上智大学
SOPHIA UNIVERSITY

Sophia University

Global Environmental Studies

Prof. Dr. Björn FRANK

Environment and Supply Chain Management

Term Paper:

Design of Experiments (DoE): Helicopter Project

Submitted by:

Names:	William Steimel	Lucas Roth
Enrollment no.:	B1778102	H1721037
Address:	Higashi-Kasai 5-27-19 Arukasaru Kasai Edogawa-ku, Tokyo 134-0084 Japan	Neue Hochstraße 11, 13347 Berlin, Germany
Phone:	+817042825179	+491629210105
E-Mail:	steimel65@gmail.com	euv155546@europa-uni.de

Degree program: Global Environmental Studies
Required Credits: 2
Date of submission: February 01, 2018

Table of Contents

List of Tables

List of Figures

1 Introduction

The purpose of this project is to design paper helicopters with different characteristics. Therefore, the goal is to find out what parameters determine the Flight Time through experimental design. This paper covers the whole experimental process. The next section focuses on the design parameters and applied combinations. The third section elaborates on the data collection process. The fourth part analyzes the collected data descriptively. The fifth section adds inferential statistics and interprets the results. Lastly, the conclusion reinforces our findings where the optimal model and a simulation of further flight time development are shown.

2 Design Parameters and Combinations

2.1 Influential Parameters

We hypothesized three parameters/features would influence flight time the most: Wing Length (Continuous), Trunk Width (Continuous), and Folded Wings (Discrete).

For the first experimental parameter/feature of Wing length, the possible values we selected were 65 mm and 110 mm. Our quick demonstrations showed that Wing Length seems to impact the falling rate, which is why we decided to choose this value.

For the second experimental parameter/feature of Trunk Width, values we selected were 80 mm and 160 mm. Trunk Width is essentially 2 x the wing width, and we hypothesized that the bigger the wings the longer the helicopter will stay airborne.

The last experimental parameter we specified was Folded Wings which has a value of either yes or no. We assume from a logical standpoint that the Folded Wings would have an influence on the rotation speed, which would impact rate of descent leading to more flight time.

We deliberately chose extreme values for the Wing Length and Trunk Width to yield significant differences in results for our experiments. All possible independent variable/parameter options as well as their total observation count can be seen in Table 1 labeled Between-Subjects Factors.

Between-Subjects Factors

		Value Label	N
Wing Length in mm	65		12
	110		12
Folded Wings	0	no	12
	1	yes	12
Trunk Width in mm	80		12
	160		12

Table 1: Influential Parameters

2.2 Constant Parameters

In addition, our group decided to keep the values of Paperclip (Discrete), Trunk Height (Continuous), Cut Pattern (Discrete), Middle Trunk Height (Continuous), and Body width (Continuous) as constant values. We specified the Paperclip value as yes since it appears to stabilize the helicopter during its decent. We also specified the cut pattern to be a T-shape and inferred that this shape would have a positive influence on the helicopters aerodynamics.

2.3 Possible Combinations

Table 2 depicts all possible combinations and provides an overview of the parameters previously described. In total, 8 different models will be tested.

Prototype	Wing length	Trunk width(2x Wing Width)	Folded Wings	Paperclip	Trunk height	Cut Pattern	Middle Trunk Height	Body Width
A	65	80	Y	yes	60mm	T-Shape	25mm	35 mm
B	65	80	N	yes	60mm	T-Shape	25mm	35 mm
C	65	160	Y	yes	60mm	T-Shape	25mm	35 mm
D	65	160	N	yes	60mm	T-Shape	25mm	35 mm
E	110	80	Y	yes	60mm	T-Shape	25mm	35 mm
F	110	160	N	yes	60mm	T-Shape	25mm	35 mm
G	110	80	N	yes	60mm	T-Shape	25mm	35 mm
H	110	160	Y	yes	60mm	T-Shape	25mm	35 mm
Data Type:	Continuous	Continuous	Discrete	Discrete	Continuous	Discrete	Continuous	Continuous

Table 2: Combinations and Parameters

3 Collection of Data

After conducting paper helicopter experiments in Sophia University's Building 2, we added 24 distinct observations of Flight Time duration (y-Dependent Variable) to our dataset, which was 3 observations per helicopter type (A-H). The respective flight times can be seen in Table 3.

