10.004: Advanced Mathematics II

SUTD 2019 1D Project Class F07 Group 9

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Mathematical Modelling

Analysis of Impact of Aircraft Noise on Singaporeans

Executive Summary

Aviation Studies Institute (ASI) has tasked us to model the impact of aircraft noise on Singaporeans. We have decided to study how aircraft noise (dB) can affect university students' amount of sleep (hours) and productivity (hours) in Singapore. We studied the effects of noise pollution from Changi Airport first before we draw any comparison to Seletar Airport.

To simplify things, we assumed noise level is the only factor affecting the student's sleeping hours and academic productivities. We also assumed that all university students face the same amount of workload. Furthermore, we set a threshold between affected and unaffected sleep and productivity to be <6 and <4 hours respectively.

We conducted a survey of a sample size of 50 students across the 6 public universities in Singapore on whether aircraft noise affected their sleep and productivity. We asked them 6 questions out of which we used the data from 3 main questions, "Which university are you enrolled in?", "How many hours of sleep do you get in a day on average?" and "How many hours of productive work do you complete in a day". From the survey, we discovered that the average sleeping hours and productivity hours of the students are 6.66 hours and 4.66 hours respectively. Hence, we conclude that only a minority of students are affected by aircraft noises as most participants get sleep and productivity hours higher than the threshold stated.

Moreover, using a 3D map we could also see that students closer to the airport are generally more affected than those that stay further away. Students from Singapore University of Technology and Design (SUTD) get an average of 6.24 hours of sleep and 5.18 hours of productive work whereas students in Nanyang Technological University (NTU) get 8 hours of sleep and 6 hours of productive work and students from Singapore Institute of Technology get 6.67 hours of sleep and 5.33 hours of productive work.

This is also supported by a qualitative equation that we inferred from the data to estimate how noise level affects the amount of study and productivity hours. The equation is logical as it highlights the inverse-square law of energy transmission. The equation is also able to differentiate and relate the impact of aircraft noise on sleeping and productivity hours based on the respective coefficients.

Finally, we used the same contour map of noise levels of aircrafts landing in Changi Airport and translated it to Seletar Airport assuming the noise level contour map generated is approximately the same. It shows that students as well as households again located 10km from the vicinity will affected to a larger extent compared to those who stay further. However, there are many other factors such as their time in co-curricular activities and time taken to travel home that affect sleep and productivity and generally, aircraft noise does not have a high weightage in the list of those factors.

1 Redefining the Problem Statement

The original problem statement is:

CAAS has recently established ASI at SUTD. In light of this article, ASI tasked SUTD students to model the impact of aircraft noise on Singaporeans.

By evaluating the given statement and isolating factors, we formed a more specific problem statement:

How does aircraft noise level (dB) affect the amount of night sleep (hours) and productivity for studies (hours) of university-level Singapore students?

2 Making Assumptions & Defining Variables

Since we simplified the problem significantly, we made the following assumptions:

Assumptions	
1.	Noise level is the only factor that affects students' amount of night sleep and productivity for studies.
2.	The threshold between affected and unaffected amount of sleep is 6 hours.
3.	The threshold between affected and unaffected productivity is 4 hours.
4.	The intensity of work being done by all university students is the same.
5.	University students only studied and did work at their universities or hostels.

We decided on the following variables:

Variables	
Independent	**Dependent**
Aircraft noise level (dB)	- Amount of night sleep (hours) - Productivity for studies (hours)

3 Getting a Solution

We conducted a survey to find out the relationship between aircraft noise level, amount of night sleep and productivity. From the survey, we can obtain data on the average amount of night sleep and productivity for university-level Singapore students. We surveyed only those in the public universities across Singapore.

From the survey, we concluded that the average sleep cycle is 6.66 hours while the average work productivity is 4.66 hours. With the results we obtained and the assumptions made above, it shows that aircraft noise slightly affects student's amount of sleep and work productivity, as average amount of sleep is 6.66 hours ($>$6 hours) and average productivity is 4.66 hours ($>$4 hours). This shows that only a minority amount of students is affected by aircraft noise.

