Final Project

Submitted to   Prof ABC

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Problem Statement:

I am working at a warehouse for a 10-hour shift on Saturday and Sunday. I have two 30-minute food breaks. The job involves a lot of walking. I want to find the optimum conditions where I will be able to walk the same distance in lesser amount of time. Although the working conditions of my experiment are not exactly like the warehouse, I have tried my best to replicate those environmental setup.

Objective:

There are three kind of factors– types of shoes , type of food and type of surface. I want to study which of these factors (mains or interactions) will have the most impact on minimising time so that I can focus my energies on that factor.

Experimental Design:
There are three factors and every factor has two levels-
1. Type of shoes- Sport Shoes(-1) and Safety Shoes (+1)
2. Type of food- Raw food(+1) and cooked food (-1)
3. Type of Surface- Hard Surface(-1) and Ground(Earth Surface) (+1)

The response variable is Time and it is measured in seconds. The replicates for each run is 1. It was really difficult to replicate the experiment. The experiment was performed

over the duration of 2 days with 4 runs on each day but the weather drastically changed over that 2 days. So, I do expect blocking effect. The experimental distance was 250 m and I used google maps to measure that distance.

I will be using 2k full factorial design method as I want to study the impact of 3 different factors on a response variable rather than a number of similar factors.

Experimental Method:

1. I did a couple of experiment runs beforehand. I first ran 400 meter to see if I could maintain the same energy level throughout the distance but I could not do that. I finished the 400 m with less speed than the one speed with which I started it. I figured out that I could maintain the same energy level for 200-250 meter distance.
2. I measured the time by using stopwatch on my phone. I always had the phone in my hand while running. At the warehouse, I have a rdt scanner attached on my wrist. So, the effect of carrying a device on my hand will be included in the experiment.
3. I do expect some effect of blocking as the experiment was performed over two days.
4. There was a minimum time difference of 3 hours between the runs. I wanted the samples to be as independent as they can so that the effect of one run does not impact the other run. The measurement of

time is in seconds and it was collected at the end of the run. The stopwatch was reset to zero after every run.
5. I kept the direction of running same for both types of surfaces so that the effect of wind on my speed is minimised.
6. There are two type of shoes that I used: sport shoes (-1) and safety shoes (+1). (B)
7. The two kind of foods I used: -(A)
    a. Raw food (+1)– (2 apples + 2 bananas)
    b. Cooked food (-1)– (2 chapatis+ 2 cooked vegetables)
8. The two kinds of surfaces I used- (C)
    a. Ground Surface (+1) (Surface in parks/soccer grounds)
    b. Hard Surface (-1) (pathways along the road)
9. I did not drink any kind of coffee before or after the runs to minimise the effect of sugary drinks on energy levels.
10.   I also made sure that I don't have to walk much to the target pathways as it will affect my energy levels. I have attached the images of the pathways in the appendix.
11.   There are no ground surfaces in warehouses but I wanted to study the impact of walking on the different surfaces.
12.   All the three factors are qualitative factors so there wont be any involvement of centre points in our experiment.
13.   I changed the run order as it was difficult to maintain the run order generated by Minitab. I ran on hard surface during the first 4 runs and ground during the last 4 runs.

14.   There are no replicates in the experiment as the experiment was difficult to perform. It is difficult to run in the winters.

Raw Data

Food	Shoes	Surface	Time
Cooked food	Safety Shoes	Hard Surface	75
Raw food	Safety Shoes	Hard Surface	74
Raw food	Sport Shoes	Hard Surface	66
Cooked food	Sport Shoes	Hard Surface	69
Cooked food	Safety Shoes	Ground	62
Raw food	Safety Shoes	Ground	60
Raw food	Sport Shoes	Ground	57
Cooked food	Sport Shoes	Ground	59

Table No. 1

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	6	331.000	55.167	110.33	0.073
Blocks	1	0.000	0.000	0.00	1.000
Linear	3	294.333	98.111	196.22	0.052
A	1	8.000	8.000	16.00	0.156
B	1	25.000	25.000	50.00	0.089
C	1	132.250	132.250	264.50	0.039
2-Way Interactions	2	8.250	4.125	8.25	0.239
A*B	1	0.250	0.250	0.50	0.608
B*C	1	8.000	8.000	16.00	0.156
Error	1	0.500	0.500		
Total	7	331.500			

Table No 2

Analysis

We can see that the contribution from blocking is negligible. We don't see a 3 way interactions as it is replaced by blocking variable in a 2k experiment.

The contributions from B and C in Adj SS are 7.5% and 40 % (approximately) respectively. The contribution of all other terms is less than 2.5%. We did not get any contribution from A*C as the minitab needed more replicates to access this interaction. We can eliminate all the other factors and reduce the model by keeping B and C. I could not do the linearity check as there were not quantitative terms in the model.