ID	Prototype	Wing length (Continuous) mm	Trunk width (Continuous) (2x Wing Width) mm	Folded Wings (Discrete)	Paperclip (Discrete)	Trunk height (Continuous) mm	Cut Pattern (Discrete) T-Shape	Middle Trunk Height (Continuous) mm	Body Width (Continuous) mm	Flight Time
1	A	65	80	1	1	60	1	25	35	16.99
2	A	65	80	1	1	60	1	25	35	15.03
3	A	65	80	1	1	60	1	25	35	16.82
4	B	65	80	0	1	60	1	25	35	20.2
5	B	65	80	0	1	60	1	25	35	23.03
6	B	65	80	0	1	60	1	25	35	19.47
7	C	65	160	1	1	60	1	25	35	16.93
8	C	65	160	1	1	60	1	25	35	14.91
9	C	65	160	1	1	60	1	25	35	15.8
10	D	65	160	0	1	60	1	25	35	20.65
11	D	65	160	0	1	60	1	25	35	21.96
12	D	65	160	0	1	60	1	25	35	20.86
13	E	110	80	1	1	60	1	25	35	20.26
14	E	110	80	1	1	60	1	25	35	20.88
15	E	110	80	1	1	60	1	25	35	20.35
16	F	110	160	0	1	60	1	25	35	27.90
17	F	110	160	0	1	60	1	25	35	28.73
18	F	110	160	0	1	60	1	25	35	26.48
19	G	110	80	0	1	60	1	25	35	19.45
20	G	110	80	0	1	60	1	25	35	19.36
21	G	110	80	0	1	60	1	25	35	17.19
22	H	110	160	1	1	60	1	25	35	18.45
23	H	110	160	1	1	60	1	25	35	17.15
24	H	110	160	1	1	60	1	25	35	18.76

Table 3: Flight Times

4 Descriptive Statistics

After the Data Collection phase our group inputted the data into the SPSS Statistical software and looked at descriptive statistics for the Independent variables. Generally, the first step in analyzing data is data exploration as descriptive statistics can help a researcher get a feel and quick understanding of the data's structure [1]. All descriptive statistics are displayed in Table 4.

Descriptive Statistics

Dependent Variable: Flight Time in sec

Wing Length in mm	Folded Wings	Trunk Width in mm	Mean	Std. Deviation	N
65	no	80	20,9000	1,88040	3
		160	21,1567	,70359	3
		Total	21,0283	1,27755	6
	yes	80	16,2800	1,08586	3
		160	15,8800	1,01237	3
		Total	16,0800	,96416	6
	Total	80	18,5900	2,87912	6
		160	18,5183	2,99348	6
		Total	18,5542	2,80043	12
110	no	80	18,6667	1,27962	3
		160	27,7000	1,13697	3
		Total	23,1833	5,06482	6
	yes	80	20,4967	,33501	3
		160	18,1200	,85422	3
		Total	19,3083	1,42525	6
	Total	80	19,5817	1,30558	6
		160	22,9100	5,32371	6
		Total	21,2458	4,08395	12
Total	no	80	19,7833	1,88830	6
		160	24,4283	3,68234	6
		Total	22,1058	3,69711	12
	yes	80	18,3883	2,41880	6
		160	17,0000	1,48564	6
		Total	17,6942	2,04653	12
	Total	80	19,0858	2,19337	12
		160	20,7142	4,71337	12
		Total	19,9000	3,69019	24

Table 4: Descriptive Statistics for the Independent and Dependent Variables

5 Inferential statistics and Interpretation of Results

When analyzing the parameters, our group decided to first isolate each variable then analyze interaction effects separately. The regression model summary outputted through SPSS can be found in Table 5.

The first essential measure to interpret, when conducting an experiment, is how well a model fits the data which can be done with the adjusted R^2 value. According to James et al. (2017), the adjusted R^2 value "measures the proportion of variance in Y that can be explained using X and varies between 0 and 1." [2]. In addition, a value closer to 1 indicates that a large proportion of response variability can be explained through the applied model [2]. The adjusted R^2 for our model can be found in Table 5 amounts .908. Hence, this model closely fits the data and explains 90.8 % of the variation in the dependent variable.

Another important factor for experiments is determining whether there is a relationship between the independent variables and dependent variables which is done through the F-value. The F-value is used to determine whether there is a relationship between the independent variables and the dependent variable, and usually indicates evidence against the null hypothesis when it takes a value above one [2]. Each variable or variable combination will have its own F-value serving as an indicator for its relationship to the dependent variable (Flight Time), and whether the null hypothesis can be rejected.

Furthermore, the corresponding p-value is considered a measure of significance in experimental design. Regardless of whether there is a relationship to the dependent variable, it is important to determine if this relationship is significant with the p-value. In general, a significant p-value is anything less than .05 but this depends on the data that is being worked on [2].

Following the results in Table 5, all but one analyzed factor or factor combinations are significant and have an impact on the Flight Time.

Tests of Between-Subjects Effects

Dependent Variable: Flight Time in sec

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	293,189[a]	7	41,884	33,484	,000
Intercept	9504,240	1	9504,240	7598,073	,000
wing.l	43,470	1	43,470	34,752	,000
fold.w	116,777	1	116,777	93,356	,000
trunk.w	15,909	1	15,909	12,718	,003
wing.l * fold.w	1,728	1	1,728	1,381	,257
wing.l * trunk.w	17,340	1	17,340	13,862	,002
fold.w * trunk.w	54,602	1	54,602	43,651	,000
wing.l * fold.w * trunk.w	43,363	1	43,363	34,666	,000
Error	20,014	16	1,251		
Total	9817,443	24			
Corrected Total	313,203	23			

a. R Squared = ,936 (Adjusted R Squared = ,908)

Table 5: Test Statistics

Finally, the Grand Mean in Table 6 details the Mean for all observations in the dataset and indicates that the average helicopter had a flight time of 19.9 seconds with a 95 % confidence interval between 19.41 seconds and 20.38 seconds. This grand mean serves as a baseline for the helicopters' experimental performance.