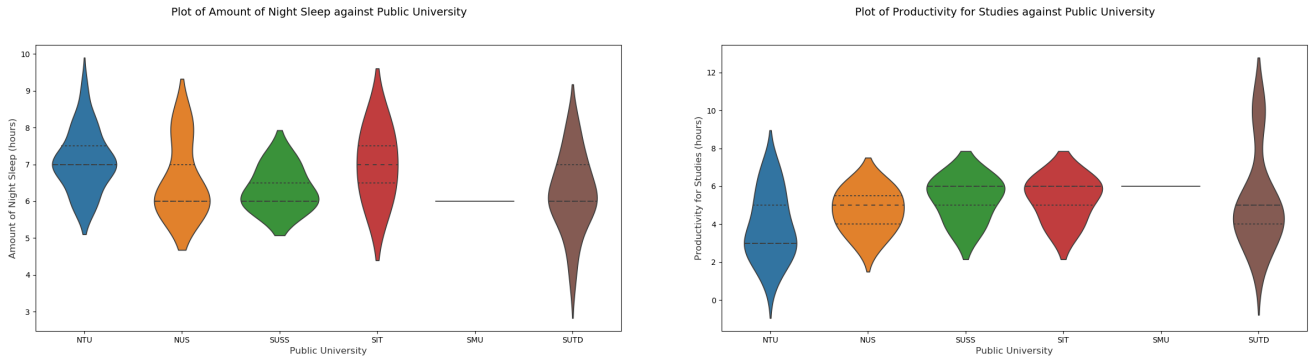

Figure 1: Distribution of data collected from the survey.

By conducting a more meticulous analysis on our collected data, we could infer a qualitative equation to roughly estimate how noise level will affect the amount of study and productivity, namely:

$$N(s,p) = \frac{4500}{s^2} - \frac{1500}{p^2}, \tag{1}$$

where N is the noise level in dB, s is the amount of study hours and p is the productivity for studies in hours. This equation makes sense as it highlights the inherent inverse-square law of energy transmission. This equation also shows that aircraft noise has less impact on amount of sleep and a more significant impact on amount of productivity (due to the respective coefficients). This is supported by our survey's data points from SUTD, NUS and SIT.

4 Analysis and Model Assessment

It is possible to correlate the productivity of a student to households and workers as well. The impact of aircraft noise would be similar for both students and households. The households we will be focusing on are those living within 10 km of Seletar Airport.

Using the survey methods, we have actually come up with the following questions to identify if aircraft noises will affect the students' amount of sleep and productivity:

1. Which university are you enrolled in?
2. Do you hear aircrafts flying past your school?
3. Does the noise of aircrafts flying by wake you up during your sleep or prevent you from falling asleep?
4. Does the noise of aircrafts flying by distract you from studying momentarily?

Those who are actually affected will carry on with the questions where we further collect the data:

5. How many hours of sleep do you get in a day on average?
6. How many hours of productive work (e.g. studying, doing assignments, projects, etc) do you complete in a day?

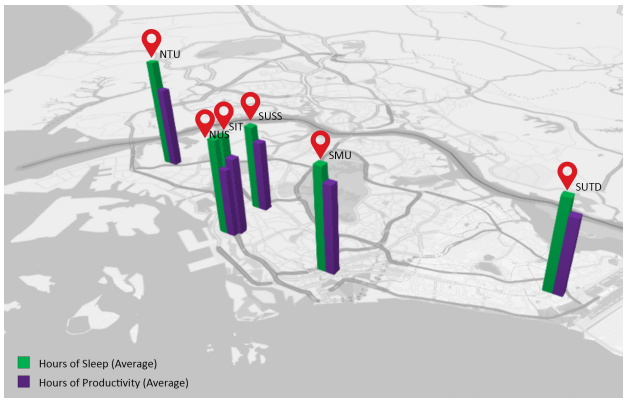

Figure 2: 3D representation of the data from the different universities.