After reducing the model, we get a table as seen in Table No 3.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	2	314.50	157.250	46.25	0.001
Linear	2	314.50	157.250	46.25	0.001
B	1	50.00	50.000	14.71	0.012
C	1	264.50	264.500	77.79	0.000
Error	5	17.00	3.400		
Total	7	331.50			

Table No 3

We see that the contribution from B has become significant as p value has become less than 0.05. We have eliminated 4 terms so the DF in error term is increased from 1 to 5. The contribution of error in Adj SS has also increased from 0.1% to 5.1%.
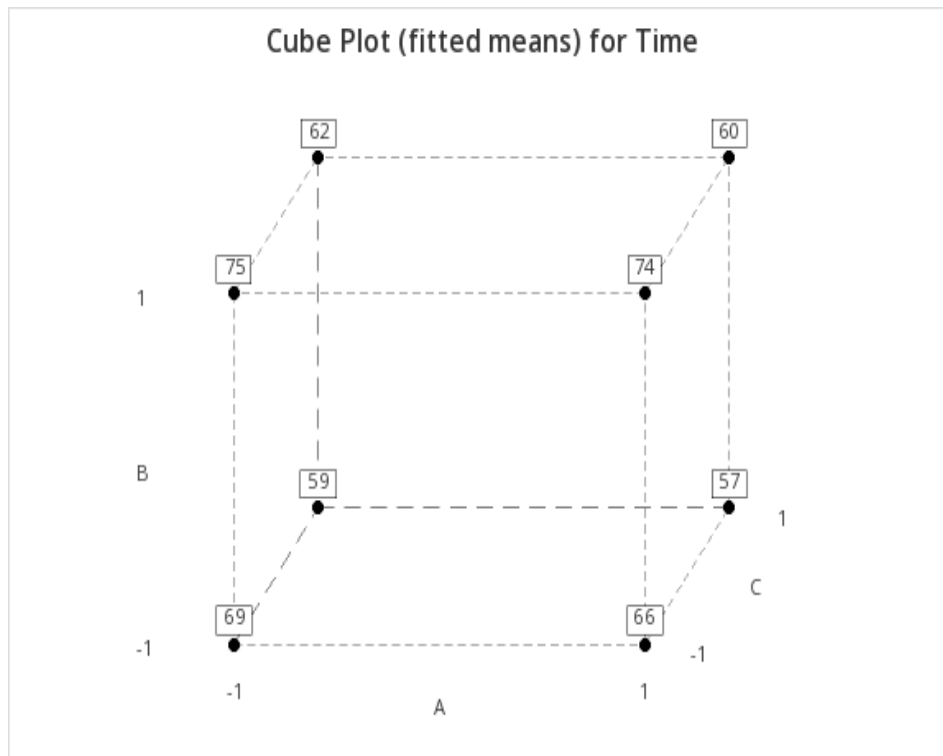
Cube Plot (fitted means) for Time

Figure no 1

Regression Equation in Uncoded Units

Time = 65.250 + 2.500 B - 5.750 C

In Figure No 2, We can see that the minimum time is possible when we B is -1 and A is +1.

Time = 65.250 +2.50*(-1) -5.750(1)= 57 seconds. (which is equal to the lowest value in the Figure No 1.)

Main effects plot:

Figure no 2
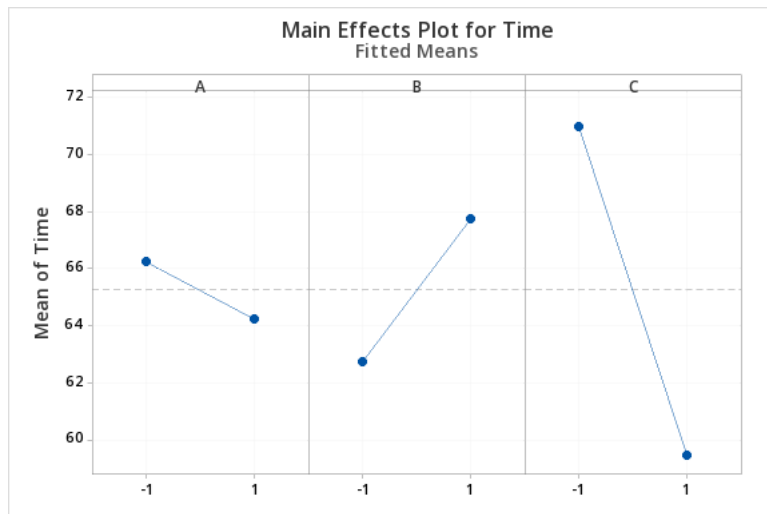
In Figure no 2, We can observe that the value of time reduces drastically when value of C changes from -1 to +1. We observe a similar but very small effect when A changes from -1 to +1. When B is changed to -1 to +1, the time increases. Since B and C are the significant terms of our model, we will only be focusing on the impact of B and C on time.
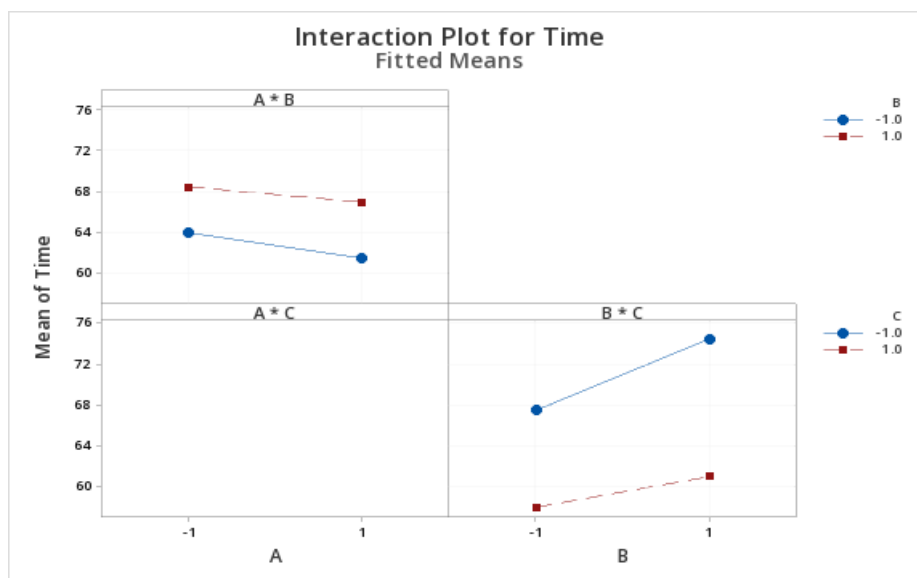
Interaction Effects:

We don't see any significant interaction between the factors from the Figure No 3. None of the lines in the plots of Figure No 3 cross each other which means there is no significant interaction.
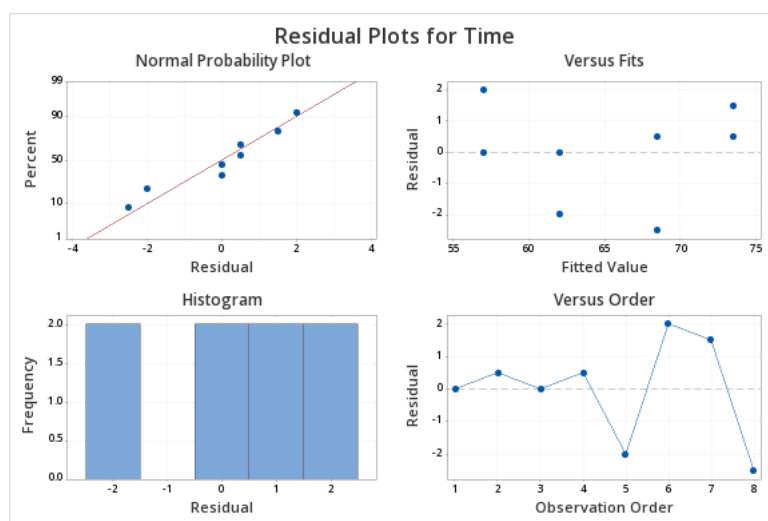
Adequacy of residual plot

Figure No 4.

In the Normal probability plot of Figure, No 4, we see that all the residual numbers are closer to the line and we don't see any point being quite away from that line. In the versus fits plot of Figure No 4, we see that there is not trend among the residual points. Hence by collectively looking at all the plots of Figure no 4, we can say that the model has been fairly adequate. We don't need to study any of the residuals separately.

Practical conclusions and recommendations:

We see that the impact of C (surfaces) is the largest on time required to cover a certain distance. When the surface was hard, the average time was 71 seconds but when the surface was ground, the average time was 59.5 seconds. I did believe that running on grass is healthier than running on concrete surfaces but I did not know that running on earth surfaces is faster than on the pathways.

I thought that the impact of food will be significant on the running time as raw foods have more active ingredients than cooked ones but the impact of food type (A) was not significant. Its possible that the impact of food becomes significant when the distances are large so either we will need more replicates, or we need our distance to be larger.

I hypothesised that the impact of type of shoes (B) will be the largest and that there will be significant interaction between types of surface and type of shoes (B*C) but on the basis of present dataset, my hypothesis was wrong. The interactions between types of surface and type of shoes was largest among the 2-way interactions but it was still not statistically significant. The safety shoes are a bit heavy than sport shoes and they do reduce the speed in a way, thus increasing the time which we have observed in this experiment. The time increases when we move from sport shoes to safety shoes.