1. Grand Mean

Dependent Variable: Flight Time in sec

		95% Confidence Interval	
Mean	Std. Error	Lower Bound	Upper Bound
19,900	,228	19,416	20,384

Table 6: Grand Mean

The following paragraphs give a detailed analysis of all factors and their respective combinations. We elaborate on whether we are able to falsify the corresponding null hypothesis to our actual assumption. The null hypothesis is rejected if the p-value amounts less than .05. The f-values and corresponding p-values for the following sections are shown in Table 5.

5.1 Wing Length

$H_{1(0)}$- Greater Wing Length has no influence on flight time.

H_1- Greater Wing Length has an influence on flight time.

Our group hypothesizes that a greater Wing Length would impact the paper helicopter's Flight Time. The plot below in Figure 1 illustrates the difference in marginal means between a smaller and larger Wing Length. Table 7 shows a clear positive relationship.

Smaller Wing Length marginal mean was approximately 18.554 ± (.70) of flight time while a longer Wing Length returned a marginal mean of 21.246 ± (.70) seconds. The longer Wing Length returned an average Flight Time above the grand mean of the entire dataset within the 95 % confidence interval. The F-value in this model is 34.752 with a p value of <.001 indicating a significant relationship between the factors, which means we can reject the null hypothesis and conclude that greater Wing Length has an influence on Flight Time.

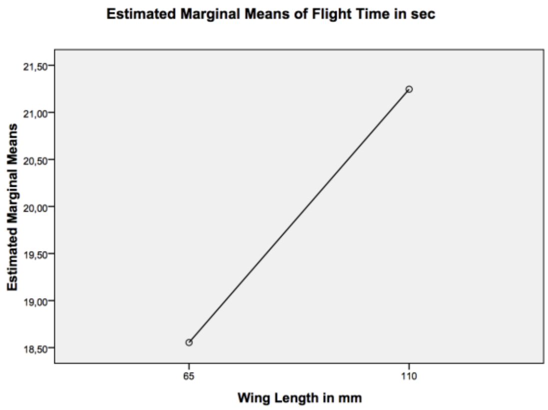

Figure 1: Flight Time Dependent on Wing Length

2. Wing Length in mm

Dependent Variable: Flight Time in sec

Wing Length in mm	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
65	18,554	,323	17,870	19,239
110	21,246	,323	20,561	21,930

Table 7: Flight Time Dependent on Wing Length

5.2 Folded Wings

$H_{2(0)}$- Folded Wings have no influence on flight time.

H_{2}- Folded Wings have an influence on flight time.

For our second parameter, we hypothesized that Folded Wings would influence Flight Time. The plot below in Figure 2 illustrates the difference in marginal means between Not Folded and Folded Wings. Table 8 shows that Not Folded averages around 22.106 ± (.70) seconds while Folded Wings averages around 17.694 ± (.70) seconds of flight time. The Folded Wings parameter returned an average flight time less than the grand mean with 95 % confidence, and is reflected by a negative/downward relationship in the graph. The F-value of 93.35 with a p-value of <.001 are indicating a significant difference. The null hypothesis is rejected. Hence, we can conclude that Folded Wings have an influence on flight time.

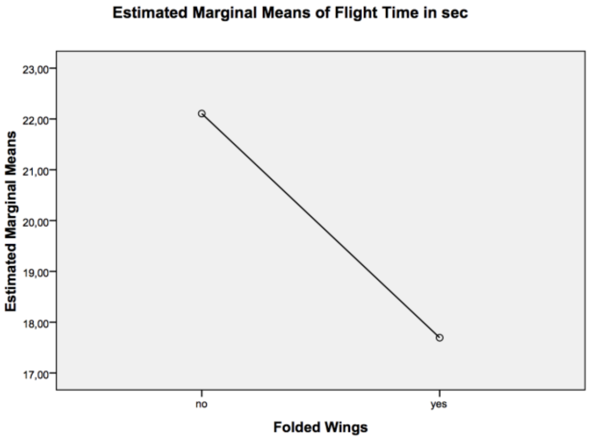

Figure 2: Flight Time Dependent on Folded Wings

3. Folded Wings

Dependent Variable: Flight Time in sec

Folded Wings	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
no	22,106	,323	21,421	22,790
yes	17,694	,323	17,010	18,379

Table 8: Flight Time Dependent on Folded Wings

5.3 Trunk Width

$H_{3(0)}$- Trunk Width has no influence on flight time.

H_3- Trunk Width has an influence on flight time.

Our group's last hypothesis was that Trunk Width impacts Flight Time. Figure 3 below details the marginal means of a small versus large Trunk Width which is clearly a positive relationship. A small trunk width returned a marginal mean of around 19.086 ± (.70) while a large trunk had about 20.714 ± (.70) seconds of Flight Time. When comparing the marginal mean of a large trunk size versus the grand mean, it appears that large trunk size is above the grand mean with 95 % confidence. An F-value of 12.71 indicates that there is a relationship between Trunk Width and Flight Time within .003 significance. This means we can reject the null hypothesis and conclude that Trunk Width has an influence on Flight Time.

