CHAPTER 1
Problem statement

Background

Tissue papers are made from plant fibres. The propose is to absorb liquid. There are many brands of tissue paper in the market today. Those brands have difference manufacturing techniques to increase absorbability and strength of their product. The effectiveness generally comes with the cost.

Objectives

1) Factor screening and characteristic
2) To find factor have the most influence on tissue paper absorbency
3) To find the best combination of factors

CHAPTER 2
Selection of the response variable

We want to measure the tissue paper absorbency. So, we select the volume of liquid that the tissue absorbed to be the response variable.

Response Variable	Unit	Measurement Precision/ Accuracy	Relationship to Objective
Volume of Liquid	Milliliter(mL)	Measured by observe the amount of liquid missing from the bowl.	Higher volume of liquid means better liquid absorbency

CHAPTER 3
Choice of factors levels and range

Factors

Table 3.1: Potential design factors classification

Design factors	Held-constant factors	Allowed-to-vary factors
Type of tissue paper	Time for soaking paper	
Type of liquid	Quantity of water	
Temperature of liquid	Size of bowl	

Table 3.2 : Nuisance factors classification

Controllable factors	Uncontrollable factors	Noise factors
	Humidity	
	Room temperature	

Factor levels and range

Table 3.3 : Factor levels and range

Factor	Level		
	1	2	3
Type of tissue paper	Facial tissue (Cellox)	Multi-purpose tissue (Tesco)	Hand tissue (Scott)
Type of liquid	Water	Syrup	Oil
Temperature of liquid	Room	Cold (~10 °C)	

Factor Details

Table 3.4 : Control variables

Control Variables	Measurement Precision/ Accuracy	Predicted Effects
Type of tissue paper	Different types of tissue have different absorbency. We choose 3 well-known types of tissue which are facial tissue, multi-purpose tissue and hand tissue for this experiment.	Multi-purpose tissue should give higher absorbency since it is designed to use for general purpose.
Type of liquid	We use 3 types of liquid with different properties. We considered water as normal, syrup as sticky and oil as grease.	Oil should give higher absorbency.
Temperature of liquid	We use 2 types of liquid temperature which are room temperature and cold temperature.	Liquid temperature should not have any effect on the tissue paper absorbency.

Table 3.5 : Held-constant factors

Held-constant factors	Measurement Precision/ Accuracy	Settings	Predicted Effects
Time for soaking paper	We use the same amount of time to dip the tissue paper.	10 sec	-
Quantity of water	We use the same quantity of water in every samples.	15 ml.	-
Size of bowl	The bowl size is constant in all samples.	460 ml.	-

Table 3.6 : Nuisance factors

Held-constant factors	Measurement Precision/ Accuracy	Settings	Predicted Effects
Humidity	Humidity may have an effect on the tissue absorbency. We run all samples in a very short period of time to minimize the effect.	-	-
Room temperature	Room temperature shouldn't have any effect on the response.	-	-

CHAPTER 4
Experimental Design

In this experiment, we want to study the effect of 3 factors. To study both main effects and interactions effect, we decided to use general factorial design. The factorial design has 18 treatment combinations and each combination has 4 replications. Totally, we performed an overall of 72 runs.

Design the Experiment

Table 4.1: Factors

Variable	Factor Name	Number of Level
A	Type of Tissue	3
B	Type of Liquid	3
C	Liquid Temperature	2

Table 4.2 : General Factorial Design

Treatment Combination	Factors		
	A	B	C
1	Facial	Water	Room
2	Multi-purpose	Water	Room
3	Hand	Water	Room
4	Facial	Syrup	Room
5	Multi-purpose	Syrup	Room
6	Hand	Syrup	Room
7	Facial	Oil	Room
8	Multi-purpose	Oil	Room
9	Hand	Oil	Room
10	Facial	Water	Cold
11	Multi-purpose	Water	Cold
12	Hand	Water	Cold
13	Facial	Syrup	Cold
14	Multi-purpose	Syrup	Cold
15	Hand	Syrup	Cold
16	Facial	Oil	Cold
17	Multi-purpose	Oil	Cold
18	Hand	Oil	Cold