The overall conclusion is that to decrease my time to cover a certain distance, I should be focusing on running over the right surface(earth) then followed by wearing the right kind of shoes.

Further Improvements:

1. I do want to conduct this experiment for longer distances. For smaller distances, the analysis becomes a bit tricky as its usually easy to have energy to run.
2. Its always good to have replicates as that will help us more in learning about interaction effects.
3. For next shoes I want to buy, I will definitely try a combination of safety shoes and sport shoes.
4. If given an opportunity to choose a track to run, I will definitely choose an earth track than the hard surface.

Appendix:

For the ground Surface:
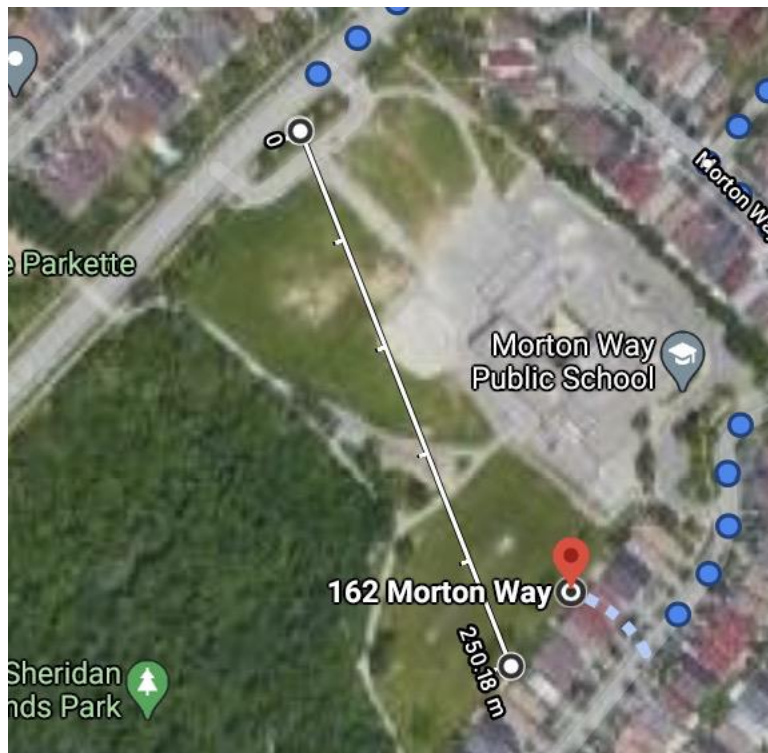
For the hard surface:
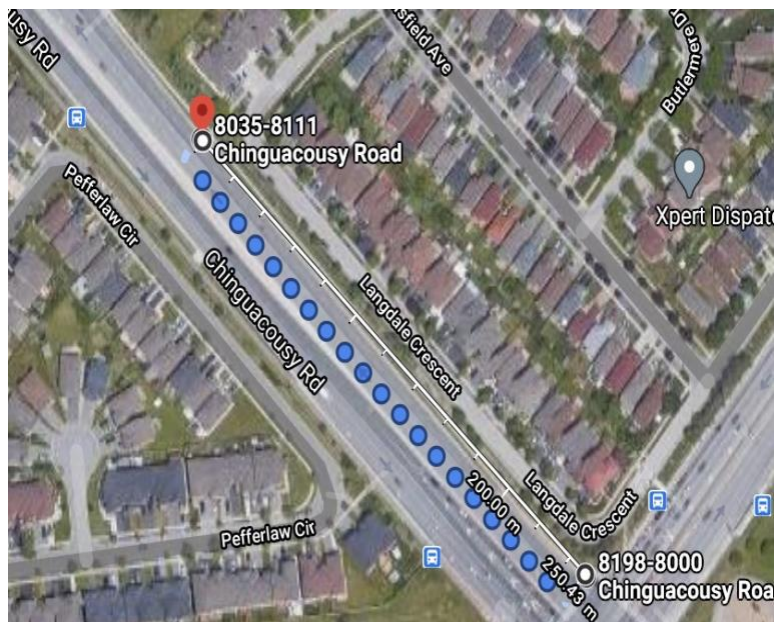
Learnings:

1. This is the most "applied engineering" experiment I did in my lifetime.
2. I can see that how science and engineering can solve a lot of problems for us. Rather than attributing the cause of anything to unknown factors, we tried to vary the inputs and then study the outputs accordingly.
3. Till now, my way of experimentation was to fix everything and change one variable but that is not a practical solution as we do not have the resources to do that. But I have found a good alternative to that.
4. Running in winters is tough.
5. Statistics is the subject where we have to focus on important things(significant ones) rather than focusing on trivial aspects(statistically insignificant ones). This is the approach I am trying to have in my life.
6. Quantifying the causes will help us in channelling energies in the right direction.