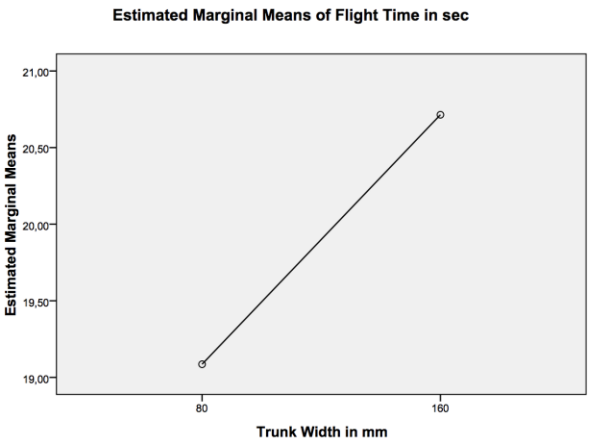

Figure 3: Flight Time Dependent on Trunk Width

4. Trunk Width in mm

Dependent Variable: Flight Time in sec

Trunk Width in mm	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
80	19,086	,323	18,401	19,770
160	20,714	,323	20,030	21,399

Table 9: Flight Time Dependent on Trunk Width

5.4 Interaction Effect: Wing Length – Folded Wings

$H_{4(0)}$- The interaction effect between Wing Length and Folded Wings has no influence on Flight Time.

H_{4}- The interaction effect between Wing Length and Folded Wings has an influence on Flight Time.

First, we examine whether there is any interaction effect between Wing Length and Folded Wings in terms of Flight Length. The F-Value for these two parameters in combination was 1.38, which is pretty close to 1 but also has a weak relationship between the two factors. From a visual perspective, the two lines in Figure 4 are nearly parallel indicating a lack of interaction effect. The differences in means are displayed in Table 10. With a p-value of .257 this relationship is not significant. This means we can accept the null hypothesis and conclude that the interaction effect between Wing Length and Folded Wings has no influence on Flight Time.

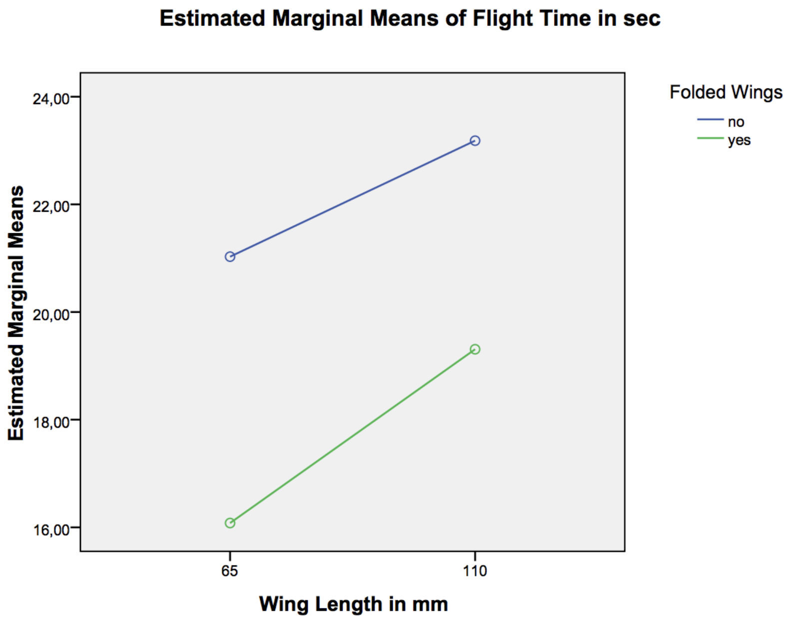

Figure 4: Flight Time Dependent on Wing Length * Folded Wings

5. Wing Length in mm * Folded Wings

Dependent Variable: Flight Time in sec

Wing Length in mm	Folded Wings	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
65	no	21,028	,457	20,060	21,996
	yes	16,080	,457	15,112	17,048
110	no	23,183	,457	22,215	24,151
	yes	19,308	,457	18,340	20,276

Table 10: Flight Time Dependent on Wing Length*Folded Wings

5.5 Interaction Effect: Trunk Width – Wing Length

$H_{5(0)}$- The interaction effect between Trunk Width and Wing Length has no influence on Flight Time.

H_5- The interaction effect between Trunk Width and Wing Length has an influence on Flight Time.

Next, we examine whether an interaction effect exists between Trunk Width and Wing Length. The F-Value for these two parameters in combination was 13.362 with a corresponding p-value of .002 indicating a significant relationship between the predictors and response. Table 11 shows a combination of large Wing Length and large Trunk Width that leads to good performance with an average of 22.91 ± (1) seconds flight time. Figure 5 indicates that Longer Trunk Width and Wing Length have a positive synergic effect.