Table 4.3: Equipment

Equipment	**Quantity (unit)**
460 ml. Bowl	3
20 ml. syringe	1
10 ml. syringe	1
10 cm^2 Facial tissue (Cellox)	72
10 cm^2 Muti-purpose tissue (Tesco)	72
10 cm^2 Hand tissue (Scott)	72
500 ml. Coloring Water	1
500 ml. Syrup	1
500 ml. Oil	1

CHAPTER 5
Experimental procedure and results

Step 1: Use 20 ml. syringe draw 15 ml. of coloring (blue) water
Step 2: Eject the liquid in 460 ml. bowl
Step 3: Dip the first piece of facial tissue in coloring water for 10 seconds then pick it up
Step 4: Use 10 ml. syringe draw the left over and record the result
Step 5: Repeat step 1 to 4 with the second to forth piece of facial tissue
Step 6: Repeat step 1 to 5 with Multi-purpose tissue and then Hand tissue
Step 7: Repeat step 1 to 6 with Syrup and then Oil
Step 8: Repeat step 1 to 7 with cold temperature (~10 C)

Table 5.1 : Experimental Records

Treatment Combination	Factors			Replications			
	A	B	C	1	2	3	4
1	Facial	Water	Room	4.4	4.2	4.4	5.1
2	Multi-purpose	Water	Room	3.8	5.1	4.8	3.8
3	Hand	Water	Room	4.4	4.2	3.2	4.6
4	Facial	Syrup	Room	6.6	5.1	6.1	5.2
5	Multi-purpose	Syrup	Room	7	7.2	7.2	6.1
6	Hand	Syrup	Room	7.6	8	7.6	8.2
7	Facial	Oil	Room	4	3.9	3.4	4
8	Multi-purpose	Oil	Room	4.6	4.8	5	5.2
9	Hand	Oil	Room	3.9	3.8	4.2	4.4
10	Facial	Water	Cold	4.5	4.4	4	4.8
11	Multi-purpose	Water	Cold	4.6	4.8	3.2	4.6
12	Hand	Water	Cold	4	3.6	3.8	4.2
13	Facial	Syrup	Cold	5	6.2	5.4	5.2
14	Multi-purpose	Syrup	Cold	6.5	7	6	6.8
15	Hand	Syrup	Cold	7.2	7	8.6	7
16	Facial	Oil	Cold	4.4	4	3.6	3.8
17	Multi-purpose	Oil	Cold	4.8	5.2	4.8	4.6
18	Hand	Oil	Cold	3.8	3.4	4	3.6

CHAPTER 6
Statistical Analysis and Conclusion

After we perform the experiment, the data are collected. We analyze the data by using Minitab software. From the results, we can observe the relationship between factors and the response variable.

We can't perform a 2-level factorial design because each factor has more than 2 levels. So we use the general factorial design option in the Minitab instead. The analyzed results are shown below.

General Factorial Regression: Volume(mL) versus A, B, C

Factor Information

Factor	Levels	Values
A	3	Facial, Multi-purpose, Hand
B	3	Water, Syrup, Oil
C	2	Room, Cold