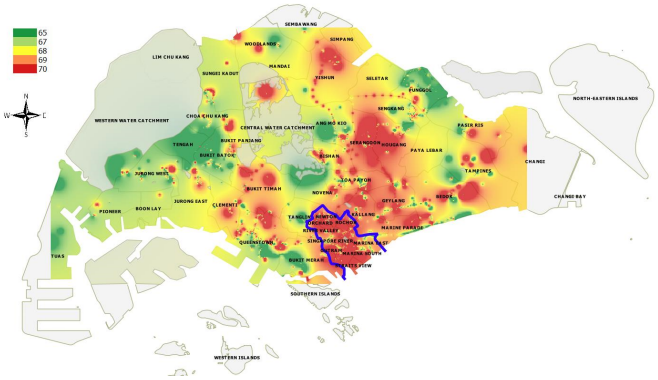

Figure 3: Latest noise heatmap of Singapore, which includes daily environmental noise.[1]

Using the data collected to compare SUTD with the other universities, we are able to see that SUTD students are generally more affected by aircraft noise. This is mainly due to it being located within 10 km from Changi Airport. Thus, by inference, we could extrapolate similar effects to those living within 10 km from Seletar Airport.

Recently, RSAF lowered their training frequency at the military air bases due to complaints and thus for this model, we are ignoring any additional effects from the jets that fly around the Paya Lebar Air Base, Tengah Air Base, etc. However, while there are several reports of incidents of Singaporeans complaining over noise pollution caused by aircrafts,[2] noise pollution due to MRT and crowds in shopping malls actually has a larger impact on Singaporeans. Other noise sources have caused Singapore to be near the upper threshold of healthy daily noise dosage (Figure 3). Thus, aircraft noise would just slightly aggravate the already negative impact of everyday noise that Singaporeans experience.

In this model, we also assume that both Seletar Airport and Changi Airport possess a similar noise contour map as the one illustrated in Part I of this 1D Project (Figure 4). This is a good approximation but it might not be completely accurate due to different flight schedule and aircraft types and thus, this can lead to further inaccuracies in the model.

By using the survey and 3D map method, we are able to collect multiple layers of data that give us a good visual representation of the data. Survey is a flexible method, where we can modify and tweak the questions we ask. This allows us to actually achieve precise results as we are able to focus and narrow our questions to obtain the desired outcomes that are related to our problem statement.

Figure 4: Noise level map centered around Seletar Airport versus Changi Airport.

However, since surveys are open to anyone and that the respondents would have no deep vested interests in the research, sometimes the data collected does not tally, leading to some anomalies. Another weakness would be partially associated to the fact that there is only one respondent from SMU for our survey, which might not be representative of the whole university. The data displayed in Figure 1 showed a generally inverse correlation between sleep and productivity, except for SUTD, which might be due to students underestimating their amount of productive hours.

This method might also be less accurate as we are not able to monitor how this survey is conducted. Survey fatigue may be one of the reasons that causes many university students to randomly select their choices and finish it quickly without thinking through.

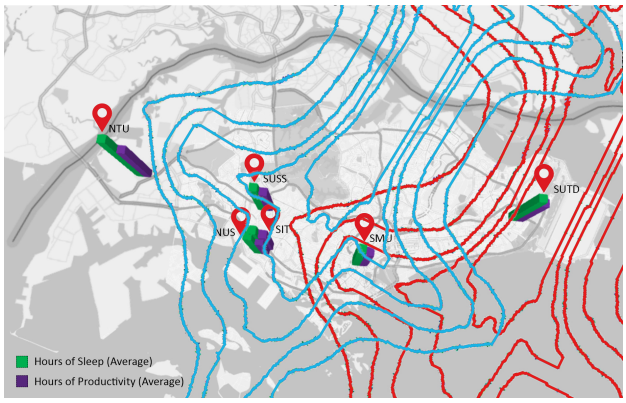

Figure 5: Overlap of the two different noise level contour maps.

In real life, there are interference patterns for sound waves (Figure 5). This model is unable to predict resultant noise level curves (from both Seletar Airport and Changi Airport) because it is challenging to superpose 2 different contour maps together, especially if they are of changing phase difference (alternating between constructive and destructive interferences), which is highly chaotic by nature (depending on weather conditions, other present noise sources, etc). For example, this model would be quite uncertain in determining whether SMU students would experience louder or softer aircraft noise.

Of course, there is a plethora of other factors that might affect the amount of sleep and productivity of university students. In conclusion, aircraft noise slightly aggravates the amount of sleep and productivity of university students in Singapore.

References

[1]Martin, W. H., & Ting, D. H. (n.d.). *Sound Exposure Levels in Non-occupational Outdoor Settings in Singapore*. Retrieved on 16 October 2019.

[2]The Straits Times. (2018, April). *The Challenge of Aviation Noise in Singapore*. Retrieved on 16 October 2019.