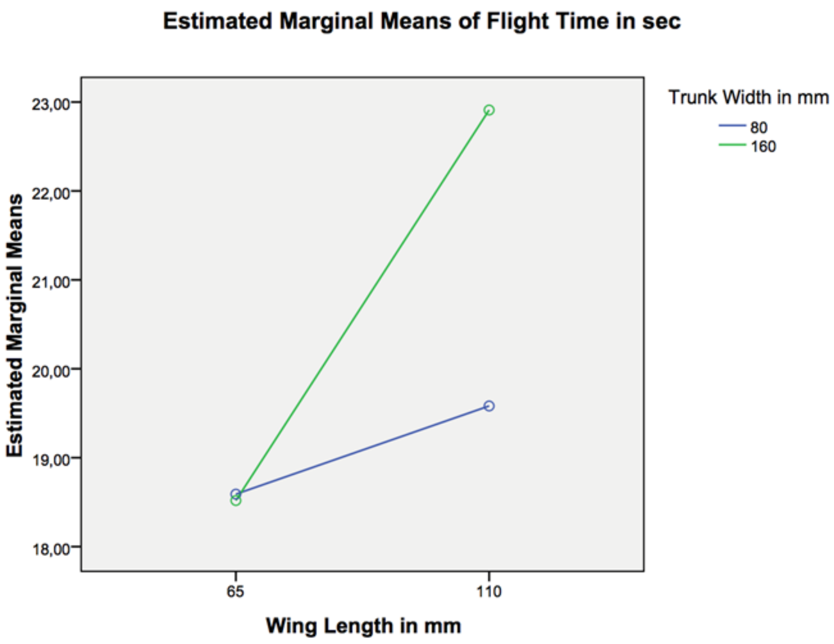

Figure 5: Flight Time Dependent on Trunk Width * Wing Length

6. Wing Length in mm * Trunk Width in mm

Dependent Variable: Flight Time in sec

Wing Length in mm	Trunk Width in mm	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
65	80	18,590	,457	17,622	19,558
	160	18,518	,457	17,550	19,486
110	80	19,582	,457	18,614	20,550
	160	22,910	,457	21,942	23,878

Table 11: Flight Time Dependent on Trunk Width * Wing Length

5.6 Interaction Effect: Folded Wings – Trunk Width

$H_{6(0)}$- The interaction effect between Folded Wings and Trunk Width has no influence on Flight Time.

H_6- The interaction effect between Folded Wings and Trunk Width has an influence on Flight Time.

Furthermore, we examined the interaction effects between Folded Wings and Trunk Width. Table 12 shows that a combination of Folded Wings and large Trunk Width lead to poor performance with an average of 17.0 ± (1) seconds Flight Time which is well below the grand mean. Figure 6 indicates that there is a negative synergic effect between Folded Wings and longer Trunk Width. The F-Value for these two parameters in combination is 43.65, indicating a significant relationship between the predictors and response. In addition, these parameters returned a high statistical significance of <.001, which means the null hypothesis can be rejected. We can conclude that the interaction effect between Folded Wings and Trunk Width has an influence on Flight Time.

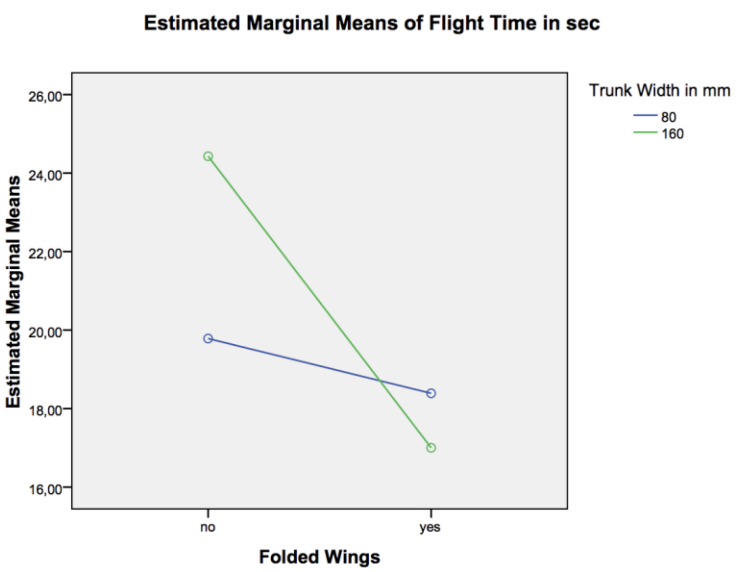

Figure 6: Flight Time Dependent on Folded Wings * Trunk Width

7. Folded Wings * Trunk Width in mm

Dependent Variable: Flight Time in sec

Folded Wings	Trunk Width in mm	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
no	80	19,783	,457	18,815	20,751
	160	24,428	,457	23,460	25,396
yes	80	18,388	,457	17,420	19,356
	160	17,000	,457	16,032	17,968

Table 12: Flight Time Dependent on Folded Wings * Trunk Width

5.7 Interaction Effect: Trunk Width – Wing Length – Folded Wings

$H_{7(0)}$- The interaction effect between Trunk Width, Wing Length and Folded Wings has no influence on Flight Time.

H_7- The interaction effect between Trunk Width, Wing Length and Folded Wings has an influence on Flight Time.