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	17	120.388	7.0816	29.36	0.000
Linear	5	101.047	20.2094	83.79	0.000
A	2	5.247	2.6235	10.88	0.000
B	2	95.395	47.6976	197.75	0.000
C	1	0.405	0.4050	1.68	0.201
2-Way Interactions	8	19.036	2.3795	9.87	0.000
A*B	4	18.663	4.6658	19.34	0.000
A*C	2	0.018	0.0088	0.04	0.964
B*C	2	0.356	0.1779	0.74	0.483
3-Way Interactions	4	0.304	0.0760	0.32	0.867
A*B*C	4	0.304	0.0760	0.32	0.867
Error	54	13.025	0.2412		
Total	71	133.413			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.491125	90.24%	87.16%	82.64%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	5.0306	0.0579	86.91	0.000	
A					
Facial	-0.3639	0.0819	-4.45	0.000	1.33
Multi-purpose	0.2819	0.0819	3.44	0.001	1.33
B					
Water	-0.8264	0.0819	-10.10	0.000	1.33
Syrup	1.6278	0.0819	19.89	0.000	1.33
C					
Room	0.0750	0.0579	1.30	0.201	1.00
A*B					
Facial Water	0.635	0.116	5.48	0.000	1.78
Facial Syrup	-0.694	0.116	-6.00	0.000	1.78
Multi-purpose Water	-0.149	0.116	-1.28	0.205	1.78
Multi-purpose Syrup	-0.215	0.116	-1.86	0.068	1.78
A*C					
Facial Room	-0.0167	0.0819	-0.20	0.839	1.33
Multi-purpose Room	-0.0042	0.0819	-0.05	0.960	1.33
B*C					
Water Room	-0.0792	0.0819	-0.97	0.338	1.33
Syrup Room	0.0917	0.0819	1.12	0.268	1.33
A*B*C					
Facial Water Room	0.071	0.116	0.61	0.543	1.78
Facial Syrup Room	-0.000	0.116	-0.00	1.000	1.78
Multi-purpose Water Room	0.046	0.116	0.40	0.694	1.78
Multi-purpose Syrup Room	-0.012	0.116	-0.11	0.914	1.78

Regression Equation

Volume(mL) = 5.0306 - 0.3639 A_Facial + 0.2819 A_Multi-purpose + 0.0819 A_Hand
- 0.8264 B_Water + 1.6278 B_Syrup - 0.8014 B_Oil + 0.0750 C_Room -
0.0750 C_Cold
+ 0.635 A*B_Facial Water - 0.694 A*B_Facial Syrup + 0.060 A*B_Facial Oil
- 0.149 A*B_Multi-purpose Water - 0.215 A*B_Multi-purpose Syrup
+ 0.364 A*B_Multi-purpose Oil - 0.486 A*B_Hand Water + 0.910 A*B_Hand
Syrup
- 0.424 A*B_Hand Oil - 0.0167 A*C_Facial Room + 0.0167 A*C_Facial Cold
- 0.0042 A*C_Multi-purpose Room + 0.0042 A*C_Multi-purpose Cold
+ 0.0208 A*C_Hand Room - 0.0208 A*C_Hand Cold - 0.0792 B*C_Water Room
+ 0.0792 B*C_Water Cold + 0.0917 B*C_Syrup Room - 0.0917 B*C_Syrup Cold
- 0.0125 B*C_Oil Room + 0.0125 B*C_Oil Cold + 0.071 A*B*C_Facial Water
Room
- 0.071 A*B*C_Facial Water Cold - 0.000 A*B*C_Facial Syrup Room
+ 0.000 A*B*C_Facial Syrup Cold - 0.071 A*B*C_Facial Oil Room
+ 0.071 A*B*C_Facial Oil Cold + 0.046 A*B*C_Multi-purpose Water Room
- 0.046 A*B*C_Multi-purpose Water Cold - 0.012 A*B*C_Multi-purpose Syrup
Room
+ 0.012 A*B*C_Multi-purpose Syrup Cold - 0.033 A*B*C_Multi-purpose Oil
Room
+ 0.033 A*B*C_Multi-purpose Oil Cold - 0.117 A*B*C_Hand Water Room
+ 0.117 A*B*C_Hand Water Cold + 0.012 A*B*C_Hand Syrup Room -
0.012 A*B*C_Hand
Syrup Cold + 0.104 A*B*C_Hand Oil Room - 0.104 A*B*C_Hand Oil Cold

