7	10.89	2.94324324
5	8.3	10.89	1.31204819
0	3.3	10.89	3.3
11	7.7	10.89	1.41428571
Total			8.96957715

From the results from the table, the Chi square value is given by

χ^2 =8.970

The tabulated Chi Square is given as (row-1) * (column-1) = (2-1) *(2-1) =1. Thus, $\chi_{(0.05,1)}$ =3.84 (McHugh, 2013).

Now, since we have both the chi-square tabulated and the calculated values, we then proceed to validate the hypothesis. Since the chi-square evaluated is larger than the Chi-square tabulated (i.e. 8.970>3.84), there is enough evidence to conclude that the lap time of a car is dependent on its weight at 5% significance level (Nickerson, 2000). In other words, the time a vehicle takes to do a lap is dependent on its weight. Therefore, as indicated by the linear model, an increase in the torque/weight of the vehicle is likely to increase the engine speed, therefore, reducing the lap time. Thus, the weight of the vehicle reduces the lap time of the vehicle, and hence, the heavier the vehicle the, the lesser the lap time.

Conclusion

The effort to examine how weight affects the lap time of a car necessitated me to undertake a study. To make this happen, I gathered data on the engine speed and the torque of several cars. After a keen analysis, I observed that the mean car Torque was 27.53 Nm while the average engine speed was 5800 rpm. The plot fitted indicated that a positive linear relationship existed between car's torque and the engine speed. Further, I evaluated the Chi-square to determine whether the two variables were independent or not. Chi-square results proved that there was enough evidence to conclude that the lap time of a car was dependent on its weight at 5% significance level. Therefore, an increase in the torque/weight of the vehicle was likely to increase the engine speed, therefore, reducing the lap time.

References

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