Lastly, we analyzed the interaction effect between Trunk Width, Wing Length, and Folded Wings. A combination of Folded Wings, 110 mm Wing Length, and 160 mm Trunk Width yields an average flight time of 18.12 ± (1.3) seconds which is slightly below the grand mean. Table 13 shows all possible combinations. The F-value of this parameter combination amounts to 34.67 and the corresponding p-value of <.001 indicates a significant effect size. The null hypothesis is rejected and we therefore conclude that the interaction effect between Trunk Width, Wing Length and Folded Wings has an influence on Flight Time.

8. Wing Length in mm * Folded Wings * Trunk Width in mm

Dependent Variable: Flight Time in sec

Wing Length in mm	Folded Wings	Trunk Width in mm	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
65	no	80	20,900	,646	19,531	22,269
		160	21,157	,646	19,788	22,526
	yes	80	16,280	,646	14,911	17,649
		160	15,880	,646	14,511	17,249
110	no	80	18,667	,646	17,298	20,036
		160	27,700	,646	26,331	29,069
	yes	80	20,497	,646	19,128	21,866
		160	18,120	,646	16,751	19,489

Table 13: Flight Time Dependent on Wing Length * Folded Wings * Trunk Width

5.8 Summary of the Results

In summary, all but one of the analyzed effects and respective interactions are significant. Figure 7 provides an overview of all standardized effect sizes. Only the combination of Wing Length and Trunk Width is found to be non-significant. Folded Wings have the biggest influence on Flight Time, followed by the interaction between Trunk Width and Folded Wings. Wing Length and the combination of all three factors have the same impact. The interaction between Wing Length and Trunk Width, as well as the Trunk Width alone, have the weakest but still significant influence on Flight Time.

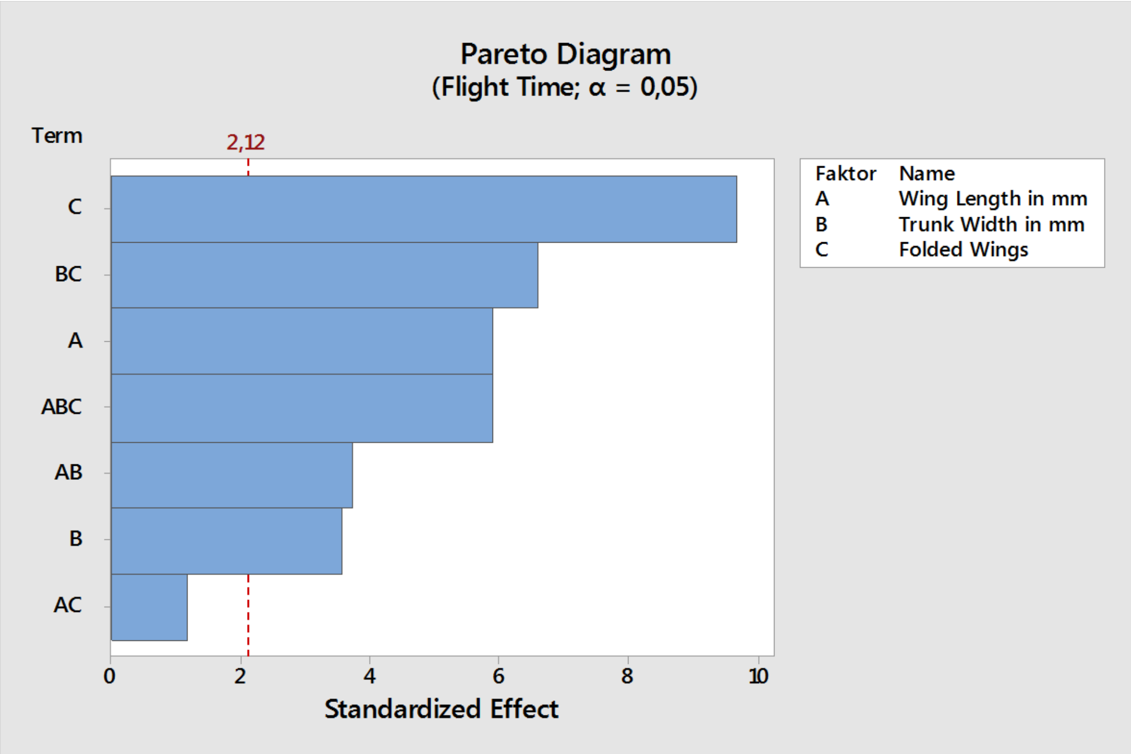

Figure 7: Pareto Diagram with Standardized Effects

6 Conclusion

Figure 8 shows that the best helicopter in our experimental design has the parameters of 110 mm Wing Length, Not Folded Wings, and 160 mm in Trunk Width. This helicopter (Model F) has a mean around 27.7 +- (1.4) seconds of Flight Time within 95 % confidence, which is significantly higher than the grand mean of 19.9 +- (.5).

With these results, we could infer that greater wing span increases Flight Time, greater Trunk Width increases Flight Time, and Not Folded Wings increase Flight Time. Longer Wing Length and Trunk Width also have a positive interaction effect increasing the Flight Time as they are increased in unison. This can be seen clearly when a doubling of Trunk Width and Wing Length also leads to an average increase in Flight Time of 4 seconds.