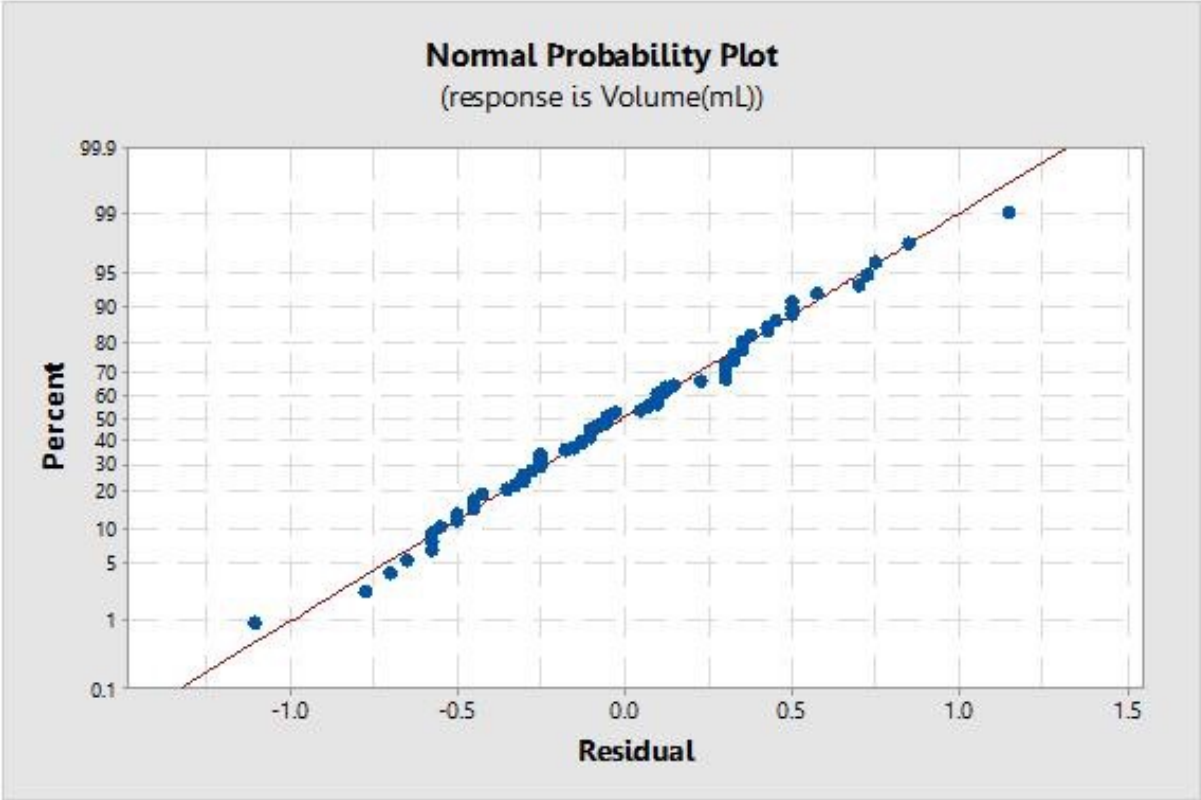
Fits and Diagnostics for Unusual Observations

Obs	Volume(mL)	Fit	Resid	Std Resid	
26	8.600	7.450	1.150	2.70	R
52	3.200	4.300	-1.100	-2.59	R