Assuming a strict linear relationship, we could infer that an optimal helicopter would have the longest wings and trunk physically possible with no fold, out of the analyses given where longer Wing Length and Trunk Width have a positive interaction effect, and helicopters with no fold performed the best from a parameter perspective.

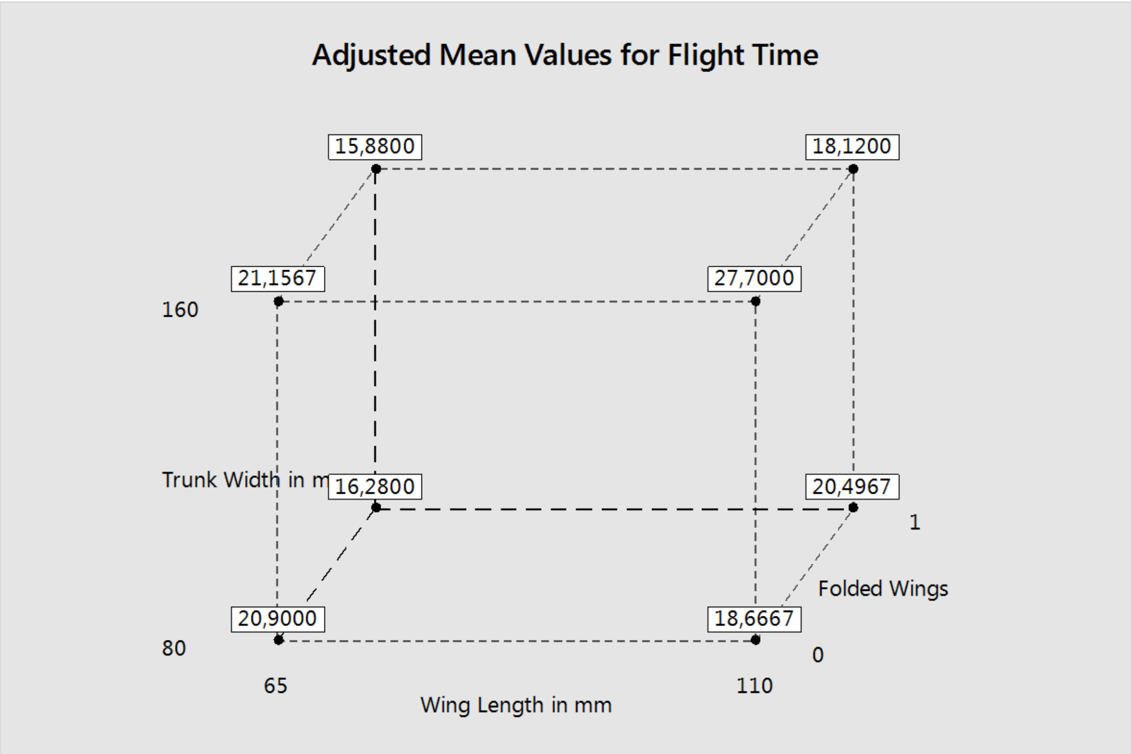

Figure 8: Cube Chart for Adjusted Mean Values

Moreover, to show how alterations of parameters within our data set would influence Flight Time, we ran a simulation with Minitab based on our experimental data. The results are displayed in Table 14. It can be observed that any other random alteration within our parameter range has a negative impact on Flight Time.

Number	Wing Length in mm	Trunk Width in mm	Folded Wings	Flight Time Adjustment
1	110,00	160,00	No	27,70
2	109,97	160,00	No	27,66
3	110,00	145,19	No	24,13
4	96,62	128,09	Yes	23,15
5	65,00	100,73	No	20,95
6	110,00	80,00	Yes	20,50
7	99,63	80,00	No	19,24
8	90,98	151,75	Yes	17,33

Table 14: Flight Time Forecast Simulation

To determine whether an increase in Trunk Width and Wing Length with Not Folded Wings would actually lead to a positive influence on Flight Time, cannot be said for certain without additional data collection. However, assuming a linear relationship, a regression model allows us to calculate a Flight Time forecast. The respective model in non-coded units looks as follows:

$$\begin{aligned} Flight\ Time = {} & 36{,}55 - 0{,}2447\ Wing\ Length\ in\ mm \\ & - 0{,}1553\ Trunk\ Width\ in\ mm - 28{,}81\ Folded\ Wings \\ & + 0{,}002438\ Wing\ Length\ in\ mm * Trunk\ Width\ in\ mm \\ & + 0{,}3823\ Wing\ Length\ in\ mm * Folded\ Wings \\ & + 0{,}1859\ Trunk\ Width\ in\ mm * Folded\ Wings \\ & - 0{,}002987\ Wing\ Length\ in\ mm * Trunk\ Width\ in\ mm \\ & * Folded\ Wings \end{aligned}$$

To understand the influence of the independent variables on Flight Time, we decided to double the continuous variables and set the discrete variable to 0:

$Wing\ Length\ in\ mm = 220$

$Trunk\ Width\ in\ mm = 320$

$Folden\ Wings = 0$ (Not Folded Wings)

These values inserted into the regression model yield the results in Table 15. Assuming a linear relationship, a Wing Length of 220 mm and a Trunk Width of 320 mm with Not Folded Wings will result in an average Flight Time of 104.67 seconds. However, a linear relationship is not likely. For instance, it has to be assumed, that at some point the overall weight of the helicopter will have a negative influence on Flight Time, which could be expressed in a second-degree polynomial relationship.