R Large residual

Model Adequacy Checking

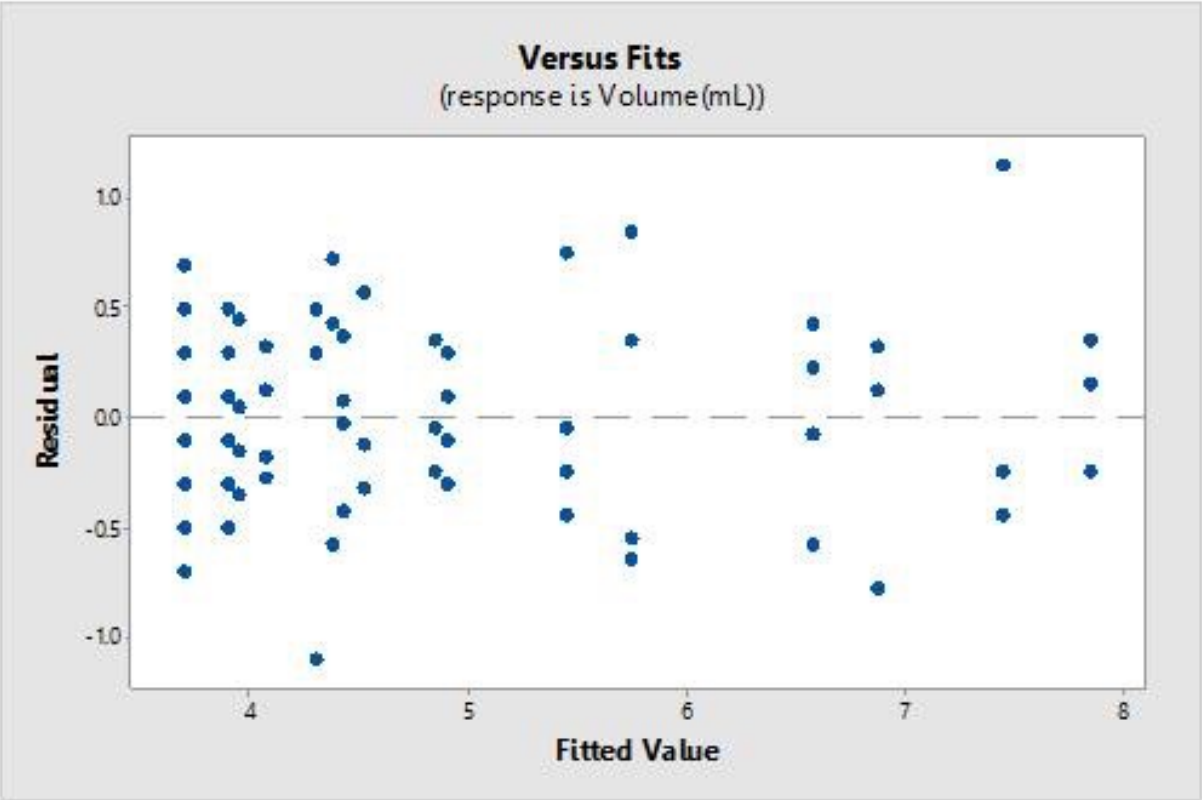
To check the model adequacy, we have to analyze if the data are satisfy the assumptions. We can use the plots and graphs to check these assumptions.



For the normality assumption, the data should be distributed normally. The residuals value in the normal probability plot should fall along the straight line.

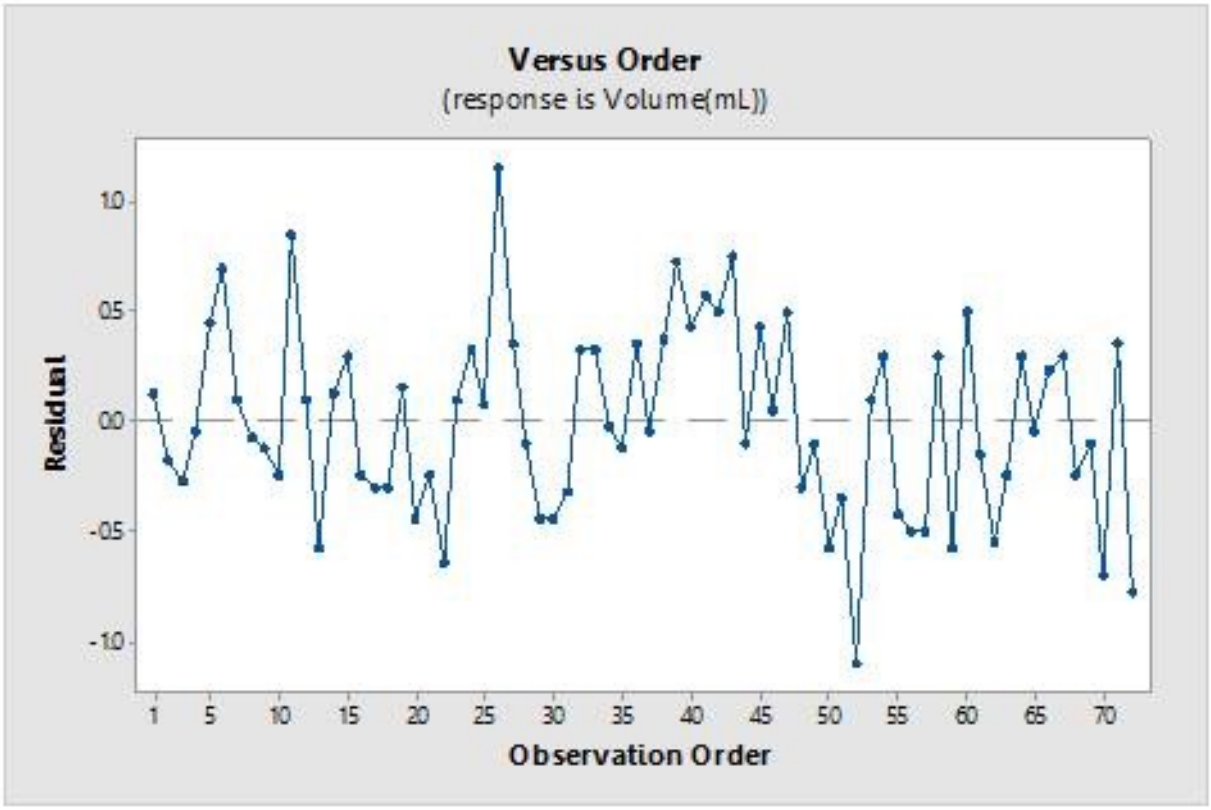
From the graph, we can see that data are fall along the straight line. Hence, it satisfies our normality assumption.

For the next assumption, the variance of the observations in the same treatment should be equal. We use the Residual versus Fits plot to check this assumption



From the graph, the residuals plot is in random pattern. So we can assume that the variances are the same in each treatment. Thus, the constant variance assumption is satisfied.

The observation should be selected randomly from the population. We use Residuals versus Order plot to check the assumption