Flight Time Adjustment	Deviation Adjustment	95%-KI
104,670	9,83353	(83,8235; 125,516)

Table 15: Flight Time Forecast

This experiment has great potential for further deliberations and expansions. For instance, it would be interesting to see until which point the extension of Trunk Width and Wing Length would actually lead to increased Flight Time. If we are able to determine the lengths/widths after which the overall weight kicks in and reduces the Flight time we would be able to perfectly simulate all possible combinations of independent variables, and the respective Flight Time to determine the actual best parameters that go beyond the horizon of our current data.

In conclusion, this project demonstrates how designing an experiment with paper helicopters can lead to further understanding about factors surrounding Flight Time. It also gives a preview on product development engineering. As this era evolves to be increasingly more data driven, there is a need to strengthen the analytical mind through a refurbishing of the basics like Analysis of Variance.

7 References

[1] Postgraduate Online Research Training: School of Advanced Study University of London. (n.d.). Exercise 1: Getting Started with SPSS. Retrieved January 23, 2018, from http://port.sas.ac.uk/mod/book/view.php?id=1516&chapterid=1061.

[2] James, G., Witten, D., Hastie, T. J., & Tibshirani, R. J. (2017). *An introduction to statistical learning: with applications in R*. New York: Springer.

Appendix

Syntax

We used the attached syntax to format the data and calculate the ANOVA. Hence, the delivered data is in raw format with missing data types, data format, variables labels and values.

```
*Datensatz einlesen.
GET FILE = 'C:\Users\lroth\Dropbox\Studium 2.0\Sophia\SSCM\Hausar-
beit\analysis\data.sav'.


***************************************************************
*************Aufarbeitung des Datensatzes**************
***************************************************************


********* Variablenlabels definieren.*****************

variable labels
id 'ID'
type 'Prototyp'
wing.l 'Wing Length in mm'
trunk.w 'Trunk Width in mm'
fold.w 'Folded Wings'
paper.c 'Paperclip'
trunk.h 'Trunk Height in mm'
cut.p 'Cut Pattern'
middle.t.h 'Middle Trunk Height in mm'
body.w 'Body Width in mm'
time' Flight Time in sec'.

value labels
fold.w paper.c
1 yes
0 no.
EXECUTE.

****Messniveau anpassen

VARIABLE LEVEL id fold.w paper.c type cut.p (nominal).
```

```
VARIABLE LEVEL wing.l trunk.h middle.t.h body.w time (scale).
Execute.


******Format anpassen

FORMATS id wing.l trunk.w fold.w paper.c trunk.h cut.p middle.t.h
body.w (F8.0).
EXECUTE.

ALTER TYPE time (f8.2).
execute.

***************************************************************
************************ANOVA*****************************
***************************************************************

UNIANOVA time BY wing.l fold.w trunk.w
  /METHOD=SSTYPE(3)
  /INTERCEPT=INCLUDE
  /PLOT=PROFILE(wing.l fold.w trunk.w wing.l*fold.w fold.w*trunk.w
wing.l*trunk.w)
  /EMMEANS=TABLES(OVERALL)
  /EMMEANS=TABLES(wing.l)
  /EMMEANS=TABLES(fold.w)
  /EMMEANS=TABLES(trunk.w)
  /EMMEANS=TABLES(wing.l*fold.w)
  /EMMEANS=TABLES(wing.l*trunk.w)
  /EMMEANS=TABLES(fold.w*trunk.w)
  /EMMEANS=TABLES(wing.l*fold.w*trunk.w)
  /PRINT=DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /DESIGN=wing.l fold.w trunk.w wing.l*fold.w wing.l*trunk.w
fold.w*trunk.w wing.l*fold.w*trunk.w.
```

Declaration of academic honesty

Declaration of academic honesty – Lucas Roth

I confirm that all this work is my own except where indicated, and that I have clearly referenced/listed all sources as appropriate, referenced and put in inverted commas all quoted text (from books, web, etc.), not made any use of the essay(s) of any other student(s) either past or present, not submitted for assessment work previously submitted for any other course, degree or qualification, not incorporated any text acquired from external agencies - other than extracts from attributed sources (including online facilities) and included an accurate word count. I understand that any false claim for this work will be penalized in accordance with university regulations.

Tokyo, January 28, 2018

____

Lucas Roth

Declaration of academic honesty – William Steimel

I confirm that all this work is my own except where indicated, and that I have clearly referenced/listed all sources as appropriate, referenced and put in inverted commas all quoted text (from books, web, etc.), not made any use of the essay(s) of any other student(s) either past or present, not submitted for assessment work previously submitted for any other course, degree or qualification, not incorporated any text acquired from external agencies - other than extracts from attributed sources (including online facilities) and included an accurate word count. I understand that any false claim for this work will be penalized in accordance with university regulations.

Tokyo, January 28, 2018

____

William Steimel