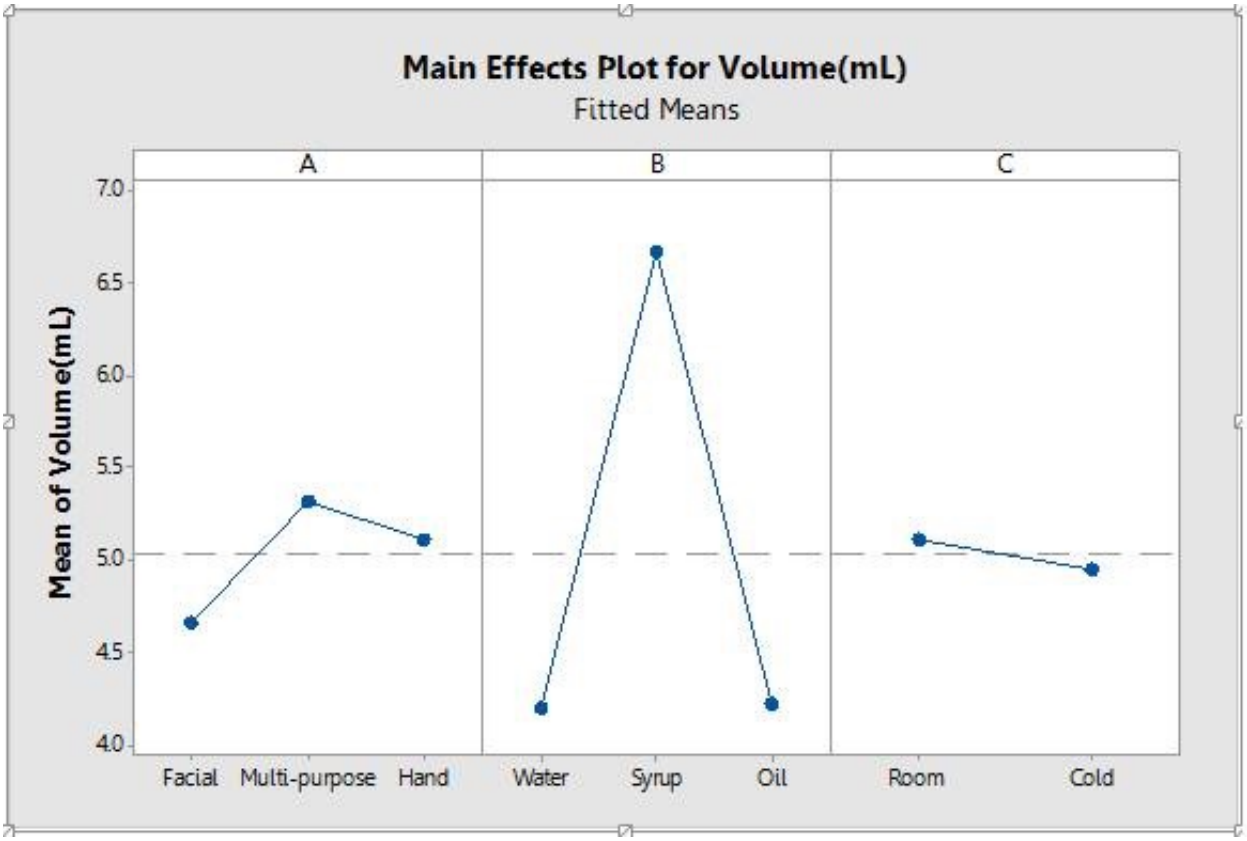
The residuals are in random pattern. So, we assume that it satisfies the assumption.
After we check all the plots, all of them satisfy the assumptions. So we begin to analyze the result.

Result Analysis

ANOVA table indicates that main effect B and A, interaction between A and B are significant.

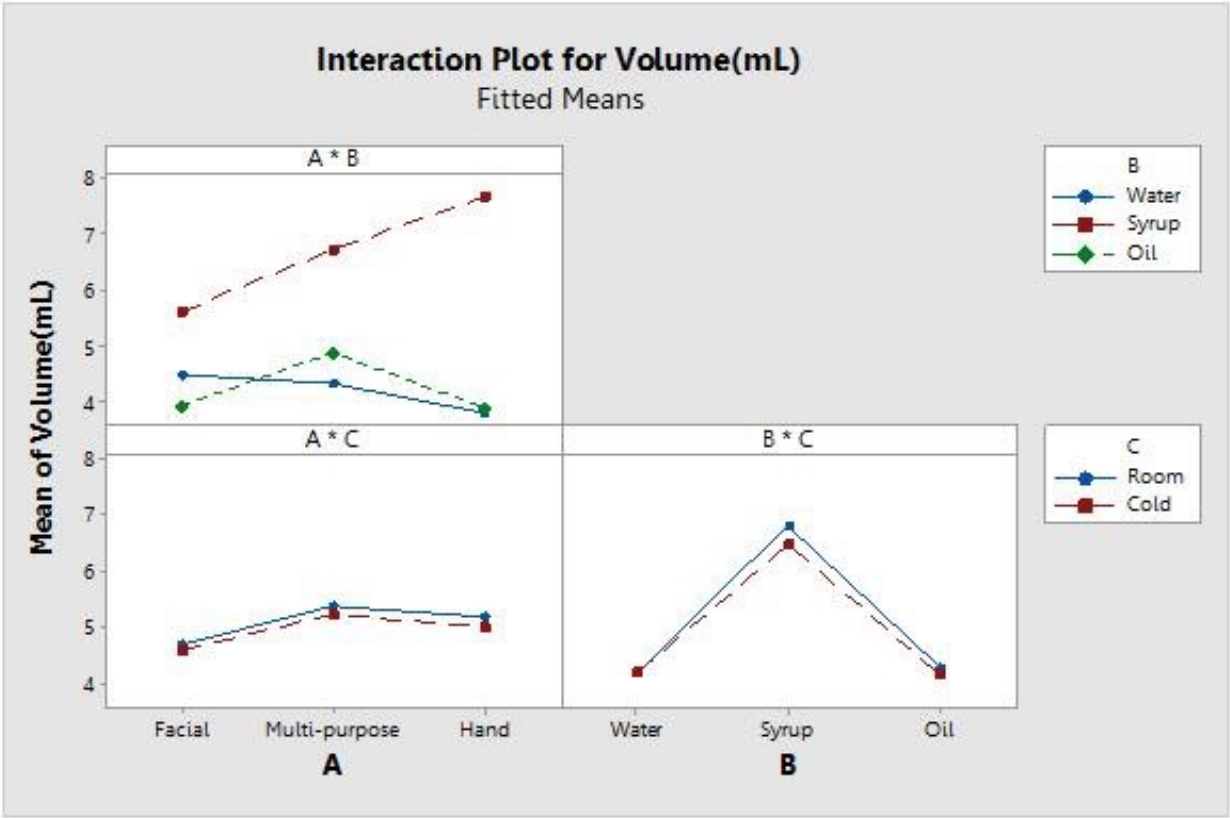
Main Effect B: Liquid Type
Main Effect A: Tissue Type
Interaction Effect AB: Liquid Type * Tissue Type

We can analyze the effect between each factor and the response variable by plotting the main effect against response.



From the plot, we can see that Factor B has the most significant effect to the response. However, if we look at Factor C. We can see that it's slightly effect the response. Hence, Factor C is not significant.

We use the interaction against response variable plot to analyze the interaction effect.



The graph above shows that the interaction effect AB has different slopes for each level of effect. It means that interaction effect AB is significant. For the remaining interaction effects, we can see that the slopes are parallel. This indicates that the interaction effects AC and BC don't affect the response.

For the conclusion, both ANOVA table and effect plots indicate that main effect A, main effect B and Interaction effect AB are significant.

Analysis compare to hypothesis

We have predicted the effect of each factor in Chapter 3. After we performed the experiment, we got an actual effect. This table will show the comparison between predicted effects and actual effects from the experiment.

Control variables

Control Variables	Predicted Effects	Actual Effects
Type of tissue paper	Multi-purpose tissue should give higher absorbency since it is designed to use for general purpose.	Multi-purpose tissue gives the highest response.
Type of liquid	Oil should give higher absorbency.	Syrup significantly gives higher response.
Temperature of liquid	Liquid temperature should not have any effect on the tissue paper absorbency.	The effect to the response is not significant.

CHAPTER 7
Conclusion

There are many brands of tissue paper in the market today. Those brands have difference manufacturing techniques to increase absorbability and strength of their product. The effectiveness generally comes with the cost.

We perform this experiment to find out which type of tissue paper has the best absorbency. There are 3 Factors to be considered in this experiment.

The first factor is the type of tissue paper. From the experiment and analysis, we can see that type of tissue has a significant effect to the absorbency. Each type of tissue offers different absorbency and the multi-purpose tissue gives the highest absorbency.

For the second factor which is type of liquid. This factor has the significant effect to the response. From the analysis, we can see that, different types of liquid clearly give different value of absorbency. The response is much higher with syrup than the other two levels.

The last main factor is liquid temperature. As we predicted from the beginning, this factor should not have a significant effect to the response. The actual result also supports out statement. The effect of liquid temperature to the absorbency is not significant.

We also considered the effect of the interaction between each factor. From the result, only the AB interaction which is type of tissue and type of liquid has a significant effect.

After we considered the main effects and interaction effects, this combination gives the highest absorbency.

Type of Tissue	Type of Liquid	Liquid Temperature	Volume of Liquid(mL)
Hand	Syrup	Room	7.85